

Case studies in

increasing
the adoption

of

Sustainable
Resource
Management

Practices



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Case Studies in Increasing the Adoption of Sustainable Resource Management Practices

A.D. Shulman and R.J. Price (Eds)



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**RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION**

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PART I

BACKGROUND TO THE CASE STUDIES

An Introduction

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Why this Publication?

There is increasing recognition that the Australian rural sector needs to develop and implement sustainable agricultural practices. However, there are debates over what these practices might be, and how best to develop them and maximise their adoption. These research, development and extension/commercialisation (R,D&E) issues are not new. Over one hundred years ago it was recognised that farmers continued to be engaged in practices which were inconsistent with the scientific facts. At the same time, researchers often failed to recognise that the practices that farmers did use were appropriate, albeit for reasons that were not well understood at the time.

Over the past two decades, a progression of models of research and development and extension has been advanced to guide researchers in R,D&E, yet the concerns continued to be voiced that agricultural R,D&E does not properly serve its constituency (Jiggins 1993; Scones and Thompson 1994; Vanclay and Lawrence 1995). We believe that past attempts to improve technology transfer have been at least partially successful, that is, within the societal and knowledge context that they were being developed and implemented. However, the knowledge base and societal expectations have changed, leading to demands for higher levels of performance by agricultural R&D scientists to develop sustainable farming practices that are adopted.

In the early 1990s, a research program was initiated in the belief that many of the barriers to increased adoption reside in the communication processes amongst the funding agencies, researchers and end-users. More over, it was also believed that many of the management practices that need to be implemented by farmers in order to become more sustainable are already known. In the view of a leading Australian rural research corporation, the Land and Water Resources Research and Development Corporation (LWRRDC), for many resource degradation issues, R&D is not the critical factor needed to reverse the process of degradation; rather, an increased uptake of known technologies is required. This 'takeup' of sustainable resource management technologies, many of which are presented in the form of decision-support systems and

whole-farm knowledge systems, is seen as a particularly complex one, largely because the incentive of immediate profit for the adopter is not so apparent. The systemic nature of natural resource management, the complex biological and physical processes involved, and the uncertainty about some of the cause and effect relationships between farming practice and resource degradation, in both a spatial and temporal sense, also present challenges beyond the means of traditional agricultural extension methods to cope. LWRRDC was thus keen to pursue means of improving these traditional adoption processes as applied to decision-support systems and knowledge systems.

It is within this search for better adoption practices that the research program was commissioned. The program concentrated on actions of project leaders and their teams that would increase the likelihood of developing sustainable agricultural practices that would be adopted by farmers and/or those who are engaged in influencing farming practices. However, as the program evolved, it became apparent that many of the barriers to increased development and adoption of sustainable practices were associated with factors external to the direct influence of actions of project teams (ie. institutional accounting and reward practices, program management structures, and cultures and unpredictable weather patterns). The models and recommendations which emerge from this program reflect the importance of considering and addressing both the actions of R&D teams and their attempts to deal with factors outside of their control. The reader will find that the examination of R&D communication practices suggests that the deficits lie not so much in the communication content but in fundamental R,D&E communication management practices that underlie how, when and with whom information is discussed and how the projects and programs are managed.

This publication details the experiences and lessons learnt from several projects funded under the program. These are dealt with as case studies, and in some cases are accompanied by summaries of issues raised by participants and observers.

The first project, led by Ian Gray, Tony Dunn and Emily Phillips, describes the farming community surrounding Wagga Wagga, NSW. Using ethnography, focus groups and

interview methods, their findings reflect the growing awareness amongst sociologists that community structures and practices are active agents and a primary resource for improving farming practices. A model is presented which researchers can use to increase their awareness about the dynamics of the communities they are to serve. This community-first model provides little room for researchers to develop better practical farming practices without addressing community issues.

The second project was led by Jenny Bellamy and Duncan Lowes. The context of this study was the ongoing development of a decision-learning tool that would facilitate a shift to best practices that were consistent with new land-use regulation. The section describes the methods used by Bellamy to deal with competing interests and changing structures of responsibility within the Northern Territory Government agencies who were the major clients. There are many lessons that emerge from this project, including an appreciation that the ways the researchers managed the development of *Landassess*, a GIS decision inquiry system, were more important than the output or product itself.

The third project was led by Peter Cox and Peter Ridge. This project examined the market potential for decision-support systems (DSS) for farmers within the Agricultural Production Systems Research Unit (APSRU) on-farm program of research. Using a range of data collection and analysis techniques, they question the relevance of the ways fellow scientists were developing DSS as products for farmers. Their views are instructive, but contentious within the research community. Like the study by Bellamy and Lowes, researchers are advised to broaden their definition of DSS beyond computer software products, to a method of joint inquiry that maximises continuous learning amongst the participants who are involved in its development. For Cox and Ridge this exploration is more likely to occur with farmers without computer DSS. A summary of the concerns raised by scientists about their conclusions forms the basis of a special response accompanying the case study.

The fourth project was an attempt by Neal MacLeod, with Peter Vance and Peter Van Beek, to test the systematic use of technical and end-user reference groups as a means of increasing adoption. Similar to the projects directed by Bellamy and Lowes, and Cox and Ridge, their technology-transfer project was part of an ongoing program of research with well established infrastructure whose major activities were funded by sources outside the communication improvement program. MacLeod summarises the unexpected strengths and challenges faced in adding a communication extension component to an existing program of research. The author, Neal MacLeod, uses these experiences to develop a prescriptive model for managing.

The fifth case study, directed by Art Shulman and Robyn Penman, provides the reader with a summary of nine paradoxes that researchers need to recognise and manage when attempting to improve adoption of sustainable resource management practices. These paradoxes frame a context for examining the progression of models that forms the theoretical environment that the individual projects were attempting to improve upon. The section ends with a description of the models that emerged from the program. The authors of this section were Art Shulman, who was the coordinator and subsequently manager of the program, and Neil MacLeod.

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The Program Origin and Context of the Case Studies

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Land and Water Resources Research and Development Corporation

Program Justification

In 1991, when this program was initially conceived, the view within Australian agriculture and environment research and development sponsoring organisations was that many of the management practices that needed to be implemented by farmers in order to become more sustainable were already known. For many resource-degradation issues, R&D was not the critical factor needed to reverse the degradation; rather, an increased uptake of known technologies was required. LWRRDC saw the issue of adoption of sustainable resource management technologies as a particularly complex one, largely because the incentive of immediate profit for the adopter is not so apparent. The systemic nature of natural resource management, the complex biological and physical processes involved and the uncertainty about some of the cause and effect relationships between farming practice and resource degradation, in both a spatial and temporal sense, also present challenges beyond the means of traditional agricultural extension methods to cope. LWRRDC was thus keen to pursue means of improving these traditional adoption processes.

Program Genesis: an ‘Unwhole’ Beginning

The origin of the ‘adoption program’ began with LWRRDC’s inaugural call for applications following its establishment in 1990. This call was widely advertised across Australia in August 1991 and invited research proposals dealing with any area of relevance to LWRRDC’s charter on sustainable use of natural resources. One of four project selection panels established by LWRRDC at that time was responsible for assessing socio-economic orientated applications. These applications arrived at a time when all of the research and development corporations (RDCs) were reconsidering their traditional approaches to supporting extension programs in light of their recent corporatisation, new and emerging paradigms of extension, and new and emerging technologies for exchanging information. Of the thirty-odd applications received in this area, five dealt specifically with farmer decision-making processes in one form or another. These five, which ended up as components of this program, are:

- **CSU3** Barriers and Constraints to the Adoption of Sustainable Farming — Ian Gray and Tony Dunn (Charles Sturt University) (Case Study 1)
- **CTC1** Decision Support for Sustainable Management of Grazing Lands — Jenny Bellamy and Duncan Lowes (CSIRO Tropical Crops and Pastures, now CSIRO Tropical Agriculture) (Case Study 2)
- **CTC3** Market for Decision Support Systems for Dryland Crop Production — Peter Cox and Peter Ridge (CSIRO Tropical Crops and Pastures) (Case Study 3)
- **CTC2** Effective Strategies for Increasing Relevance of Research Results — Neil MacLeod (CSIRO Tropical Crops and Pastures) (Case Study 4)
- **RIA1** Improving Communication Practices — Arthur Shulman and Robyn Penman (Communication Research Institute of Australia); Neil MacLeod (CSIRO Tropical Crops and Pastures) (Case Study 5)

Individually, the five applications did not hold particular interest for LWRRDC, particularly as they were likely to benefit only specific regions or industries and had no means outlined for making the benefits more widely applicable. The assessment panel judged, however, that as a suite of projects, together with a clearer focus on improving R&D methodologies to assist farmers adopt sustainable resource management practices, the combined applications had considerable merit. A panel recommendation to the Board of LWRRDC that a workshop be convened to assess the feasibility of developing an amalgamated second-stage proposal for joint RDC support was agreed to. The workshop, involving the five original applicants, representatives of LWRRDC, the Grains Research and Development Corporation (GRDC), the Rural Industries Research and Development Corporation (RIRDC) and the Meat Research Corporation (MRC), and two independent researchers with relevant qualifications and who had recently completed research on barriers to the adoption of natural resource management research results for the National Soil Conservation Program, was convened in December 1991.

Conception Challenges

The proposed amalgamation of the five projects into a single program was problematic.

- First, none of the applications had as a specific objective the desire to develop better methods to improve sustainable resource management adoption levels, although they all related to this aim.
- Second, the original applications had vastly different methodological approaches, ranging from ethno-methodology to complex biophysical model development.
- Third, the regions covered by the individual projects ranged from the sheep–wheat zone of southern NSW to the Brigalow country of central Queensland and the tropical savannas of the Northern Territory.
- Fourth, while four of the five research parties were located in Brisbane, one was located 1000 km distant in Wagga Wagga.
- Fifth, few of the researchers had previously been involved in interdisciplinary and multi-organisational research programs, at least to the extent proposed by the joint program.
- Sixth, the commitment shown to the proposed program by some of the researchers was based more on the motivation to see their individual work funded under some form of structure rather than not at all.
- Seventh, the Bellamy project was designed to meet specific institutional and legislative requirements and not farmer decision-making requirements at all.
- Eighth, with the exceptions of the Shulman and Penman project and the Wagga Wagga based study of Gray and Dunn, all other projects were companion projects that were deeply embedded in ongoing programs of research which had their own agendas and management structures. For these projects, [*Landassess*, a Decision-support System for Use by the N.T. Government', by Bellamy et al. (CTC1), 'Market Research for Decision Support', directed by Cox et al. (CTC2) and 'Effective Strategies for Increasing Relevance of Research', directed by MacLeod et al. (CTC3)], the funding provided by the RDCs focused on improving adoption practices in the context of ongoing 'hard science' research programs for which they held some leadership responsibilities. At the beginning of this program, researchers associated with these three 'hard science' projects were already focusing on technical and human resource barriers. All the project leaders recognised that the issues surrounding adoption were complex, requiring the input and 'participation' of multiple stakeholders (farmers, government, private sector, scientists, etc). However, as characteristic of the literature on adoption practices in 1991–92, the three 'hard science' projects did not initially address the operational issues of what should be discussed with which constituents, how and when such involvement should occur, or how relationships should be managed. Addressing these issues became a major theme of the program. In essence, the component projects differed

in: what the issues of sustainability are, the 'technologies' being developed for 'transfer', who the technologies were being developed for, the espoused models of transfer, and the views of the responsibilities and roles of potential end-users, the R&D funding bodies, researchers and their research institutions.

- Finally, the research funding bodies and many of the third-party collaborators (see list below) had little experience at this time in developing joint programs.

These different starting points provided opportunities for a range of approaches to be monitored and adjusted over the three years of the program.

Collaborating Organisations

Charles Sturt University
Communication Research Institute of Australia
Computer Aided Livestock Marketing
Conservation Commission of Northern Territory
CSIRO Division of Tropical Crops and Pastures (now CSIRO Tropical Agriculture)
Department of Lands and Housing, Northern Territory
Grains Research and Development Corporation
Land and Water Resources Research and Development Corporation
Queensland Department of Primary Industries
Rural Industries Research and Development Corporation
University of Queensland
University of Western Sydney

Program Support

The program design workshop resulted in recommendations put to the Boards of LWRRDC, RIRDC and GRDC to formalise an agreement to structure a program of R&D activities which would encompass the five projects. The life of the program was planned as July 1992 to June 1995. The recommendations included suggestions for restructuring the projects to work towards achieving common goals and objectives as well as individual project objectives, for arranging joint funding by LWRRDC, GRDC and RIRDC, and for administrative matters to be handled by LWRRDC on behalf of GRDC and RIRDC. Dr Art Shulman, principal investigator of one of the five projects, who had extensive experience in managing collaboration across organisations (but had little experience with rural-focused organisations) was asked to operate as program coordinator. MRC formally declined to be involved in the program, but indirectly maintained participation through its funding of two of the major ongoing research programs which the MacLeod

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project used as case studies, and by its support of activities which Bellamy's project used as sources of data for building a decision support system.

Program Design and Objectives

A rudimentary portfolio design was used. The individual objectives as proposed within each individual project formed a composite list of objectives and there was an expectation that the results of each of the separate projects would need to provide synergy in addressing the overall goal to 'increase the adoption of economically and ecologically sustainable technologies in the cropping and grazing industries'. The design was not specified with respect to how these individual projects would balance the riskiness of individual projects, nor (with the exception of the Shulman and Penman project) on how each of the projects could create specific synergies and add value to other projects within the program. The composite objectives for the program are listed below.

Original objectives

- Identify communication practices that facilitate sustainable production/natural resource management practices.
- Understand the bio-physical, social and economic factors that prompt or hinder the adoption of technologies.
- Identify indigenous technical knowledge upon which farmers base their sustainable agricultural practices.
- Identify barriers and gateways to adoption of sustainable strategies in the context of social relations among farmers, extension officers and researchers.
- Identify opportunities for DSS to assist resource users to formulate and evaluate alternative strategies for the sustainable management of resources.
- Facilitate the uptake of the results of the program within the adoption strategies of the wider research effort.

Collaboration

There was an expectation placed on the researchers by the funding partners that, as part of a broader program, each project should add value to each of the others, and that resources, expertise and data should be exchanged wherever possible. For example, it had been proposed that the Cox market research project would use the Bellamy DSS (*Landassess*) as one of its case studies, and that the sociological data emerging from the Gray et al. project could shine light on decision-making processes within the MacLeod project case studies. The overall budget made available to the program, however, was less, although not considerably, than that of the aggregated sum of the original budgets proposed. Moreover, the diverse nature of the projects and

the short time given to garnering commitment to achieving joint program goals meant that the relationships between each of the individual projects and between each project and the program were less than clear. Most of the projects were embedded in their own programs of research, which had their own objectives and issues to address. This embeddedness provided excuses not to create opportunities for synergies to emerge, at least to the extent that was initially expected by some members of the management committee. For these reasons, and with the refocusing of the Shulman project to include responsibility for coordinating, compiling and communicating the lessons learnt from all of the projects, the creation of synergies between individual projects was less than first envisaged.

Target audience

Each of the individual projects had multiple target audiences identified to varying degrees of clarity. For the most part, these were the CSIRO Division of Tropical Crops and Pastures and the APSRU, which were specifically looking to improve the outcomes of some of their existing projects and to establish improved methods for designing and undertaking future research activities (Cox and MacLeod projects), the Queensland Department of Primary Industries as the major extension arm for agriculture in Queensland (Cox and MacLeod projects), and the Northern Territory Government as the user of a DSS to support its land-use legislation (Bellamy project). The academic nature of the Gray project did not serve specific client interests, although it was intended to provide input into improving group extension activities such as were being adopted by many agricultural and conservation agencies across Australia. Only the Shulman project had initially identified a generic audience. The target audience for the program received scant attention in the initial deliberations of funding.

Methodology

Each project, in addition to carrying out the specific methodologies originally proposed, was required to provide information to the program coordinator on their stakeholder interactions. This information was to be compiled as part of the non-coordination aspect of the Shulman project, which aimed to explore and devise improved communication practices between researchers and their clients.

Program Management

From its establishment, the program was managed at two levels: first, at the strategic level between the program coordinator and the funding bodies (LWRRDC, GRDC and RIRDC), and second, at the operational level between the program coordinator and the project researchers. Funding administration was carried out by LWRRDC on behalf of the Corporation partners.

Strategic management

At the strategic level, a Program Management Committee was established comprising representatives of the funding bodies. This committee was expanded during the first six months of the program to include representatives of CSIRO and the Queensland Department of Primary Industries, both of which, initially at least, were contributing substantially to the program through their in-kind contributions as participating research organisations. The initial task of the committee was to develop a program management strategy which would articulate the goals, objectives, milestones and achievement criteria of the program as negotiated at the conception workshop and in ensuing discussions with the coordinator. The strategy was also intended to cover reporting, coordination and communication arrangements for the program. The committee met approximately once per year to review progress being made in the program, and on additional occasions to address specific critical issues which arose during the life of the program.

A Program Management Agreement, in the form of a legal contract, was developed by IWRRDC to cover arrangements for administering the program on behalf of the funding partners. This enabled all funding matters to be handled through IWRRDC rather than separately between each funding partner and each individual research organisation. It also provided for each funding partner to have a stake in the program as a whole rather than in specific projects within the program. The agreement essentially outlined the responsibilities of the lead funding agency and its obligations to other funding partners, and provided for the establishment of a Program Management Committee to oversee strategic directions. (Note: this form of agreement has now been widely adopted by most Australian RDCs to structure administrative arrangements for jointly funded programs.)

Operational management

At the operational level, during the first sixteen months, when base-line data were being collected, the program coordinator worked closely with all Brisbane-based researchers and held regular meetings with the researchers both on an individual basis and as a team through periodically convened workshops. This pattern of research collaboration continued and formed the basis of further joint activities, but also provided an environment for the subsequent emergence of ambiguity in the coordinator's evolving roles as program manager and collaborator. Physically the coordinator was located close to most of the project researchers, other than the Gray project group, and this enabled a high level of interaction with key participants throughout the program. A considerable amount of the coordinator's time was spent assisting and guiding the researchers through the processes of data collection and analysis, and in the preparation of publications. Milestone reports, which described progress made against set achievement criteria, were prepared by each of the

researchers and compiled annually by the coordinator for consideration by the Program Management Committee.

Program Appraisal

Achievements

A number of aspects of this program, particularly in terms of its conception and design, made it difficult to manage and to therefore show appreciable achievement against all the original program objectives. From an individual project perspective, however, the potential achievements have been significant, and represent a dichotomy in individual project objectives being enhanced through the involvement in the portfolio versus the attainment of synergistic program objectives.

Within the program coordination arrangements, the attempt to compile baseline data on communication approaches and adoption levels proved both complex and arduous, in part because the programs that the individual projects were embedded in had not attempted to systematically do so, nor had the resources to do so. However, significant advances in documenting the unfolding of communication processes within each project were accomplished, albeit on an individual project level. The period of monitoring undertaken, and the changing interaction patterns within the projects, means that longer-term evaluation of the program's impact will be difficult. The results of the individual projects are outlined elsewhere in this publication and represent an enormous accumulation of knowledge. To date, while there have been numerous publications emanating from the projects, the institutional changes sought, ie. adoption of new and improved ways of undertaking and communicating research, seem to have been limited to the few organisations participating in the program as primary research agencies. The distribution of this volume is intended to broaden the program's influence, but to some extent it is a delivery mechanism at odds with much of the philosophy espoused by the program and its constituent projects.

Program framework

From the time that the funding agencies expressed interest in incorporating the five projects into a program, project proponents were unclear as to how their project related to the program as a whole, and to other projects within the program. When each proposal was originally prepared, it was done so without knowledge that it may eventually be incorporated into a program. No doubt some researchers were frustrated at being informed that their project did not warrant funding on its individual merit. Moreover, the diversity of the projects, and the unclear nature of their logical relationship, made it conceptually difficult to develop a coherent program framework, and in a strategic sense, this matter was only considered cursorily by the Program Management Committee after commencement of the program.

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The ambiguous linkages between the projects also translated into difficulties with working relationships. The first cause of consternation among some of the researchers was the decision to place one of the five project researchers in the position of program coordinator. This presented a number of dilemmas. Foremost, the coordinator was immediately placed into a hierarchical position of management, rather than partner, in the program and this altered the personal relationships developed at the proposal stage. To some extent, the researchers were worried that their roles as principal investigators in the projects were being usurped, although this was never the intention and ultimately proved not to have occurred. In the case of the Bellamy project, which was only peripherally about researcher–farmer communication, but which was intended to provide case study material for other projects, the principal investigator was very sensitive about the intended relationship with the program coordinator, especially given that his qualifications and expertise lay totally outside of her comprehension of what her project was about. The Gray project group had similar reservations about both the coordinator and the notion that they might be required to share sensitive academic information, collected on a confidential basis, with others in the program for purposes other than their own. They were also perplexed as to how their data, collected within a different agro-ecological zone, covering different industries and based on a totally different methodological approach, would be of use to others in the program.

Program coordination

The role of the coordinator was an unenviable one, and one often at conflict with both the researchers' and Program Management Committee's expectations. In early meetings between the Management Committee and the researchers, the coordinator was inclined to act as a spokesperson for the researchers. This was made all the more awkward as the researchers tended to take a strongly defensive position against the Management Committee on program issues until the committee's role was better defined and explained as one intended to provide advice and garner the necessary resources and cooperation from the collaborating organisations. This clarification and negotiation of roles emerged from the need to deal with unanticipated shortfalls in access to trained social scientists in three of the projects, and the necessity to renegotiate what could be achieved within the program. The early surfacing of project and program inadequacies created (unnecessary) defensive posturing, and inhibited the development of a program team, particularly at a time when individual project leaders were facing major downsizing and reorganisation within their own organisations. The coordinator, who had no control of resource allocations, was thrust into the middle of an *us versus them* tussle with conflicting allegiances and found this difficult to manage without strong backing from the Management Committee.

The expectations placed upon the coordinator were also poorly defined, and this led to uncertainty between all parties as to the extent of his role in participating within projects versus coordinating across projects. Mid-way through the program an attempt was made to clarify this role by increasing the authority of the position so that it had a greater degree of leverage required to ensure that coordination activities could be adequately carried out, and at the same time address some of the shortfalls in the ability of individual projects to collect and analyse data on changes in their ways of going about technology transfer. These changes occurred after the first year, leading to improved program and project performance, but also to a 5% increase in program costs.

Institutional arrangements

Problems with third-party contributors to individual projects occurred periodically throughout the program. For example, the Queensland Department of Primary Industries, which was contributing significant in-kind support to one of the projects in particular, withdrew this support in the second year because of financial constraints and internal reallocation of priorities. Their third-party contributions to the program were not legal obligations executed under contract, and so there was little recourse to seek remedial action from that agency. Of greater significance than losing project resources, however, was that the withdrawal of support meant one of the primary potential end-users of the research results no longer had a stake in the outcomes of the program.

Issues of intellectual property, and information ownership and sharing between program partners, and between each of these and their case study partners, were major impediments to achieving some of the anticipated synergies. Partnerships identified in the original project proposals often proved very weak after the projects commenced, reflecting to some extent a certain amount of lip-service given to pre-project consultation and target audience identification as a means of securing funds. Territorial issues, including those about who gets to the goalpost first (including in publication), limited data sharing, and the consequent siege mentality which this occasionally gave rise to prevented any chance of a program *esprit de corps* truly emerging.

Lessons

The reader will no doubt learn much from the experiences outlined in each of the case studies. Such lessons will include how best to design and undertake research that will enhance the likelihood of the adoption of research results. Some will give guidance to the best means of developing decision support tools so that the process of development becomes as critical as the tool itself in transferring knowledge. The case studies will also provide insights into the social processes at play within research as well as farming communities.

PART 2

THE CASE STUDIES

Case Study I

Barriers and Constraints to the Adoption of Sustainable Farming Techniques in the Sheep/Wheat Industry: the Sociological Context

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Barriers and Constraints to the Adoption of Sustainable Farming Techniques in the Sheep/Wheat Industry: the Sociological Context

Abstract

The project aimed to analyse the practices of farmers from a sociological perspective. This was done to develop improved models for the adoption of sustainable farming techniques. To achieve this a background understanding of the social, cultural and economic conditions in which farmers are immersed was developed for the benefit of all participants in the research process.

The research was carried out using standard social science techniques drawn from anthropology, sociology and agricultural extension. These included; surveys, focus groups and participant observation and within all these a range of interviewing techniques and questionnaires were employed. Considerable expertise and development of these methodologies was required to do the work. This is seen as an important outcome of the project.

The study paid particular attention to the ways in which farmers perceive and interpret their economic positions (especially in a macro or structural context) as well as their personal histories and those of their farms. In a broad sense the project explored how their situations are changing. In a narrower context the study examined relationships among members of farm communities, including extension agents and agribusiness representatives with a view to examining the local social structures and behaviours (ie. local cultures) in which farm practices are adopted and decisions are taken. Careful observation was made to identify constraints and restrictions that individuals faced in their real behavioural choices.

A key finding was that farming practice is nested in a cultural context as well as an economic one, and that farmers can describe those contexts and explain how they affect what they do. One important finding is that cultural 'influences' can be very local and can help determine what is regarded as 'good farming' in the area. From this it is inferred that proponents of sustainable farming practices who wish to promote their 'model' should recognise existing 'indigenous' views on the question and that differences are likely to exist between all agencies and interest groups involved in promoting change.

A sociological perspective on policy formulations to effect the extension of sustainable agriculture must include a fostering of relationships in which all individuals and agencies are able to explore their interests and collectively plan the pursuit of those interests. A 'Farm and Community Planning' approach is advocated. This extends participatory models of extension across all stakeholders and places people and their cultures and relationships at the centre of a long-term planning process.

Dissemination of the project findings and the concepts developed have been discussed at program meetings, seminars and conferences, and a range of publications have been produced or are in production.

From Personal Barriers to Community Plans: a Farm and Community Planning Approach to the Extension of Sustainable Agriculture

Tony Dunn, Ian Gray and Emily Phillips

Preamble

Extension theory and practice have changed significantly in the past 10 years, partly because agricultural and land-use problems have been found to be more complex, but also because of demands for a changing role of farmers in research and extension. In the same vein, government policies, agencies and funding have also undergone changes. It is therefore important to examine extension theory in the light of these changes, with particular emphasis on concepts and procedures used to guide extension and research programs.

Rural Australia is also undergoing a period of fundamental change. It is not just a matter of economic decline or population change or a combination of both. These are long-term trends. There are also transformations occurring, perhaps more rapidly, in social, economic and political relationships in families, communities and among regions across Australia. As part of these, Australian agriculture can be seen to be being 'detraditionalised' within families and communities. The old cultures and institutions which have underpinned Australian rural society are either changing or disappearing. In the immediate term, this is affecting the ways in which farm families run their farms. It also has direct and indirect implications for the social, economic and environmental sustainability of agriculture and, more pertinently here, for the ways in which the extension of sustainable agriculture is carried out.

This paper advocates a holistic approach to extension which takes into account the full range of interests that farm people have in sustainable development and the means of achieving it. It does so by first discussing extension theory and highlighting some of its shortcomings. It then presents the findings of research that applied a cultural model to farming, to illustrate the breadth of issues which extension must take into account. Finally, some procedures for the holistic planning of farm sustainability are suggested.

Part I EXTENSION THEORY

Introduction

There is an extensive body of literature available to guide and evaluate changing extension and research activities in land and water use relevant to sustainable agriculture. Agricultural activity and urban development both have an impact on the natural environment, and action arising to address related issues must be underpinned by sound extension theory. Furthermore, it is clear that the central concepts in extension theory are often not known or understood by field workers and educators. Of special interest to sustainable agriculture is the use (or misuse) of terms like 'barriers to adoption' and 'top-down' or 'bottom-up' extension. In a sense, they have become jargon, but with meanings that do not necessarily concur with extension literature and theory.

This section traces the major changes in thinking on extension in recent years and discusses the theories and ideas that are currently driving extension policy and practice. Also described are some of the newer extension ideas and sociological theories which, we contend, will improve the research and extension of complex land, water and resource use problems. Our central argument is predicated on a critique of the key concepts of 'barriers to adoption' and 'top-down' or 'bottom-up' extension. The later discussion also makes use of recent sociological research that aims to develop a cultural model of sustainable agriculture. Finally, the results of an empirical application of a cultural model are presented.

Models of Social Change in Extension

Early models of extension depicted change in agriculture as the adoption of innovations by progressive individuals fol-

lowed by a process of 'diffusion' (that is, communication) amongst all farmers in the social system. It was generally assumed that the new ideas (innovations) were 'discovered' by researchers and that the process of communication was enhanced by extension professionals. Concern arose when some farmers were found to be slow to adopt innovations. Rogers with Shoemaker (1971) reviewed 1500 diffusion studies that described how innovations are communicated throughout a social system and identified the variables which influence the speed and effectiveness of the process. Because all individuals in a social system do not change their behaviour at the same time, diffusion researchers constructed a set of hypothetical adopter categories classifying people according to how soon they adopted a new idea. So all farmers could be theoretically categorised this way and all manner of 'personal' variables and farm characteristics could be correlated with so called 'adoption behaviour'. A key outcome of such research was an attempt to describe communication behaviour that would help extension programs reach farmers with their messages which usually advocated change.

Generalisations of this research are depicted as models such as the 'change agent model' (Rogers with Shoemaker 1971) and a model by Rogers and Burdge (1972) which uses a very catchy diagram depicting the flow of innovations from the research station to all farmer categories (early adopters to late adopters). Both models are appealingly simple and, although it is not explicitly mentioned, strongly imply that communication of change is one way and 'top-down'.

Gartner (1990) was one of the first extension writers to observe that 'top-down' had been derived from popular language to express a view that 'knowledge and techniques were generated in, and transferred from, centres of learning and centres of administration to centres of production'. The concept 'barriers' is also a relatively recent idea, introduced along with the term 'transfer-of-technology' (or technology-transfer) as subtle—but illegitimate—additions to the diffusion model.

In the current free-market conditions, the theory of diffusion and adoption has been taken up by marketing texts as an acceptable way of explaining human behaviour in product acceptance and consumer change (Stanton et al. 1991). Rogers with Shoemaker (1971) mention that marketing studies also used diffusion concepts to research rates of uptake for new consumer items. This is an interesting application of the theory to a different field—buyer behaviour. It is also interesting to note that the original ideas embodied in diffusion are retained and linked with family and reference group behaviour.

However, none of the applications of diffusion theory above uses the term 'barrier'. Thus, the problem of change for the market researchers as well as extension workers is the *time taken* for members of a social system to adopt an innovation. In the literature this is called 'adoption lag', but the unit of analysis is *the individual* rather than *the barrier* or the innovation.

Although the term 'barrier' was not used in the original writings on diffusion, by inference it is notionally part of the communication process by which adopters take up innovations. It is also accepted that an audience could be more effectively targeted using knowledge of farmers' communication behaviour and other personal characteristics (Rogers with Shoemaker 1971; Rogers 1983). Finally, although the use of idealised adopter categories such as 'laggard' is part of the diffusion theory, this does imply criticism or blame—for not being progressive. Furthermore, in today's 'transfer-of-technology' (ToT) world, where research and development milestones and outcomes are paramount, blame and judgment are just as intense for farmers who are irrational enough not to adopt proven technology because of barriers they encounter. Vanclay (1992) is one who refutes the idea of 'farmer blame' by arguing that, within the diffusion paradigm, it is just as rational for farmers not to adopt technologies that do not fit their social or economic context.

Another early reference to the notion of barriers to change can be found in the theories of the social psychologist Kurt Lewin who, although not working in agricultural extension at the time, did have considerable influence on the discipline, via his theories, on the field work and teaching in extension. Lewin's concept of field theory (de Rivera 1976) led to applications in group dynamics that were used by extension theorists in the 1960s and more recently by action researchers.

Of particular relevance to the terms discussed above is Lewin's experimental work in developing methods for removing 'blockages' to change, leading to people taking certain action to change their behaviour: the group discussion being far superior to the lecture (Lewin 1947). Here he contended that groups are held together by forces which come to an equilibrium, but which are always dynamic. When it came to promoting a change, the approach was to identify forces resisting the change as well as those supporting it. Lewin proposed a process that he called 'force field analysis', in which forces for and against change are identified and quantified in a graphical form for the whole group to see. In this way he showed how group discussion could be used to reduce the opposing forces, thus allowing forces in favour of change to operate and bring about the desired result. In a sense this notion is similar to that of 'barriers to change' although there is no evidence that the two are linked theoretically (Lewin 1951, as cited in Tyson 1989).

Further attempts to trace the origins of these terms in the extension literature revealed similar terminology in the field of rural sociology. For instance, Sofranko (1984) mentioned sociological and economic 'obstacles to agricultural change' for which he advocated group strategies and participation to avoid the unintended consequences of technological change. The emphasis here was to understand the farmers' sociological context as a rational 'obstacle' to change—one which the extension worker should be aware of rather than attempting to remove. McCorkle and McClure

(1995) made an interesting analysis of what they describe as the 'communication for technology transfer' evolution of models. Instead of 'top-down' thinking beginning with the technology, they assert that Berlo's communication model was developed to reflect the United States' experience with agricultural research and development where the source of knowledge was 'research' and the receivers were the farmers. The extension task then became one of deciding how to formulate the message and through which channels to send it. There was no feedback in the model (Berlo 1960).

The Emerging Use of Top-down Thinking in Extension

The term 'top down' was not used in early extension literature. However, Rogers with Shoemaker (1971) do use the words 'trickle down', and Maunder (1972) mentioned the idea of 'inducing change at the top of the social structure' and of using 'top end channels of communication' in an effort to understand the folkways and social structure of farm people and their communication channels.

No matter what the terms were, they all assumed that new ideas come from 'above' and move 'down' to the farmers. Rogers and Shoemaker are quite precise about which parameters could be important in communication when they discuss who pairs up with whom in the giving and receiving of information, *viz.*: 'do receivers seek sources (pair-wise) who are higher or lower in social status, innovativeness, technical competence, and so on than other sources?' (Rogers with Shoemaker 1971). Whatever the origins of the term 'top-down', it is now well established in extension policy terminology, despite the absence of a precise definition in diffusion theory.

Its use is now most often associated with ToT which is widely used in extension literature and has similarities to The World Bank's Training and Visit (T&V) system—with its rigid hierarchy and top-down communication direction (Benor et al. 1984). Although it is beyond the scope of this paper to trace the precise origins of these terms, their effect on extension thinking and practice is crucial because they have become *de facto* theory in research and development.

The terms did not appear in extension texts until about the mid 1980s. For example, they are not mentioned in Adams (1982), Bradfield (1975) or Maunder (1972), but Watts (1984) (in Swanson 1984) talks about 'agricultural extension for *technology diffusion*' (emphasis added). About the same time as ToT appeared, criticisms of it were made by Chambers and Ghildyal (1985) who asserted that it enabled scientists to maintain power and prestige over knowledge generation and sources. By the time Roling's book on extension science was published, the idea of ToT was well established, but it was also being systematically challenged by alternative paradigms (Roling 1988). ToT thinking has also been challenged in Australia. Russell et al.

(1989) and Woods et al. (1993), for example, describe some of its shortcomings, and Shulman (1993) suggests some alternative models. Dunn (1997) discusses its current use and where this is appropriate. Despite its shortcomings, technology transfer ideas are logically consistent with diffusion theory and the 'trickle down' process of adoption.

In the literature and in extension practice diffusion and adoption theories complement one another. The former describes, in an idealised way, how change happens in a social system, whereas the latter attempts to explain the social psychology of change and decision making in an individual. Both theories were extensively researched in the 1940s and 50s, but were criticised because they were too behaviourist, one problem being that farmers were seen as isolated 'actors' responding to stimuli in their environment (Buttel et al. 1990). However, this notion suited the research and development (R&D)/industry with its efficiency objectives and sponsored research which stipulated tangible returns from finite budgets. This approach depicted technology as something which could be marketed—even sold—to farmers who were assumed to be rational decision makers. In this sense, the transfer of technology was assumed to be a communication matter—or something around which marketing targets could be set. Failures in 'transfer-of-technology' strategies were blamed on poor communication, irrational farmer behaviour or barriers between those who had the knowledge and those who supposedly needed it!

Diffusion theory and ToT strategies reveal their limitations because they assume there is only one way of acquiring new knowledge and a more efficient agriculture. Furthermore, they assume that knowledge is transferred easily, and that farmer behaviour is rational. It is interesting to note that the problems and limitations of diffusion theory were described by Goss (1979) nearly 20 years ago, but were apparently ignored by extension policymakers and practitioners of the day. In the academic world, however, (in the United States at least) the criticism resulted in a 'new sociology of agriculture' based on political economy (Buttel et al. 1990) and a more critical appraisal of diffusion—one which recognised the problems (often environmental) caused by over-zealous adoption of technology. In Australia, such a view was not appreciated until Lawrence (1987) wrote about it in his book 'Capitalism and the Countryside'. Further evidence that important structural forces were dominating farming were aired in the writings of Roling et al. (1987) who pointed out that agriculture had become 'technology propelled', and of Nitsch (1979) who noted that the problem of adoption was too much information rather than too little. Farmers were being overwhelmed by new products and services, few of which were useful to their circumstances. In a sense they were experiencing their own form of 'future shock'.

Another flaw with diffusion-based extension was that it was ineffective in describing how to spread environmental advice. This was noted by Fliegel and van Es (1983) who

also pointed to another, long-suspected flaw in adoption theory—similar to that described by Presser (1969) who noted that, irrespective of an understanding of the mechanics of adoption for one innovation, this did not provide a good basis for prediction of the adoption of other new ideas. The problems of diffusion of research were partly due to inadequate method, a point made by Rogers with Shoemaker (1971): who admitted that it was too focused on the farmer as the unit of analysis, and by Buttel et al. (1990), who said it was too behaviourist. As a result, extension programs have been unable to cope with environmental and sustainability related problems which rely on farmer knowledge and community responsibility.

From the above, it is apparent that conservation farming and environmentally benign production methods are poorly promoted by extension strategies based on diffusion and adoption theories. Buttel et al. (1990) also point out that the behaviourist approach is also at fault because it presumes that farmers' learning can be manipulated psychologically and by improved communication strategies—an approach refuted by Salmon (1980). Despite all this, naively simple approaches to change still dominate R&D programs in that adoption should be simple and rational. Notwithstanding this criticism, diffusion theory still has a place in conventional marketing of 'off the shelf' technology products, such as those which yield short-term productivity gains as distinct from questions about longer term sustainability and economic viability. Such problems are too complex and too socially involved to be solved by relatively superficial paradigms, and require alternative extension approaches. Our research into a cultural model of farming activity, and recently constructed models of participative and 'bottom-up' extension, offer an alternative paradigm.

'Farmer-first'

In the literature, one expression of bottom-up extension and research is the 'farmer-first' model. While the Australian Landcare movement, and other emerging extension methods such as Participatory Action Management or PAM (Chamala and Mortiss 1990), are similar to farmer-first, in this chapter the term 'farmer-first' is used in a generic sense to include all bottom-up and farmer participative activities by extension and research workers.

Farmer-first emerged as an extension idea by starting intervention from the farmers' perspective and by recognising that top-down diffusion approaches had often caused problems as well as solving them. Mostly this occurred by introducing technology which solve what scientists, but not farmers, saw as problems. In other cases, technologies were not available equally to all farmers, and in some situations they disrupted social and economic structures in unintended and unforeseen ways. Rhoades and Booth (1982) developed a model called 'farmer-first-and-last' which was refined by Chambers (1990) into 'farmer-first'. Chambers and Jiggins

(1987) added another dimension to the 'farmer-first' idea with their criticism of ToT and what they called the 'normal professional' way of solving agricultural problems. In addition to the practical methodologies of a bottom-up approach, the literature also describes the theoretical and philosophical underpinnings around the world, viz: Europe (e.g. Chambers 1992; MacRae et al. 1989), the USA (e.g. Kloppenburg 1992) and developing countries (e.g. Khon Kaen 1987; Rhoades and Booth 1982; Whyte 1991).

Much of the aforementioned innovative thinking is being adapted to Australian conditions, and includes the application of action research and soft systems methodology (Checkland 1981). Although these approaches are philosophically compatible with farmer-first, it is beyond the scope of this paper to discuss them.

Most farmer-first ideas challenge the underlying assumptions of diffusion and ToT, such as the primacy of research knowledge, communication and rational decision making. William Foote Whyte is one who recognised the need to embrace the knowledge and action of farmers and local people in research and development activities (Whyte 1991). Rhoades and Booth (1982) were among the first to use the term 'farmer-back-to-farmer' to encapsulate the tenet that research should begin and end with the farmer. This thinking was later developed into 'farmer-first' (Chambers 1990), 'putting people first' (Cernea 1991) and 'farmer participatory research' (Farrington and Martin 1988).

New extension theory proposed that farmer participation, putting the 'farmer first' in research and technology development, would help prevent the formation of 'barriers'. The central ideas in the new research and extension process include involving farmers in R&D from the outset, using their knowledge and perspective's of the problem, and that researchers could learn from locals and work with them in a partnership. In farmer-first, the idea of identifying barriers to change and proceeding to remove them is deemed inappropriate: complex human systems and problems are involved, and the environmental and social consequences of change are unknown.

Participatory Research in Australia

Participatory research and extension are being embraced in Australia, but not always as a product of extension theory. Rather the move has arisen as a way of counteracting the negative social and environmental effects of development, and from by government and farmer organisations who realised that farmer participation is essential where public good and market failure are apparent. Landcare is an example of a 'bottom-up' co-operative activity able to address the negative externalities of past and current land use. Beginning as an alliance between the National Farmers' Federation and the Australian Conservation Foundation, it gained government support for a national program (Campbell 1994).

In a sense Landcare was a movement whose time had come. Farm families, lobby groups (NFF and ACF) and extension agencies—especially those with a conservation bent, grasped the opportunity to harness local people's enthusiasm and knowledge to do something for themselves and their environment (Poussard 1987; Disken et al. 1988). Early proponents and facilitators used a myriad of group extension and management training methods (mostly rediscovered) to meet the need. Chamala and Mortiss (1990) is a good example of the resurrection of group theory and methods—much of it well-known but discarded from earlier extension training manuals. Moreover, this useful text adds a theoretical dimension to landcare in the Participative Action Management model which Frank and Chamala (1992) describe as an 'organisational system by which various interests in the community and other outside agencies are organised into groups at various levels which offer true partnership to all stakeholders in sustainable agriculture'. Many other participatory initiatives are also being tried by farmers and R&D organisations in an effort to make research more relevant to farmer needs, and to address complex problems which are not amenable to solution by normal scientific methods (Woods et al. 1993; Dunn 1993). While the theory and methodologies are still developing, notable Australian achievements bring together constructivist social science methodologies and participatory extension approaches to solve agricultural problems (Hamilton 1995; Senn 1996). Furthermore, multi-disciplinary research initiatives combine natural and social science philosophies into unified methodologies such as participatory research.

But there are pitfalls in learning to use these 'new' methodologies. For instance, rapid rural appraisal (RRA)/participatory rural appraisal (PRA) require team work, with membership usually drawing on people from different disciplinary and vocational backgrounds. But as well as being an advantage, the interactions of people often cause problems that can jeopardise a project. Recent experience has also shown that it is often difficult for team surveys to train, collect and analyse data, write a report and encourage participation with the community. Specific problems include time and commitment. Time is often 'donated' in that RRA/PRA's are often done with minimal funding; people become involved through a desire to experience the methodology but are not far enough away from their regular jobs to be independent from them. Other problems arise because the method deals with qualitative data—a field that some people are not suited to (Dunn et al. 1996). It is one thing for an aspiring team to agree to team aims, open-ended questions and descriptive data, but when it comes to using a semi-structured interview protocol many team members lose confidence and may try to use direct or structured questions. It is surprising how difficult it is for team members to remove their regular work 'hat' and 'put on the team hat' and stick to the methodological rigour.

Participatory Research: Towards Empowerment

Farmer-first and participatory approaches are the first step towards equity in that farmers potentially have some say in what problems should be tackled, who should act and how action should proceed. On face value this would appear to be a workable alternative to ToT and already there is a plethora of participatory approaches with little agreement on a generic model. Anecdotal evidence indicates that group methods, which are often the basis of participatory extension, are too demanding and time consuming. While there is scant research evidence to support this, experience in the field suggests that special knowledge and skills are required. Woods et al (1993) provide a baseline description of the range of extension methods in use at the time. A similar picture emerges in the 'state of play' of participatory approaches. At the global scale a critical literature is emerging—particularly in developing countries. One view is that participatory methods are idealistic and naive (Thompson and Scoones 1994) but there is also a positive judgment that says they have changed the way extensionists, researchers and farmers work together (Chambers 1997 and Whyte 1991). In Australia, work by Campbell (1994) and Syme (1992) supports the latter view, however, there is no doubt that bottom-up (participatory) approaches are at an early stage of development and a critical literature should help their evolution. There is no doubt that radical alternatives to traditional research and extension processes are needed—ones that recognise that the 'dif-fused' technologies may not be appropriate for the well-being and prosperity of all farmers, and that the problem of negative externalities from agricultural development (especially environmental) has been underrated.

There is no doubt that landcare embraces significant participatory/bottom-up ideas, and associated policy initiatives seem to exemplify a new spirit of local and government initiative, however, more profound changes are likely to come from social science disciplines and philosophies. These go beyond criticising ToT where it fails to work by also raising questions of social equity. For instance, at one extreme a Marxist (critical) view was applied (see Hulme 1990) in arguments against cash-cropping in developing countries. However, in the late 1970s, in addition to the critical approach, there was a move toward participation which was seen as a way around the inadequacies of 'barriers to adoption' and for enhancing change. These approaches were complementary rather than competitive, the first operating at a macro level and the second at the local.

Through the work of Paulo Friere there was also a touch of revolutionary zeal to motivate local people to change things for themselves. This thinking has been influential in extension practice via the 'activist participatory research' approach (Chambers 1992). It was also recognised that farm-

ers could not always be expected to act in their own best interests (Fliegel and van Es 1983). Again, participation was seen as a solution, as it still is (Pearson 1994; Bell 1991).

From the literature, it appears that 'farmer-first' had a liberating effect on farmers and extension workers alike in that they were freed from the ToT paradigm and the idea that all technology was adoptable, desirable and beneficial to all farmers. Participation was the method by which 'farmer-first' developed into action by the interest groups involved in agricultural development. Though it represented a substantial conceptual change from diffusion, it was found to be inadequate. Diffusion was discarded because the idea of obstructions ('barriers') did not help to unblock the flow of ideas from researchers to farmers. On the other hand, a free flow of ideas which could have been expected to result from the exchange of ideas among farmers and researchers (implied by 'farmer-first' and participation) did not appear to be the full answer either. While there is evidence that the flow of ideas between researchers and farmers has increased (eg. participatory research projects are commonplace and R&D corporations frequently require evidence of farmer support and co-operation) evidence of 'barriers to adoption' thinking persists in the rhetoric and expectations of funding bodies and researchers. This suggests that the flow is not as free as proponents might have hoped. The concepts of 'barriers' and 'adoption' remain in research parlance and the extension literature (see, for example, Vanclay (1992)). Participation does not guarantee a stronger flow. Participation practitioners, such as Syme (1992) acknowledge that not all people are equally likely and able to participate, and moreover, that participation professionals often seek discussion framed around their own rationality, rather than that of the participants. The elitism inherent in many rural communities militates against universal participation (Gray 1992).

The participation approach has not eliminated the notion implicit in the top-down model of diffusion that the basic flow-of-ideas can be impeded. It is assumed that if no 'adoption' is detected on farm(s), despite an idea being promulgated by researchers, there is something obstructing the flow (diffusion) of the idea. That is, adoption is assumed to be the norm, and deviation from it requires explanation. Participation, however, does not rule out some exchange of ideas, and 'farmer-first' principles advocate an appreciation of social structures. However, 'farmer-first' in this context suggests that though farmers are consulted first, at the end of the day they are expected to be prepared to accept ideas rather than 'diffuse' their own. Syme (1992) acknowledges that participation is not about a transfer of power. The extent to which power is to be offered to participants should, according to guidelines discussed by Syme (1992), be laid down by those who conduct the participatory project. The perspective offered by a focus on 'indigenous technical knowledge', which has also gained popularity in the wake of 'farmer first', has led to more interactive data collection processes (Hulme 1990) but has not reversed the flow of ideas implied by the concept of 'barriers to adoption'.

Farmers are showing signs of wanting to participate in research and are able to contribute. There are many examples of this but at this stage there has been scant evaluation. For instance, although the FAST project (Rendell et al. 1996) was evaluated by Cary and Wilkinson (1996), the matter of farmers' interests in the research process has not been questioned theoretically.

The problem of interests—in this case farmers' interests—also becomes relevant when considering who selects the participants and who benefits from change. To explore these questions in a theoretical sense, two names are relevant: Marx and Friere. Both espouse action by the poor and powerless, which although understandable in a peasant economy would not appear to apply in Australia. However, who participates and with what resources are political questions which are not normally addressed (overtly) in determining extension and research priorities. We believe that unless this is done in such a way that farmers are shown how to recognise their interests and protect them against those of others (eg. other farmers, community groups or institutions) very little will be achieved by the participatory method. To address these issues, we advocate the inclusion of sociologists in extension and research programs.

Beyond Farmer-first Toward Farmer Action

A move beyond farmer-first must be based on:

- imputation of the 'objective' interests of farmers;
- inquiry into the perception or non-perception of their interests by farmers;
- understanding of the relationship between interests and objectives; and
- interpretation of the cultural construction and reconstruction of interests and objectives among both farmers and researchers.

This represents an agenda for research which demands more than participation by farmers in research and its planning. It makes no claims to empower farmers merely by offering them participation. Farrington and Martin (1988) see participation as a means of achieving understanding, but understanding on the part of either farmers or researchers alone will not alter power relations. Understanding, including the attribution and perception of interests of all interested parties by all interested parties, is only a starting point for the negotiation of objectives based on interests.

Extension that serves the interests of farmers must help them to perceive their objective interests and act upon them. This means empowerment which comes only from the kind of enlightenment offered by awareness of cultural construction and the structural forces shaping it. It also requires change in those forces, which can, as Bachrach and Botwinick (1992) argue, be achieved from arousal of con-

sciousness and consequent social action. Not all farmers are unconscious of their structural position (Gray 1994; Gray et al. 1995). A significant move beyond farmer-first will entail fostering awareness by promoting reflection on social structural conditions and assessment of interests in the light of the processes in which those conditions are reconstructed.

In the enlightened form of participation, farmers' involvement might be able to broaden what MacRae et al. (1989) called the narrow world-view and even self-deception of researchers. There is some irony in the observation that those who claim to identify barriers to the adoption of new practices, may in fact be those who are conservative in their own world-view and have been reluctant to change their goals (Beus and Dunlap 1992; Kloppenburg 1992; MacRae et al. 1989). This kind of participation implies a genuine reversal of the diffusion process, of the kind advocated by Kloppenburg, in which local knowledge and the priority of farmers' interests obtain legitimacy in both farming and research communities. Such change requires creation of the institutional conditions in which the interests of farmers and researchers can be perceived mutually and submitted to arbitration.

Arbitration will depend not only on the mutual perception of and respect for interests, but also on the legitimacy of the institution in which it takes place. Current institutions, such as public research corporations at one end of the spectrum and farmer organisations at the other, may not be suitable arenas for arbitration if they cannot foster reflection on social as well as scientific conditions. Only arenas in which the wider forces of individual, community and capital are able to pursue their real interests, under conditions which offer equal access to resources, will provide genuinely pluralist participation. Assumptions that the interests of individual, community and capital will necessarily converge are no longer tenable, given the critical turn in the extension literature. The literature records a growing willingness to conceptualise extension in terms of power relations, advocates the deconstruction of science and notes an apparent rise in consciousness of these issues among farmers. The legitimacy of the arbitration of competing interests rests on it being seen to be pluralist. Non-pluralistic institutions may feel they have to alter their structures to become providers of research effort as well as outcomes of this research as it affects all actors and interest groups. This would be a significant challenge in the user pays, reduced public good society today. Research into the cultural bases of agriculture is an essential precursor to the design of arenas in which the interests of all parties can be recognised and options for the fostering of sustainable agriculture negotiated.

Part 2*

SOME CULTURAL FACTORS IN THE EXTENSION OF SUSTAINABLE AGRICULTURE

Introduction: from Rational Action to Cultural Construction

When extension theory drops its assumption that development of sustainable agriculture is merely a matter of seeking adoption of sustainable techniques and recognises that a process of arbitration of interests is necessary, it becomes apparent that the cultural conditions which sustain the institutions of agriculture must be negotiated. Attempting to encourage behavioural change among farmers is insufficient. Altering decision-making behaviour ceases to be a reasonable objective when the issue to be confronted is rooted in the culture within which decisions are made, rather than the decision processes themselves.

Much research on changing practices in agriculture focuses on decision-making, and takes the perspective offered by rational action theory. This can include the 'farming sub-cultures' or 'farming styles' approach taken by Vanclay (1992) and Vanclay and Lawrence (1995), insofar as it is stilled framed by a notion of rationality. While it does not necessarily deny either the social construction of practice or the cultures within which practice occurs, a rational action perspective does not permit exploration of the cultural antecedents to practice. Rational action theory cannot explain behaviour which is either unconscious, habitual or responsive to social norms and values. As Hindess (1988) argues, intentions and subsequent actions arise from beliefs and desires which are socially and culturally constructed. Rational action theory assumes that people are able to recognise their interests, the consequences of possible actions and how they might carry out such actions. Waters (1993) argues that these assumptions are tolerable when applied to those material interests of actors [= participants]

* This part is based on Phillips, E. and Gray, I. (1996). Sustainability and the restructuring of tradition: analysis of farm practice and social change in three rural localities. In Lawrence, G., Lyons, K. and Momtaz, S. (eds.) *Social Change in Rural Australia: Perspectives from the Social Sciences*. Rural Social and Economic Research Centre, Central Queensland University.

which might be achieved in a short time, but are otherwise dubious. They have been, Waters claims, made for the sake of methodological convenience.

Farm practice is a social activity. Farmers navigate their community and society as they go about operating their farms. As phenomenology would tell us, 'they interpret their world in terms of common-sense categories and constructs which are largely social in origin' (Heritage 1987). (In this sense, phenomenology is close to the constructivist approach used by Hamilton (1995) to investigate the relationship between participatory extension methods and farmers changing to more sustainable practices.) The most significant problems for the rational action perspective arise from the rationality aspect, rather than as a theory of action. Hindess (1989) points out that analysis of action does not require assumptions or assertions that action is necessarily either rational or irrational. He recommends that we examine 'capacity to employ conceptual tools and devices to construct a connected chain of reasoning or argumentation' before considering the rationality of those tools. We should therefore study those conceptual tools. 'Actors use tools for thinking, and what results depends on the tools, on how they are used and on what they are used to work on' (Hindess 1988). This implies, as Craib (1992) has recognised, that the rational action view has directed research away from 'the ethnographic detail that actually enables us to understand how people think, how they see and in one sense, actually construct the world they live in'. Their world includes the information upon which their decisions and actions are based, and that information includes features of the social relations manifest in their everyday lives (Phillips and Gray 1995).

Alongside such theoretical arguments against rational action approaches, and implicitly economic determinism which is sometimes, though by no means necessarily thought to accompany it, comes a large quantity of research illustrating the apparent economic irrationality of farmers. During his early studies, Weber encountered German farm workers whose values so directed their efforts that they appeared to behave highly irrationally. 'Innumerable workers prefer to pay any price to a jobber for a piece of land and to live in abject dependence on creditors who charge usurious interest-rates, all this for the sake of the 'self-dependence' which they crave...' (Verhältnisse der Landarbeiter, quoted in Bendix (1962). This observation long precedes extensive research, such as Salamon (1985) in the United States, which reveals the strong influence of farm traditions, and contrasts the actions of farm families of different traditions.

For extension, it becomes necessary to devise systems in which farm people can bring change to their own culture in ways which serve their own interests, while not necessarily countering the interests of others. This demands foreknowledge of that culture—appreciation among farmers and researchers of what each party takes for granted and accepts as valuable or truthful. Culture is embedded in tradition, but is by no means fixed.

Farming Tradition

The cultural basis of agriculture has been extensively explored (e.g. Salamon 1985; Bennett 1982), and has been considered as a factor in adoption of farm practices by Vanclay (1992a and b). This is part of an extensive literature dealing with rural values and ideology. There can be no doubt that the values, norms and beliefs associated with farming differentiate farm life from other lifestyles. They also provide the tools with which farmers make, or do not make, choices about adoption of farm practices. Given that these tools will not be homogeneously spread or used, farmers will not make uniform contributions to participation in research and extension under farmer-first. Scoones and Thompson (1992) make this point with regard to the effects of social structures. It applies also to cultures.

Traditions are aspects of culture which are handed on through the generations. They can include ways of thinking and ways of doing: what people believe and what they do in their everyday lives in normal circumstances and on special occasions. Some people say that what people believe to be part of tradition is often more important than the actual practices and beliefs that have been carried on in the past. But, however regarded, tradition is an important prop to, possibly the keystone of, the social organisation of agriculture.

Agrarian identity and ideology, farm succession and inheritance practices, and farm knowledge have been the principal features of research into farm cultural tradition. The culture of family farming, as it has been transmitted across many generations among many societies, helps to explain the persistence of the family farming system amid conditions which militate against its survival. Craig and Phillips (1983) see it a little differently, discussing the ways in which agrarian ideology, a component of tradition, has legitimated the exploitation of family farms. However seen, farming tradition is an important factor in sustaining agriculture. Farm inheritance is central to the maintenance of that tradition. It provides an means for transmission of beliefs, values and practices. With the family and community relations it implies, it also provides a conduit for the knowledge upon which farm practices are based.

While tradition has been found to be important to the maintenance of the family farm system, it varies in its nature and implications. Farmers have been found to operate their farms differently according to subcultural norms: ways of working their farms which are accepted and commonly practised. They are believed to constitute the right way to run a farm (Vanclay and Lawrence 1995). Variation in tradition has been seen to produce different outcomes as farm families struggle to maintain their livelihoods (see, for example, Salamon (1985) for a discussion about the effects of contrasting ethnic and religious traditions).

Cultural tradition varies from place to place, among local communities. Ways of doing things can vary from one

area to another. This view is consistent with a 'local diversity', as opposed to a 'globalisation', perspective (Buttel 1994), the latter highlighting the ways in which agriculture is becoming standardised to meet the demands of large-scale food and fibre processing and manufacturing industries across the world. We present here evidence that change in the social relations and conditions of agriculture is affected by cultural attributes which may vary from place to place despite the advance of agribusiness and globalisation.

Tradition and Sustainability

Farm tradition, as far as it determines the practice of farming, has vast implications for the sustainability of agriculture and the family farm system. Unlike the extensive research which has connected culture with responses to farm economic and financial crises (including, in Australia, that of Gray et al. (1993)), examination of the association between culture and farm practice related to conservation of farm land is barely beginning. Locally derived and transmitted knowledge, sometimes known as 'indigenous technical knowledge' (Farrington and Martin 1988; Kloppenburg 1992) or 'craftship' (Mooney 1988) can be seen as a significant aspect of farm tradition as it provides a rationale for farm operation. Variability in farm practice associated with subcultures among farmers has been noted (Vanclay and Lawrence 1995). The significance in terms of land conservation practice of the other aspects of tradition, which are related to but distinct from knowledge, is little understood. Apart from some European research which has related intergenerational succession to farm conservation and development (Ward and Lowe 1994), little is known about how traditions of succession might affect the sustainability of agricultural land.

With much of Australia's agricultural land continuing to degrade, the relationship between farm tradition and sustainability is of great significance. Sustainability can be defined in terms of the capacity of social and economic, as well as environmental systems, to support the continuation of agriculture in the long term. There is evidence that farmers in the New South Wales Riverina see it in such terms (Ampt and Phillips 1994).

The relationship between tradition and sustainability has environmental, social and economic dimensions. It can be seen as more or less direct, but with some mediating factors. Tradition, in the form of inherited land use habits, directly impinges on the environmental dimension of sustainability. This is implicit in the point made by Vanclay and Lawrence (1995) about the prescriptions of subcultural norms: farmers suffer pressure to conform to the practices which are endorsed by fellow farmers. However, not everybody is a conformist. As some people find new ways of doing things, others may choose to follow, beginning a process of change as new subcultures emerge. The existence of subcultures, their significance and change are open to research in terms of the social relationships which develop, as suggested by Phillips and Gray (1995).

Association between culture and what people do may be apparent when tradition is seen to provide meaning to what people do, as it defines the 'kind' of people they are to themselves, families, friends etc. The work of Salamon (1985) in the United States has shown how these factors are related. Aspects of tradition, including beliefs about the value and meaning of farming, can be associated with different traditions. Specifically, farmers who are more entrepreneurial, seeking greater financial reward by risk-taking, have been found to be more prone to failure than those who adhere to a less materialistic tradition and can call on support of family and community in times of stress. With regard to environmental aspects, Stone (1992) has proposed that those communities which have weaker social organisation are less able to take the necessary collective action against land degradation. This point is implicit in much of the debate surrounding the community-based, but arguably government-controlled, Australian Landcare 'movement', upon which much hope for the perpetuation of Australian agriculture rests.

Detraditionalisation

Traditions can disappear without the loss of tradition in a general sense. Human motivations driven by attributes of culture can take different forms over time without a loss of tradition. In a sense, societies can be equally traditional when their traditions are recent inventions. Moreover, traditions may appear to be the possession of one interest group while serving the interests of another, as has been said of the way in which the traditions of family-based agriculture have facilitated the exploitation of farm family members to the advantage of agribusiness (Craig and Phillips 1983). The approach taken by Phillips and Gray (1995) recognises that tradition is continually reconstructed from within agricultural society, and is particularly visible at the local level. That process may occur under conditions created beyond agricultural society and farm-based interest groups.

The forces stimulating detraditionalisation can have horizontal or vertical orientations, corresponding to Shils' (1981) concepts of exogenous and endogenous factors. Horizontal forces present a spatial dimension, arising commonly with population movement. Immigrants bring traditions which may threaten indigenous culture. Of potentially greater significance are the vertical forces upon farming: those of economic decline amid the global restructuring of the agri-food industry.

Each of the approaches to the association between tradition and agricultural sustainability described above assumes that farm people have some degree of autonomy, even if only in their possession of a subculture. Each on its own focuses attention on the attributes of farm tradition. But farm tradition is not a construction of farm people alone; nor of course are the conditions in which sustainability is sought. The value placed on family farming and its attendant lifestyle is a so-

cial construction which has served the interests of urban-based capital as farm families have been moved to persevere through adverse conditions created largely by international business and trade. The significance of this aspect of tradition has been argued by Poiner (1990) in terms of local social relations and more generally by Craig and Phillips (1983). Phillips (1997) uses ethnographic analysis to show how farm family members use locally specific traditions as they struggle against global economic forces with local cultural tradition and their own life courses. While some struggle to preserve their way of life, others are more susceptible to the forces of globalisation.

The conditions under which farm people seek sustainability are such as to raise questions about the possibility of them even attempting to do so let alone achieving it. They must operate with the land available to them in the condition in which they obtained it and under economic conditions determined by national and international agencies. They are being forced to intensify production, thereby accelerating long-term environmental degradation (Lawrence and Vanclay 1994). Farmers find themselves placed on economic and technological 'treadmills'. The farm 'treadmills' on which farmers are forced to continually increase production at the same time as their returns decrease, were recognised in the United States as early as the 1950s (Buttel et al. 1990). The concept might be equally applicable to Australia in the 1990s and it represents a situation which is recognisable to farmers (Gray et al. 1995).

Australian farm tradition is under pressure to change. One can reasonably ask if it is sustainable. Australian farmers have persevered on a high-input treadmill, pursuing increased productivity with declining state support and knowing that doing so cannot be sustained socially (in terms of the strength of family and community relations), economically or environmentally. Farmers are questioning this predicament (Gray et al. 1995). Pile (1990) found that, somewhat ironically from an Australian perspective, pressure on British farmers to reduce production was making them question traditional values, seeking an escape from the production treadmill. This might seem to be a positive change. However, a tension emerges when the meaning of farming as a multi-generation family enterprise becomes questionable. A 'motivation crisis' arises, but it can be avoided by changing the meaning of farming as tradition is denied and changed. Such reflection has also been revealed by Ward (1993).

A Cultural Model

Farm practice forms part of cultural as well as more instrumental strategies (see Phillips and Gray 1995). It endows individuals with 'cultural capital', from which they obtain social standing, at the same time as they participate in the construction and reconstruction of cultural capital. Phillips (unpublished studies) has found that value placed on tradition, including succession, is related to the ways in which farm practices are changing amid globalisation. These findings emanated largely

from intensive ethnographic research using a small sample to examine direct relationships between farm practices and cultural factors as they are revealed in the everyday lives of farm people. The research discussed below seeks to relate, across a larger sample, the broader process of social and cultural change, beyond the construction, application and reconstruction of 'cultural capital'.

A cultural model of sustainability would suggest that those families who had stronger farm and community ties through longevity of farming and community membership would be more traditional and hence more likely to sustain their farm by handing it on to the next generation. Those who adhere to tradition may also be less materialistic in their ambitions, but if their adherence runs to farming practices, they may be more conservative, opting to retain traditional land-management habits.

There are many possible associations between detraditionalisation and approaches to sustainability. As a start towards looking at the factors involved, specific associations will be considered between values pertaining to farming life, intergenerational transfer of farms, and social networks and local demography as aspects of tradition and the economic, social and environmental dimensions of sustainability. The latter factors will be viewed in terms of perceptions of the high-input treadmill, intergenerational transfer and farm operating practices

An interview survey of 153 farm people on 79 farms was conducted across three areas in the Riverina region of New South Wales. Forty-two per cent of respondents were women. Respondents were aged from 18 to 79 years with a mean of 49 years. The three areas, each identified as a local community by respondents, have been given the fictitious names of Greater Redwood¹ (67 respondents), Milldale (37 respondents) and Grenbrook (49 respondents). Milldale and Greater Redwood are adjacent but have different soil types, the latter occupying an area of red loam, excellent for cropping. Milldale has a mixture of clay and granite soils. Both are flat to undulating. Grenbrook is about 80 kilometres from Redwood and Milldale. It is less consistent in landform and soil type. It contains rich alluvial land with some swampy and sandy areas, and a lot of heavy soil unsuited to cropping. The three localities provide a variety which illustrates many of the physical conditions for mixed farming in the NSW Riverina. Interviews were conducted on all but five farms in Greater Redwood, six in Milldale and four in Grenbrook.

The sample was obtained by identifying a small number of farmers in each community and asking them for the names of other members of the community until all families recognised as community members had been identified. Included were some families which did not consider themselves part

¹ 'Greater Redwood' consists of 33 farms of which the 20 farms discussed in Phillips (forthcoming) are a subset clustered in an area near the centre of Greater Redwood.

of particular communities, but were considered to be so by others. Interviews were carried out in late 1994. Family members were interviewed together. Separate responses were recorded for each member and discussion was encouraged.

The bearing of cultural tradition was measured in terms of values and longevity and strength of community membership. Values were explored using 25 questions seeking indications of the level of importance (on a 5-point scale) given to features of farm life including family and community relations and lifestyle as well as material factors like building up a big farm and having a high income. An open-ended question also asked what features were felt to be important. Longevity of community membership was measured using questions about the number of generations in which respondents' families had lived in their communities, how long respondents had lived in those communities and for how many generations their farms had been in their families. Community network density was measured using questions about proportions of friends and relatives living locally. Social sustainability was measured in terms of desires and expectations about intergenerational succession, and for those who had children old enough to have taken a career, how many of their children had taken on their farm as a career. Economic sustainability was seen in terms of farm equity and perceptions of the 'high-input treadmill', as the latter would suggest an unsustainable situation developing.

Given that there is much technical debate about which techniques will in the long term give rise to sustainability (Barr and Cary 1992) and given that not all techniques are likely to be appropriate on all farms, environmental sustainability was explored by asking about the types of farming techniques which respondents saw as most likely to conserve their land. They were then asked to what extent they used those techniques. This approach acknowledges the inherent subjectivity of sustainability. Although a large majority of Australian farmers are aware of land degradation and the measures which can be taken to combat it (Gray and Dunn 1992; Vanclay and Lawrence 1995), it was considered prudent to examine the range of conservation practices perceived by respondents.

Findings

Tradition

Features of farming life related to family, community and lifestyle were widely given great importance, suggesting that traditional values were being maintained. For example, 90% of respondents felt that having social contact with other farmers was important; 91% felt that having the appearance of their crops and livestock compare well with those of others was important; 95% felt that giving children a chance to farm was important; and 100% felt that being free to make their own decisions was important. However, rather fewer (77%) felt that having a high income was important and fewer still

(62%) gave importance to building up a big farm operation. Responses to the open-ended question fell into four categories: those raising independence ('being your own boss') (offered by 60% of respondents); lifestyle and environment (65%); aspects of farm tradition like 'love of the land' and 'working with your family' (24%); and the satisfaction of confronting a challenge (27%). While some respondents lamented that farming was now 'just a living', none mentioned material prosperity as important.

Respondents stated that their families had lived in their communities for between one and five generations, with 39% stating one generation and 36% three generations. They had lived in their communities for between 1 and 79 years (mean 31 years). Farms had been in their families for between one and four generations. About half of the respondents said that some of their relatives lived in their local community. More than half said that some and about one quarter said that more than half of their relatives live in their local community.

Having friends and relatives in the community is related to longevity (Table 1). Of those who had both friends and relatives locally, 77% said that all of their friends knew some or all of their relatives.

Those who, in response to the open-ended question about what was important to them, mentioned independence, tradition and challenge, had been living in their localities for longer in average terms than those who did not mention these features, although the difference between means for those who raised tradition is not statistically significant. Those who mentioned lifestyle and environment aspects had lived locally on average for a shorter period (Table 2).

Table 1: Correlation coefficients among longevity and social network density variables

	Proportion of relatives living locally	Proportion of friends living locally
Generations farm in family	0.53	0.32
Years living locally	0.41	0.31
Generations living locally	0.65	0.34

All coefficients are significant at the 0.01 level.

Table 2: Mean years lived locally among those raising aspects of farming as important

	Mentioned	Not mentioned	t-statistic	p
Independence	33.6	27.5	2.06	0.05
Lifestyle/environment	28.7	35.6	-2.28	0.02
Tradition	34.1	30.2	1.12	0.27
Challenge	37.0	29.0	2.46	0.02

t-value calculated on unequal variance where Levene's test for equality of variances $p < 0.05$.

Those who mentioned traditional aspects as important tended to be less materialistic. This is suggested by comparison of the mean scores of those who did and those who did not mention traditional aspects on a 'materialism' scale formed from 6 of the 25 questions about farm values. The six questions asked about importance given to having a high income, being seen to have a high income, building up a big farm operation, having a new car, having an annual holiday and having an attractive homestead. They offer an alpha reliability coefficient of 0.75. Those who mentioned tradition at the open-ended question had a mean score of 3.2 on this scale while the others had a mean score of 3.6. While not large, the difference is statistically significant at the 0.01 level ($t = -2.59$ assuming equal variances based on Levene's test of equality of variances).

Social sustainability

A weak correlation is apparent between longevity of local residence and wanting children to continue in farming (including those children who were already farming) ($r = 0.19$, $p = 0.028$) when wanting children to continue is scored on a scale of 1 to 3: no – uncertain – yes). A stronger correlation ($r = 0.28$, $p = 0.001$) appears between period of residence on the farm and wanting children to continue farming.

Neither of these dependent variables refers either to the respondent's own farm or to what is actually happening. Those respondents who had sons or daughters old enough to have taken a career were asked how many of their children had chosen their farm as a career. When those whose sons/daughters had taken on their farm were compared with those whose sons/daughters had not, a stronger pattern emerged (Table 3). A similar pattern appears across all three variables, with some limitations due to sample size, among those who had sons in their households and those who did not in terms of longevity of residence.

One might expect local longevity to be related to age, and therefore to likelihood of having a child taking on the farm. However, no association is apparent between age and local longevity. One might also expect that level of equity in the farm might be related to the taking of the farm as a career, either positively as prospects for the farm are better, or negatively because additional labour was needed. Neither such association is apparent. The mean level of farm equity among those passing on the farm is the same (89.7%)

for those whose sons/daughters had taken on the farm and for those whose sons/daughters had not. This does not eliminate the possibility of both effects occurring, however. (Stated levels of equity ranged from 30 to 100%.)

Economic sustainability

Three-quarters (75.8%) of the respondents perceived themselves as being on a treadmill. There is no association suggested between either farm equity or tradition in terms of local longevity/social network density and perception of being on a treadmill. There is some indication that those who place importance on tradition are likely to perceive themselves as being on a treadmill (80.6%). Mentioning challenge was less frequently associated with perception of the treadmill (63.4%).

Environmental sustainability

When asked what types of farming techniques respondents saw as most likely to conserve their land, a large variety of answers was offered. Most followed the prescriptions of conservation farming: reduced tillage, crop rotation, tree planting, lime application, perennial pastures, etc. Some preferred lower inputs: lower production and, in particular, reduced use of chemicals, reflecting the predicament which farmers face when deciding on means of conserving their land. When asked how extensively they use those techniques, a range of answers was again offered against a 4-point scale (Table 4).

Respondents were also asked if they used them as much as they would like to and those who said no were asked what was preventing them from doing so. Seventy-three per cent of those who were not using conservation practices as much as they would like to attributed this to costs. Twenty-eight per cent (43 respondents) mentioned other factors, about half of which related to either lack of knowledge or conservatism: 'sceptical, cautious, watching others, dad disagrees'. Seven respondents said that they had no choice but to over-crop their land. There is no evident association between attachment to tradition and citing conservatism or ignorance to explain lack of conservation activity.

There is, however, a relationship indicated, with some qualification due to sample size, between having a son/daughter return to the farm and extent of conservation activity. The mean score on the conservation activity scale for those with at least one son/daughter who had taken on the

Table 3: Mean scores on local longevity variables for those whose sons/daughters had and had not taken on the farm

	Son/daughter had taken on farm as career	Son/daughter had not taken on farm as career	t-statistic	p
Generations farm in family	1.8	1.4	1.76	0.08
Years living locally	43.3	30.2	3.18	0.01
Generations living locally	2.1	1.6	1.99	0.05

t-value calculated on unequal variance where Levene's test for equality of variances $p < 0.05$.

farm is 3.2, compare with 2.5 for those without ($n = 33$ farms, $t = 2.88$, significant at 0.01 level). When extent of conservation activity is divided into those stating not at all and a little, and those stating moderately and extensively, the relationship is clear (Table 5).

Table 4: Extent of use of techniques thought to conserve land

	Percent of farms
Not at all	5
A little	14
Moderately	65
Extensively	16
Total	100

Table 5: Having at least one son or daughter on the farm and extent of conservation activity

	Son/daughter on farm (% of respondents)	No son/daughter on farm (% of respondents)
Conservation activity low	9	40
Conservation activity high	91	60
Total	100	100

Those who had at least one son or daughter working the farm were less likely to explain lack of conservation activity in terms of cost. Ninety per cent of those who did not have a child working the farm attributed lack of conservation work to cost. There is no such association with conservatism/lack of knowledge.

Discussion

Tradition is important to farm people. Aspects of farm life often thought of as important parts of tradition were almost universally acknowledged as important and often raised spontaneously. Material aspects of farming were not considered to be so important and were not raised spontaneously. Some association is apparent between community and tradition, in terms of longevity of presence and strength of social networks. Those with longer-term local associations raised independence, cultural traditions and challenges as important features of farm life, but were less inclined to mention environment and lifestyle aspects. Perhaps they offered no novelty, especially if people were confronted with isolation and a harsh living environment.

There is only weak evidence of a dichotomy between those of a materialistic orientation and those who adhere to family and community aspects of tradition. Findings like those of Salamon in the United States are most unlikely. Salamon's

farm cultures were based on contrasting ethnic origins provided by the presence of people with German background among 'yankees'. No such contrasts of tradition were available in the study sites.

The relatively high frequency of apparent intergenerational succession, or at least potential succession, among those with stronger community ties is more significant. Possible explanations might include the greater stake which more intensively connected people have in their community, as it provides family and social contacts and associated security. Cultural rather than economic factors appear to be significant to social sustainability. There is no association between them: those who would bear tradition, having greater community affiliation, may be in a similar financial situation to relative newcomers after the borrowing activity of the 1980s and the cost-price squeeze and drought of the early 1990s.

Perception of latter-day farming as a 'treadmill' is widespread across the three localities. There is only a weak suggestion of association with tradition, in that those who espouse the importance of tradition may be more likely to see themselves on a treadmill. Perception of a treadmill could be associated with tradition and a desire to maintain the strength of commitment to the farm and family in order to work towards a way to stop the treadmill and get off. However, awareness of a treadmill would seem unlikely to be accompanied in the long term by faith in the values which helped to create a situation in which farm families' interests continue to be subjugated to those of larger capital. Farm people may lose faith in tradition as they find it has placed them on the treadmill, rendering them unable to exercise the very freedom to determine their futures which farm families have long valued.

Some farmers acknowledge conservatism in farm practices, but there appears to be no association between valuing traditional aspects of farm life and reluctance to try new land conservation measures. The finding that those farms on which a member of the second generation has chosen to take up a career use conservation techniques more extensively is more important, even if necessarily tentative because of the small sample size. Use of family labour is itself part of farming tradition. It is more likely to occur among the bearers of tradition: those with stronger community ties.

Ethnographic evidence collected in two of the communities (Phillips, 1997) suggests that they differ in terms of tradition. Relationships between groups and communities with different traditions may be very important. Further understanding of those relationships and processes is needed to complete this cultural perspective on sustainability.

Nevertheless, the detraditionalisation of farming can be seen in both vertical and horizontal dimensions. As the restructuring of agri-food industry proceeds and farmers find themselves more firmly tied to the treadmill, those who adhere most strongly to traditional values may be those most

likely to question their predicament. Those who see the challenge as important may be more willing to accept the treadmill and try to make the most of it. This point requires further examination. Nevertheless, perception of the problems associated with high-input, high-production agriculture, along with concern about specific inputs, shows that at least some farmers are questioning their practices.

Horizontal detraditionalisation may also be occurring. The point that intergenerational transfer of farms may depend at least in part on the strength of community ties suggests that the social sustainability of agriculture will be under growing threat. As the populations of farming communities decline and, moreover, long-term residents who succumb to financial pressure are replaced by newcomers, the stake which subsequent generations have in their farming communities will decline. Along with this may come a spiralling decline in farm succession and maintenance, which will be very difficult to stop. It implies that the supply of family labour upon which the family farming system, or perhaps rather urban and transnational capital's exploitation of it, has been based will be eliminated. Just as the family farm system has needed family labour to survive economic crises, so it now needs the input of family members in terms of labour and perhaps knowledge. They may be called upon to carry out the changes and the work necessary to climb off the treadmill and to take the steps needed to avoid continuing environmental degradation. But the decline of local tradition, along with the attraction of alternative careers, may eliminate this historical support mechanism.

Farm and Community Planning

The evidence presented above illustrates the interconnectedness of cultural factors and farm practice. It also indicates the potential breadth of such factors. Its most important finding, however, is the confirmation that farm practice is embedded in cultural practice, as it is indicated by community continuity and farm succession. Extension practice needs to move its focus away from individual decision responses toward fostering the cultural conditions in which farm people are empowered to make decisions which can account for the range of factors affecting their lives.

The social context for acceptance of a more sustainable agriculture is thereby cast in terms of change away from a 'traditional' agriculture, set in terms of social relations as they affect farm practice, rather than in narrow terms of a farm operation/production system perspective (Phillips and Gray 1995). Conditions in which people can recreate their own culture become the objective of extension. This requires reflection on that culture, and the windows it offers people to understand their own interests. It demands the fostering of a discourse in which the factors affecting all members of farm families and communities can be opened to discussion and negotiation. Men and women, young and old, have

different interests in farm practice, and the relationships among them, with regard to farm succession among other factors, can be significant to change in farm practice.

Genuinely participative approaches to research and extension are needed to create conditions in which farmers' interests are clarified and long-term goals can be set. A process of 'arbitration' by way of facilitation is required. This moves well beyond a ToT/linear information flow paradigm towards a 'Farm and Community Planning' (FCP) model for extension. The model will take a holistic approach, based on a broad systems perspective of community cultures and social structures and local traditions, as well as the physical, biological, geographic and social features from the socio-political and institutional environment (e.g. state and private organisations, firms etc.).

The planning aspect refers to the need to take a long-term view rather than to consider sustainability as a matter for isolated and/or short-term management practices. The community element is essential to coordinate the actions of farmers along integrated management principles, and to permit collective consideration of a wide range of options that affect farm sustainability, including community continuity and change in terms of social relations, as well as diversification into sustainable enterprises and off-farm development.

The key to this approach is to bring together farm family members to discuss their needs and the means by which they might be met. This requires planning for all aspects of their lives, going beyond the current notion of 'whole farm planning' to take into account their long-term financial, social and even emotional needs in relation to the farm. This adds great depth to the notion of participation, as it implies processes of problem solving, rather than just expression of views or interests. It brings interest groups, representatives of agribusiness, research and government (including regulatory agencies) and the local community to discuss their interests and possible action in agriculture and the local economy. A facilitator will help farm people and other stakeholders to see themselves in the contexts of the community cultures and social structures within which they can, or cannot, make choices and take action. The objective of FCP is to promote action beginning at the local level and moving to wider levels to achieve environmentally, economically and socially sustainable agriculture.

A key component of the FCP model is a form of social monitoring that recognises the centrality of people and their interests in the agricultural and land-use system. People provide the purpose and goals for agriculture, and their welfare is paramount to efficient and effective land-use systems and communities. Existing approaches to monitoring land systems concentrate on physical, biological and geographic factors but acceptance of a broader process requires additional levels of expertise. This has significant implications for retraining extension and research staff.

A collective model of extension would complement established trends seen in Landcare, Farm Management 500, Kondinin, the FAST project and similar co-operative activities which demonstrate a bottom-up/delegated approach. Research and development organisations are also attempting to foster a bottom-up community inclusive action—especially in matters of land and water sustainability. For instance, the Land and Water Resources Research and Development Corporation (LWRRDC) strongly supports participative community action in many of its projects. It commissioned a report (with other agencies in New South Wales, Victoria and Queensland) to promote technology transfer and adoption in irrigation. The report (Cape et al. 1994) is based on the PAM model described earlier (Frank and Chamala 1992; Chamala and Mortiss 1990) and is currently being trialled in five technology transfer R&D projects funded by LWRRDC. The outcomes are described as ‘social inventions’ and are designed to introduce change in and between organisations, and bring social science to agricultural development. The context of this work is international but its aims, personnel and institutions are all applicable to Australian circumstances. Methodologies which can be used to implement FCP build on rapid rural appraisal (RRA) and participatory rural appraisal (PRA). Useful features from RRA and PRA include those which enhance exploration and collaboration in solving complex problems, multi-disciplinary team work, collecting and using qualitative data, and community participation. Australian examples of this work are documented by Webber and Ison (1995), Ison and Ampt (1992) and Dunn et al. (1996).

Existing institutions such as Landcare, will not be adequate, however. While they may provide a base to build a FCP approach, they are currently too narrowly focused to foster the broad range of discussion and action needed to promote a culture for sustainability—that is, one in which diversity and change are valued and the old symbols of success in farming are questioned. FCP should be carried out at individual and group levels. Groups may help people to define their interests and objectives in the light of what appears feasible and desirable from a community perspective in which the full breadth of collective interests is recognised. The same forum should also discuss not only property management planning, but also business diversification, off-farm opportunities and farm succession. The farm people involved must then draw up their own plans for their farms and families, obtaining assistance where necessary from scientific, financial and family advisers (Gamble et al. 1995).

Great benefits would flow from the coordination of advice from disparate sources such as agronomists, financial planners and rural and family counsellors. Farm people could then plan holistically for all the aspects of their lives that might affect the sustainability of their farm, resolving contradictions which might later frustrate their plans. This would offer a degree of empowerment which, while not removing farmers from production treadmills and not neces-

sarily offering solutions to technical problems, would at least maximise the ability of farm families to respond to their own needs within the constraints imposed by international markets and other forces inherently beyond their control. The results of the research discussed in this paper suggest that environmental sustainability is, in part at least, dependent on social sustainability. Farm and community planning offers a means of marrying the two.

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Case Study I. Barriers and Constraints to the Adoption of Sustainable Farming Techniques

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Aspects of Rural Culture and the Use of Conservation Farming

Ian Gray, Emily Phillips and Tony Dunn

Summary

Research on the use of farm conservation practices has taken little account of farmers' subjectivity and, with a few recent exceptions, appears to be locked into a rational choice framework for explanation of farmer action. It focuses on the acts of decision-making rather than examining the characteristics of the social relationships which provide both context and rationale for decision-making. This research explores the literature on conservation farming and rural cultures to develop a model of the use of conservation farming in which account is taken of cultural tradition as well as farmer perspectives on conservation. Focusing particularly on community ties and farm succession, it uses a survey of farms in three communities in the New South Wales Riverina to examine relationships among cultural and structural factors associated with the use of conservation techniques. It concludes that community ties are significantly related to use of conservation techniques as defined by farmers, but that their significance arises through association with farm succession rather than behavioural norms or group membership. It advocates consideration of cultural factors in extension programming.

Introduction

Issues surrounding the application of conservation farming techniques remain prominent in both biophysical and social scientific literatures. Just as the biophysical sciences strive to improve such techniques, so the social sciences try to explain their level of popularity among farmers, and extension practitioners try to improve their frequency of use. Social science and extension, and perhaps indirectly the biophysical sciences, are suffering, however, from narrow conceptualisation of the so-called 'problem of adoption'. This narrowness is manifest in a failure to consider the potential significance of cultural factors which lie beyond the activities of land management in the practice of adoption of conservation farming in western societies. While some steps have been taken in this direction, they remain tentative and have failed to explain farmer actions.

This omission is perhaps surprising given that much research has been carried out on farming cultures in Australasia, Europe and North America. At least a start has been made in this project to understand Australia's farming cultures both theoretically and empirically. Some attempts have been made to apply cultural models to explain conservation practice. Little progress has been made, however, due to narrow conceptualisation and lack of empirical application. This is surprising, as conservation in agricultural and wider contexts is a prominent public issue in Australia, and cultural analysis techniques are prominent in social science discourse. It would seem that while culture has been discovered and analysed in many contexts in Australian rural society (see Share (1995) for examples) little attention has been paid to it in relation to conservation farming.

The Call for Conservation Farming in the New South Wales Riverina

The New South Wales Riverina is a diversified agricultural region producing a wide range of products on land devoted to grazing, dryland and irrigated crops and horticulture. It is part of the most important agricultural region in Australia: the Murray–Darling Basin. The entire Basin suffers from land degradation. Its soils are thin and lack nutrients. They suffer from erosion, salinisation, acidity and loss of structure (Lawrence and Vanclay 1994). Further degradation is occurring under all kinds of land use in the Riverina, but that which occurs in the 'mixed farming' (grazing and dryland cropping) area is of particular concern and is the focus of the research reported here.

Conservation farming is advocated by many researchers and extension agents as a means to ensure the sustainability of agricultural production within the constraints of the physical and economic environments. It has been defined as 'the management of the land in accordance with its capability, the emphasis being on maintaining or enhancing the economic viability of agricultural production, the natural resource base, and other ecosystems which are influenced by agricultural activity' (Walters and Rovira 1994). In terms of farm operating practice, conservation farming as undertaken

in the Riverina involves reduced tillage and the direct-drilling of crops; use of preferred crop rotations and replenishment of soil nutrients by application of fertiliser; gypsum and lime to condition soil where appropriate; reduction of weeds and other pests through rotations; crop variety choice; and application of chemicals (Steed and Pratley 1993, 1994; Walters and Rovira 1994).

Many commentators agree that adoption of conservation farming is increasing but not as quickly as is necessary to guarantee a sustainable agriculture. Lack of adoption of conservation farming is widely considered to be a problem and is either explicitly stated as such (by, for example, Vanclay (1992)) or assumed to be (by, for example, Rose (1992) and Sinden (1988)). The problem is, however, more complex than such consensus might suggest. Estimates of the rate of adoption of conservation farming are made difficult by variation in appropriateness of practices among farms. Each farm and each paddock on it can require different management (Walters and Rovira 1994). Steed and Pratley (1994), however, report that 30% of farmers in south-eastern Australia use direct drilling, an almost universally applicable conservation practice which is often considered to be a radical change from earlier methods. Rose (1992) reported that 40% of Australian broadacre farmers had undertaken soil conservation work, but only 12% had changed their crop management practices for conservation purposes during the previous five years. Many of those farmers known to have soil conservation problems were reducing their tillage. Mues et al. (1994) report that 73% of mixed farms had undertaken minimum or reduced tillage and 37% were direct-drilling. Although estimates of its occurrence vary, there is little doubt that conservation farming is not used as widely as it could be. Whether it is used as widely as it should be remains an open question.

Other commentators raise doubts about conservation farming and the advocacy of change in farm practice in order to obtain sustainability. Such scepticism comes from those who question the practices *per se* and those who see the problem of sustainability as grounded in the effects of international business and economics. From the latter perspective, Lawrence and Vanclay (1994) see land degradation in Australia to be a result of agricultural 'productivism' enforced by an international system which demands exploitation of rural land in a context of world over-production of food and fibre, and national policies which worsen the vulnerability of farmers to such forces. Changing practices on the farm will not help farmers to escape the economic treadmill on which they are forced to continually increase production at the same time as their returns decrease. This problem has been recognised since the 1950s (Buttel et al. 1990). It has been exacerbated as land has degraded and greater inputs are required to maintain its productivity.

Conservation farming practices have been questioned by those concerned about extensive use of chemicals, an important component of conservation tillage practices. Barr and

Cary (1992) point out that, although chemicals have in many ways made production and consumption of food safer, they are potentially hazardous. Moreover, while they undoubtedly promote the commercial success of agribusiness which produces and sells them, they are not likely to offer permanent sustainability to agriculture. The inevitable increase in the use of chemicals, which conservation tillage and 'chemical fallowing' imply, has been seen by farmers and others to place farmers on a technological as well as an economic treadmill. The challenge to perfect farming techniques can result in farmers knowingly and voluntarily placing themselves on a treadmill (Pile 1991), though they may be well aware of the predicament implied by a treadmill which delivers certain long-term costs but doubtful long-term benefits. The call for adoption of conservation farming may be a simplistic ideal in behaviourist terms and an untested technology in a long-term ecological sense. The questions posed raise issues for research on conservation farming practice.

The Problem of Adoption of Conservation Farming

The literature abounds with studies seeking to explain the adoption/non-adoption of conservation farming. The issue has been developed from a long tradition of investigation into the diffusion of innovations among farmers. From this perspective, research has assumed that the problem to be investigated is that of non-adoption. The adoption of sustainable farming remains an important research problem, regardless of whether specific conservation practices continue to be seen to be sustainable and therefore beneficial to farmers. Questions about their beneficence, however, raise other problems. Should research treat non-adoption as a problem when doubts can be raised about whose interests will ultimately be served by an increase in adoption? This question makes it difficult to treat non-adoption as the singular problem implied by much of the literature on conservation farming. The acceptance of conservation farming by farmers is obviously of benefit to those who develop and profit from the associated technologies. However, from the perspective of farmers the issue is more complex.

Much research on the adoption/non-adoption of conservation farming has identified uncertainty and risk as factors inhibiting farmer adoption of such practices. Fliegel and van Es (1983) found that adoption of conservation practices does not follow the same pattern as production technologies. Cary (1992) and Guerin and Guerin (1994) see attitude to risk as a significant factor inhibiting adoption. Gorrard (1993) acknowledged safety risks associated with chemical-use to be significant for farmers. Lockie et al. (1995) found concern among farmers about committing themselves to an expensive high-input mode of agriculture. Vanclay (1992) and Vanclay and Lawrence (1995) argue that farmers perceive risks associated with conservation farming, and that non-adoption from their perspective is rational, given their sub-

cultural orientations, knowledge and interests. There is much debate about the value and validity of farmers' knowledge (see Kloppenburg, 1992) and their perceptions of risk (Lockie et al. 1995), but there can be no dispute that all conservation farming practices will not necessarily serve all farmers equally well in all circumstances, or that farmers do have their own specialist knowledge of their land and their own perceptions of what is best for their farms. However, in common with much research on rural change, the study of conservation farming has largely ignored this subjectivity and assumed that conservation farming techniques as prescribed will best serve the interests of all farmers (see Harper (1987) for a discussion about humanistic approaches to rural research).

If we accept that farmers are in a position to assess their own interests and the ways in which those interests might be served, the problem of adoption is one of farmers taking action which will best serve what they see to be their interests—given short-term imperatives and long-term goals—in terms of conservation of their land. Such action can be defined only by farmers themselves. Therefore, the dependent variable for adoption research should arguably be farmers' perceptions of appropriate conservation action for their farms and its outcome. None of this argument suggests that it should be assumed that farmers have perfect or even extensive knowledge of the possibilities for conservation practice or even the nature of their own real interests (as argued in Gray et al. 1997), although it seems likely that a large majority of Australian farmers is aware of land degradation and the measures which can be taken to combat it (Gray and Dunn 1992; Vanclay and Lawrence 1995). No research on the adoption of conservation farming practices has yet taken this subjective or humanistic approach—using as its dependent variable what farmers see to be conservation practice.

Levels of Social Explanation

With its attention to decision-making, research which has attempted to account for adoption/non-adoption of conservation farming has largely focused on the individual characteristics of farmers, failing to take account of the communities to which they belong and the social relations in which they participate. It has therefore in large part been 'methodologically individualistic', proposing that action on conservation farming is simply the sum of the actions of individual farmers. As the practice of extension has been aimed largely at individual farms and their operators, with a recent trend towards group extension methods, the focus on individual behaviour in extension research is not surprising.

Research has, however, tended to the social end of the spectrum of individualism outlined by Lukes (1970), in which aspects of social context are 'built into the individual' but have been 'swept under the carpet' as objects for research. Social context can, however, be very important in explaining individual behaviour. Explanations for human behaviour can often

lie outside the individual and lie, rather, in relationships among individuals or between individuals and society at large. For much behaviour, social context provides a more satisfactory explanation than interpretation of behaviour as the rationally determined and intended decisions and actions of individuals. For example, much behaviour has unintended consequences. Agricultural production which pushes prices down is a good example. More pertinently, much behaviour is habitual and/or taken-for-granted as the socially accepted thing to do.

It is important, therefore, that the social element beyond rational decision-making be explored. This is not to say that any behaviour is necessarily to be seen as either rational or irrational. But it does imply that there may be more than one kind of rationality, based on different sets of social prescriptions or habits. Extension research has tended to take a positivistic approach using explanations derived from rational-action models to the neglect of more phenomenological approaches which may assist understanding of how social context comes to 'build in' predispositions to certain courses of action. The analysis to be carried out here retains a positivistic approach, attempting to establish the 'facts' of social context behind farming practices, while dispensing with the assumptions of rational action models. The accompanying paper by Emily Phillips takes an ethnographic approach which leads to deeper exploration of cultural factors in an attempt to interpret the meanings attached to symbols and behaviours rather than just their social context.

Among other positivistic research, non-adoption has been explained in the international literature in terms of economic and demographic features of farms and farm operators (see Saltiel et al. (1994) and Warriner and Moul (1992)). Australian studies have focused on financial status (Cary 1992; Gorrdard 1993; Guerin and Guerin 1994; Rose 1992; Sinden 1988; Vanclay 1992), age of operator (Rose 1992) and the complexity of the technology involved and beliefs about it (Cary 1992; Gorrdard 1993; Steed and Pratley 1994). All of this research indicates empathy with the predicament which farmers face when confronted with a call to spend money while incomes are falling, short-term benefits are negligible and long-term benefits are uncertain, but it neglects the cultural elements behind such issues.

Much research, including some of that mentioned above, comes closer to a cultural perspective when it considers socially constructed attitudes to conservation (see Saltiel et al. (1994) and Warriner and Moul (1992) for reviews of the international literature). Studies of attitudes, however, suffer from three problems. They impose objective categories on subjective factors; they have a questionable relationship with action; and they offer no clues as to the processes through which they are socially constructed. It is sometimes argued that the problem of association between attitudes and actions is a product of procedures used to measure attitudes in which global attitude indicators are related to specific actions (Beus and Dunlap 1994). Further refinement of indicators will not, however, overcome the issues of subjectivity

and social construction. Vanclay (1992) points out that attribution of non-adoption to the attitudes of farmers leaves responsibility for conservation on their shoulders. One might infer that the frequent consideration given to attitudes in studies of the adoption of conservation farming is a product of concern to achieve adoption by changing the attitudes and actions of farmers alone rather than seeking policies directed at structural impediments, as suggested under the political economy perspective. Ison (1993) recommends that rather than focus on farmer attitudes, research should attempt to alter the relationship between farmers and institutional authorities in which the knowledge and values of farmers suffer continued subjugation.

However, Cary (1992), Ison (1993), Sinden (1988) and Vanclay (1992) show that there need be no association between having positive attitudes towards stewardship or conservation and the practice of conservation farming, and that attitudes are not a constraint on adoption. Attempts to change them would therefore be of little value and are dubious from ethical and social equity perspectives.

Some research, including that discussed above, acknowledges that farmers' actions may be responses to social norms of behaviour. The models derived from this view assume rationality on the part of farmers while not assuming any particular basis to that rationality. Saltiel et al. (1994) propose that peer group acceptance is an important factor in adoption decisions. Goreham et al. (1992) indicate that farmers who choose alternative practices lose prestige as they can no longer be judged according to locally-accepted norms of good farming. Bultena and Hoiberg (1983) note the importance of perceived support for change in farm practices among other local farmers. In the Australian context, Gorrard (1993) found pressure from neighbours, family and professional advisers to be significant, but dismissed it as irrelevant to extension. Vanclay (1992) sees this in terms of farming sub-cultures, within a broad rural Australian farming culture (described by Stone (1992, 1994)) but steps back towards individualism by interpreting this process as farmers applying their own sub-culturally determined rationality.

A similar step away from individualism is taken by Warriner and Moul (1992). They argue that emphasis should be moved from analysis of the characteristics of individuals and towards analysis of social networks. The focus of research thereby moves to features of kinship networks and their association with decisions to adopt conservation farming practices. Such approaches make aspects of culture the objects of analysis. This serves to focus attention on the cultural characteristics of farming society rather than farmers as individual actors.

Cultural Models of Conservation Farming

Change to conservation farming practice, whoever defines it, represents change in cultural tradition. All aspects of culture can be part of tradition. The only essential element of cultural tradition is its historical transmission through generations. It can encompass objects, but beliefs and habits rather than physical realities may constitute its most significant features. Shils (1981) offers a broad definition: 'anything which is transmitted or handed down from the past to the present' through generations. It can encompass 'all accomplished patterns of the human mind, all patterns of belief or modes of thinking, all achieved patterns of social relationships, all technical practices, and all physical artifacts or natural objects' (Shils 1981). Belief about culture may itself become a tradition, regardless of the reality of any cultural attributes to which the status of tradition is attached. This possibility is raised in terms of 'invented' tradition, but not seen as genuine tradition, by Hobsbawm (1984), and considered to be an important feature of tradition by Giddens (1994). Giddens asserts that what is thought to be 'tradition' can be more important than what has long and genuine historical roots. The practices of farming and beliefs about them, involving the technologies applied, the habits of behaviour, the decisions made and the social relations, beliefs and mythologies of those involved in such activities, may be directly related to the conservation aspects of farming.

Inherited land use tradition directly impinges on the environmental dimension of sustainability. This is implicit in the farming styles perspective (van der Ploeg 1989) discussed in the Australian context by Vanclay (1992) and, in particular, his point about the prescriptions of subcultural norms: farmers suffer pressure to conform to the practices which are endorsed by other farmers. Non-conformity is logically predicated on conformity and as such it suggests pressure for change, although the sub-culture model makes no accommodation for change. Moreover, it takes no account of other aspects of cultural adherence and the interactions among them. Departure from the constraints of an individualistic, rational-action perspective permits a broader consideration of the relationship between culture and farm practice, because it introduces a range of intervening factors and offers a potential perspective on change.

Moving towards a cultural model, Stone (1992) has proposed that those local communities which have stronger social organisation, and presumably stronger traditional ties, are better able to take necessary collective action against land degradation. Those who participate in Landcare groups have been found to be more likely to adopt some conservation farming practices (Curtis and de Lacy 1995; Mues et al. 1994; Ockerby and Roper 1994) but the evidence has been weak and inconsistent. It may offer some indication that Landcare membership is an instrument for gathering the collective energy of communities with strong ties and directing it towards conservation. But as Mues

et al. (1994) point out, the direction of causality has not been confirmed. Landcare participants may be predominantly those who perceive degradation problems and are seeking to solve them. Nevertheless, Landcare membership could be proposed as an intervening variable between community ties and conservation practice.

Such models oscillate between individualistic action interpretations and cultural explanations unconstrained by rational action theory. An example of the latter which introduces analysis of social relationships is that offered by Phillips and Gray (1995) and Phillips (1996). Moving away from the 'farming styles' approach and the more traditional approaches to farm management which include decision and rational action models, this perspective brings anthropological, sociological and geographical perspectives to bear on the problem of farm sustainability. Phillips and Gray (1995) and Phillips (1996) draw on concepts developed by Bourdieu (1990) in order to understand how cultural structures such as stratification, which reward good farming ability, constrain or enable or in any way influence the construction of farming practice. In creating and struggling to redefine farming ability as a criterion and dimension of stratification within the social field of farming, it is argued that farmers create the opportunity to gain symbolic and cultural capital from farming their land in certain approved ways.

As the cultural construction of farm practice can influence the adoption of sustainable practice, the central problem becomes one of understanding how 'good farming' is defined. The process of cultural construction, however, is carried on under structural and cultural conditions which extend beyond the farm, the local community and the labelling of farm management. The notion of 'good farming' can be applied to all aspects of farm tradition: a 'good farmer' might also be a good parent. Nevertheless, if this process has resulted in redefining good farming in terms which comply with the demands of conservation practices, there would seem to be greater likelihood of extensive conservation activity.

Intergenerational Farm Transfer

The intergenerational transfer of farms relates cultural tradition to family and community relationships which may impinge on conservation practice. The practices of succession and inheritance, along with agrarian identity and ideology, farm knowledge and operating practices have been the principal foci of research into farm cultural tradition. Farm succession and inheritance, or at least belief in their virtues, are central to rural culture and have fundamental importance to the family farm system (Potter and Lobley 1996a,b). When succession occurs, it offers maintenance of tradition by way of the provision of an instrument to transmit beliefs, values and practices, as well as ensuring a continued supply of labour. With family and community relations, it also provides a conduit for knowledge which may be significant to farm practices. Locally derived and transmitted knowledge as a basis

for farm operation, 'indigenous technical knowledge' (Kloppenburg 1992) or 'craftship' (Mooney, 1988), can be seen as a significant aspect of farm tradition. It may be accounted for in Vanclay's (1992) approach to farm sub-cultures and Phillips' (1996) dynamic model which places farm practice in a context of local social relations. The significance of other aspects of tradition, such as intergenerational transfer of farms and local community ties, which are related to but remain distinct from traditional knowledge and farm operating practices, is little understood.

Intergenerational transfer is central to farming tradition in many cultures (Ward and Lowe 1994). Although Nalson and Craig (1989) see an element of mythology in succession and inheritance tradition, they acknowledge that it does reflect practice to a significant extent, with three-quarters of Australian male farmers being sons of farmers. While Australian farming tradition has been drawn from Europe, it has never contained the strong 'peasant mentality' identified by Bohler and Hildenbrand (1990), but the importance of the farm and the commitment of family members to it have been features of Australian rural culture. As in Europe (Symes and Appleton 1986; Symes 1990) there is evidence of modernisation: less value being placed by 'modern' families on continuity of the farm in the family as they place greater value on farming as a business (Hannibal et al. 1991).

The value placed on succession can remain strong even when, as Gamble et al. (1995) report, families do little to formally arrange it. However, it would seem likely that Australian farm communities lack the 'common purpose' (Symes and Appleton 1986) which had been a feature of English farm communities, associated with strong local networks and family continuity. Nevertheless, as succession declines as a practice, so will the community ties upon which the value placed on succession is partly founded. Even if values remain strong the structural condition of farming is making succession less attractive (Gray et al., 1993). The significant change occurring in Australia may be one of reality rather than values: rather than farm families becoming more materialistic in their succession and inheritance goals, they are questioning whether a farm career will serve their children as they might wish.

How might intergenerational transfer affect conservation farming? With regard to direct effects from intergenerational transfer, one might expect that farmers who anticipate that at least one of their offspring will continue operation of their farm would be more interested in its long-term viability. Moreover, those farms which have been taken on as a career by a younger family member may receive the benefit of new ideas, possibly drawn from educational opportunities not available to the older generation during its education or not so accessible to it more recently. The presence of a successor on a farm also provides more labour, thereby reducing the costs in terms of time and money of effecting change in a farm's operation. European research has found that older farmers who have successors are more likely to seek to ensure that their farm is well-developed, so that their heirs will

take over a productive operation (Potter and Lobley 1992a,b). Providing a productive farm for an heir means leaving one without degraded land. When applied to Australia, this implies, somewhat ironically, that those farmers with successors may be just as likely to conserve their land, the opposite of Potter and Lobley's (1992a,b) finding that those with successors are more likely to exploit it for higher production. Such is the dilemma for Australian farmers who might seek a more profitable operation for their heirs but may be just as concerned about ensuring that land degradation does not render their asset unproductive.

None of these factors has been explored in the context of conservation farming in Australia. Sinden (1988) considered the presence of a potential heir as a factor but found no association with conservation practices. This does not eliminate an association between involvement of a potential or actual heir and conservation practice. By no means all potential heirs, or their parents, aim for the younger generation taking on farms as careers at times when the terms of trade for agriculture seem to be in permanent decline (Gray et al. 1993) and, as Nalson and Craig (1989) point out, it is unusual for a farm to remain in a family for more than three generations. Guerin and Guerin (1994) saw age of offspring and the likelihood of succession and inheritance as possible factors affecting conservation farming, but they could find no evidence for this and they do not place such factors in their list of priorities for conservation extension research. The effect of the presence of a successor working on the farm has not yet been explored.

Community Ties

The cultural conditions conducive to both succession and conservation practices could hypothetically include strong community ties. The diffusion-of-innovations literature implies this to be a necessary condition for the use of conservation farming: ideas are more likely to flow where networks provide communication pathways. Warriner and Moul (1992) offer support for such a proposition in the context of conservation farming, having found some correlation between conservation tillage activity and the connectedness of farmers' communication networks. This implies some consideration of community ties as a cultural attribute. However, they look at this association individualistically: as a factor in decision-making rather than seeing it as a feature of a broader cultural tradition in which habits and values develop and change without necessarily conscious deliberation.

Strong community ties could foster conditions in which redefinition of good farming and change in farm practice occur, possibly by way of interaction facilitated by Landcare groups. The dependence of community on succession has been discussed above. More pertinent perhaps, is that succession might be dependent on community. Those children whose families share community life may be more disposed to continue farming in their community where their friends

and relations form the locale of their socialisation and continuing everyday lives. Successors who have been exposed to new ideas may be likely to foster the adoption of new practices on their parents' farms. However, farmers' strong ties to the community could hypothetically also be related to maintenance of cultural traditions which impinge directly on farm practice and in which 'good farming' is defined in traditional rather than 'modern' conservation terms.

In summary, the literature on adoption of conservation farming practices neglects the farmers' subjectivity and takes an individualistic approach. In order to remedy these problems, research needs to use farmers' perceived levels of appropriate conservation action as a dependent variable and examine its association with socio-cultural attributes. Of the latter, values and practices related to intergenerational transfer and the strength of ties to the local community are suggested in some literature to be worthy of examination in the Australian context. However, strength of community ties is conceptually unclear. Strong ties could be associated with the maintenance of traditional land management practice at the same time as they promote conservation activity by way of farm succession and/or participation in Landcare. This point of conceptual uncertainty demands understanding of the processes through which farmers come to terms with these forces. Such processes can be fully understood only through ethnographic study of the interpretations which farmers make of these factors and their own cultural traditions. This research attempts to explore the relationships among these factors as far as it can under the limitations of a relatively small interview survey. The following propositions, derived from the forgoing analysis, can nevertheless be proffered.

- 1 Farmers' perception of practices which are most likely to conserve their land demonstrate some conflict over issues such as use of chemicals.
- 2 Farmers who have children are more likely to undertake what they perceive to be conservation practices than those who do not have children.
- 3 Farmers who expect any of their children to continue farming are more likely to undertake what they perceive to be conservation practices than those who do not expect children to continue farming.
- 4 Farmers who have a successor taking on their farm as a career are more likely to undertake what they perceive to be conservation practices than those who do not have a successor.
- 5 Farmers who have stronger ties to their local community are more likely to undertake what they perceive to be conservation practices than those who have weaker community ties.
- 6 Farmers who define good farming in terms which encompass conservation farming techniques are more likely to undertake what they perceive to be conservation practices than those who do not.

- 7 The effect of community ties on conservation practices is mediated by succession, membership of Landcare groups and/or redefinition of good farming practice among community members.

Consideration of these factors does not imply that others found to be significant should be ignored. As Warriner and Moul (1992) discuss, many individual and contextual factors are likely to be important in making decisions about land conservation. It is equally important to note that the cultural conditions in which conservation does or does not occur either intentionally or habitually are very complex and interrelated. Furthermore, the farmers' subjectivity cannot be seen as necessarily accommodating only cultural attributes. Their cultural orientations are better seen to be in constant interaction with the economic and demographic conditions confronting them. Such conditions encompass farm financial position, farmers' age and education and the area of their farm under crop and therefore potentially most demanding of conservation.

Research Design

An interview survey of 153 farm people on 79 farms was conducted across three areas in the Riverina region of New South Wales. Forty-two per cent of respondents were women. The age range of respondents was 18 to 79 years with a mean of 49 years. The three areas, each identified as a local community by respondents, have been given the fictitious names of Redwood (67 respondents), Milldale (37 respondents) and Grenbrook (49 respondents). Community samples were chosen so that variables pertaining to the community networks of respondents could be examined. The sample was obtained by identifying a small number of farmers in each community and asking them for the names of other members of the community until all families recognised as community members had been identified. Included were some families which did not consider themselves to be members of the communities, but were so by others. Interviews were conducted on all farms except five in Greater Redwood, six in Milldale and four in Grenbrook. These families were either unwilling or unavailable to be interviewed. Interviews were carried out in late 1994. Family members were interviewed together. Separate responses were recorded for each member and discussion was encouraged.

Variables were derived to indicate the concepts specified in the propositions above. They include conservation farming practice, succession, community ties, the labelling of good farming, participation in Landcare, and economic and demographic factors.

Conservation practice

Perceived level of conservation farming activity was measured by first asking respondents about the techniques which they saw as most likely to conserve their land. They were then asked to what extent they used those techniques, with

responses recorded on a four-point scale from 'not at all' to 'extensively'. They were then asked if they used those techniques as much as they would like to. Those who replied in the negative were asked why they did not use conservation techniques more extensively.

Succession and community ties

Independent variables include expectations about succession by offspring and the number of offspring who had actually taken on the farm as a career, cross-checking by questions about presence and age of children. Strength of community ties was measured by a question which asked respondents to state the number of their five nearest neighbours whom they had visited over the previous 12 months. Longevity of community membership was measured by asking how long respondents had lived in their local communities. Questions were also asked about proportions of respondents' relatives and friends living in their local communities.

'Good farming'

Definitions of 'good farming' were sought by asking open-ended questions about what respondents see on a good farm and what they think makes a good farmer. The questions were open-ended to avoid leading respondents towards issues related to sustainability which had been the focus of much of the interview. In this way we also sought to minimise any influence the researchers' institutional employer may have on the interviews by way of its pre-eminence in conservation farming research and teaching. These indicators remain broad as they do not recognise the process nature of definition of good farming which can only be explored ethnographically (see accompanying paper by Emily Phillips) They do, however, suggest what is on farmers' minds as they judge and rank themselves with each other.

Landcare

Respondents were asked about the farming organisations of which they were members in an open-ended question that allowed for wide definition of relevant organisations including Landcare.

Other factors

On the basis of earlier Australian and overseas research (such as Rose (1992) and Culver and Seecharan (1986)), economic and demographic factors were explored using questions about the level of equity respondents held in the farm, the total area under crop on their farm, their levels of education and their age.

Findings

Conservation farming practice

A wide range of farming practices was mentioned, with respondents mentioning on average almost three practices each (Table 1). Ninety per cent of responses related to management of soil and plants. Only a small minority of respondents mentioned a practice other than recommended types of conservation farming. Some (18.9%) gave general responses indicating a broader view of the relationship between conservation and sustainability, while fewer (9.9%) mentioned considerations reflecting the possible conflict between conservation techniques and the need for a viable farm operation. There was some disagreement among family members about the techniques thought to conserve land. In 10% of

Table 1: Farming practices seen by respondents as most likely to conserve their land

Conservation technique stated	Responses	Respondents
Management of plants and soil:		
minimum tillage	14.9%	42.8%
Crop rotation	13.3	38.2
Perennial pastures	12.2	34.9
'Not overworking land'	9.9	28.3
Lime application	9.4	27.0
Direct drilling	8.3	23.7
Tree planting	7.6	21.7
Chemical fallowing	6.7	19.1
Spray topping	3.7	10.5
Applying fertiliser	2.1	5.9
Soil testing	1.1	3.3
Applying gypsum	0.5	1.3
Adopting a farm plan	0.5 90.2	1.3
General aims:		
'Putting back what taken out'	2.1	5.9
Decreasing production	1.4	3.9
Minimising salinity damage	0.9	2.6
Stopping soil erosion	0.9	2.6
Managing water	0.9	2.6
'New techniques'	0.5 6.7	1.3
Other practices:		
Minimal spraying	1.6	4.6
Some conventional cultivation	1.4	3.9
Maintaining viability	0.2	0.7
Maximising efficiency	.2 3.4	0.7
Total responses	100.0	286.8 ^a
<i>n</i>	436	152

^a Respondents total greater than 100% as multiple responses were offered.

interviews, differing responses were obtained despite household members being interviewed together. Moreover, when asked what practices were degrading land in their area, more than half mentioned excessive cultivation, but 5.3% also mentioned chemical use and 4% the more general factor: high inputs. These findings indicate some conflict in perception of what conservation practice involves both among farms and among family members. Thus, the first of the propositions listed earlier obtains support.

Almost two-thirds of respondents described themselves as moderate users of the techniques they believed would conserve their land (Table 2). Three-quarters said that they did not apply conservation techniques as much as they would like to. There was disagreement between respondents on this point on only two farms.

Table 2: Stated extent of use of conservation techniques

Extent of conservation	Respondents
Not at all	5.3%
A little	14.5
Moderately	64.4
Extensively	15.8
Total	100.0
<i>n</i>	152

Three-quarters of respondents attributed their lack of conservation activity to either cost or time, or a combination of both. The remainder were about equally divided, with half mentioning other constraints which prevented them from choosing more conservation work and the other half mentioning more subjective factors (Table 3). Agreement on reasons was not universal. On five farms, some family members differed in the factors they perceived. While those who stated cost or time had slightly lower equity in their farm than others, the difference was not statistically significant at the .05 level. This adds further support to proposition 1.

Intergenerational transfer

A very weak association ($r = 0.12$) between expecting a child to continue in farming and extent of conservation activity is revealed in Table 4. It can be attributed largely to the 'not at all' responses. A similar result arises when having children, rather than expectations for them, is entered as the independent variable. It is notable that while uncertainty about having a child continue in farming is relatively rare, expectations are divided about evenly between positive and negative responses. Propositions 2 and 3 obtain very little support.

A different view emerges, however, when the independent variable changes from *expectations* about succession, to the *occurrence* of succession: that is, when children become old enough and take on the farm as a career (Table

5). While the sample size does decline, the relationship appears to be relatively strong ($r = 0.41$). There is also some correlation between having a successor on the farm and being able to use conservation techniques as much as desired ($r = 0.22$). Proposition 4 receives strong support.

Table 3: Reasons for not using conservation techniques more extensively among those who did not use stated techniques as much as they would like to

Stated reason	Responses	Respondents
Cost or time or both	67.3%	76.5%
Other constraints		
– must overcrop	4.8	5.5
– weather	2.4	2.8
– father’s influence	2.4	2.8
– divorce	1.2	1.4
– weeds	1.2	1.4
– government controls	0.6	0.7
Subjective factors		
– scepticism	3.6	4.1
– dislike chemicals	3.0	3.4
– caution	2.4	2.8
– lack of understanding	1.8	2.1
– watching others	1.8	2.1
– ‘not used to it’	1.2	1.4
Total	100.0	113.8 ^a
<i>n</i>	165	145

^a Respondents total greater than 100% as multiple responses were offered.

Table 4: Stated extent of use of conservation techniques by expectation that a child will continue farming

Extent of conservation use	No child expected to farm (%)	Uncertain (%)	Child expected to farm (%)
Not at all	8.2	0.0	0.0
A little	13.1	0.0	16.7
Moderately	62.3	77.8	63.0
Extensively	16.4	22.2	20.3
Total	100.0	100.0	100.0
<i>n</i>	61	9	54

Community ties

Of all the factors suggested by the literature to be significant, having a successor taking on the farm offers the strongest correlate with extent of use of conservation techniques (Table 6). Community ties, measured in terms of neighbours visited, also provides moderate correlation, with age, area cropped and equity showing weaker correlations. (Numbers of neighbours visited ranged from 0 to 5 with a mean of 2.2

and a standard deviation of 1.3.) Those who had a successor taking on the farm were much less likely to explain lack of conservation activity in terms of cost. Ninety-four per cent of those who did not have a successor on the farm attributed lack of conservation work to cost, compared with 55% of the others. Proposition 5 obtains support.

Table 5: Stated extent of use of conservation techniques on farms with and without a child who has taken on the farm as a career

Extent of conservation use	Child taken on farm	No child taken on farm
Not at all	0.0%	5.2%
A little	11.1	31.6
Moderately	62.2	63.2
Extensively	26.7	0.0
Total	100.0	100.0
<i>n</i>	45	19

When having a successor taking on the farm, neighbours visited, equity, level of education, age and total area under crops are entered stepwise into a linear regression model with stated extent of use of conservation techniques as the dependent variable, only the first three variables emerge as significant predictors of stated extent of conservation activity (at 0.05 significance level). Having a successor on the farm is the strongest of the three factors (Table 7). The total variance explained by these factors is 31%. While not very strong, this model does indicate that succession is a significant predictor of perceived extent of conservation activity.

Good farming

In answering the open-ended question about what indicates good farms and what indicates good farmers, respondents offered up to four criteria. Few respondents mentioned anything specifically related to use of conservation techniques. When asked what sort of thing they saw on a good farm, 6.8% mentioned ‘sustainable practices’ or avoiding overworking land, while 8.8% mentioned being ‘modern’. The remainder raised many indicators by which they judged a farm to be good, including having fences and gates in good condition (56.1%), general tidiness (41.9%) and having well-maintained buildings (26.4%), and a range of similar comments on the condition of crops, livestock and, very rarely, profitability (2.7%). Among all the criteria mentioned by all respondents, those which referred to sustainability or modernity were rare, constituting 2.3% and 3.0% of total responses, respectively. This suggests that conservation is rare among the criteria which farmers use to judge other farms and such criteria are therefore unlikely to offer explanation of the stated extent of conservation activity. No support for proposition 6 is offered.

Case Study I. Barriers and Constraints to the Adoption of Sustainable Farming Techniques

Table 6: Pearson correlation coefficients between stated extent of use of conservation techniques and selected explanatory factors^a

	Having a successor on farm	No. of neighbours visited in previous 12 months	Age	Total area under crop	Equity held in the farm	Length of local residence	Respondents' level of education
Extent of conservation	0.41	0.35	0.24	0.24	0.23	0.15	-0.03
<i>p</i>	<0.01	<0.01	0.05	0.05	0.07	0.23	0.82

^a Among respondents with children old enough to have chosen the farm as a career

Table 7: Regression coefficients for significant variables on stated extent of use of conservation techniques^a

Factor	Beta
Having a successor on farm	0.34
No. of neighbours visited in previous 12 months	0.29
Equity held in the farm	0.26

^a Among respondents with children old enough to have chosen the farm as a career

Judgment of farmers alone, rather than farms, is more promising. Being innovative or flexible was more common among comments on the attributes of a good farmer, being raised by 44.3% of respondents. Demonstrating care for the land and promoting sustainability were relatively infrequent responses, however, at 6.1% of total responses and mentioned by 15.4% of respondents. Being a good manager was the characteristic mentioned by the largest proportion of respondents (38.9%), followed by willingness to work hard (24.2%) and determination (18.8%). While there is at least a suggestion that sustainable farming and Landcare may be significant, applying innovativeness or flexibility as criteria for good farming does not appear to be associated with stated extent of use of conservation techniques. Of those 15.4% who mentioned *sustainable farming and landcare*, 87.0% stated that they used conservation techniques moderately or extensively, but of those 44.3% who mentioned *innovativeness or flexibility*, 62.0% said that they used conservation techniques moderately or extensively. That is, more than one third of those who saw innovativeness as a quality of a good farmer did not claim to use conservation techniques even moderately. Of those who mentioned other criteria, 79.3% stated moderate or extensive use of conservation techniques. Innovativeness may be seen to be manifest in ways other than conservation farming, typically in terms of product diversification or merely in terms of doing something differently from the previous generation. Proposition 6 receives only weak support and then only in terms of an association between 'sustainable' and landcare practices as criteria and stated extent of conservation activity.

Intervening factors

The number of neighbours visited is related to the presence of a successor taking on the farm as a career ($r = 0.31$).

This suggests that the effect of community ties may be largely indirect, being positively related to farm succession and thence to perceived extent of conservation farming activity, rather than having only a direct effect as, for example, by providing means for the diffusion of ideas and practices.

Confirmation of this indirect relationship, in which succession intervenes, is provided by 'partialling out' the presence of a successor on the farm. This finds that the zero-order Pearson correlation coefficient of 0.35 between neighbours visited and extent of conservation activity becomes a first-order correlation coefficient of 0.26. In a similar but less powerful fashion, length of local residence loses its weak correlation, declining to zero when succession is 'partialled out'. Again, the correlation between age and stated extent of conservation farming ($r = 0.24$, $p = 0.05$) declines to $r = 0.16$ ($p = 0.21$) when succession is 'partialled out'. This explains the seeming contradiction suggested by older farmers seeing themselves as more extensive users of conservation farming.

Consideration of a relationship between community ties as indicated by other variables, reinforces the connection between succession and community networks (Table 8). A relatively strong correlation emerges between having a large proportion of friends in the local community and there being a successor among respondents' children. Other factors offer similar and significant correlations.

Table 8: Pearson correlation coefficients between having a successor on the farm and community ties variables^a

	Proportion of friends living locally	Length of local residence	No. of neighbours visited in previous 12 months	Proportion of relatives living locally
Having a successor on farm	0.39	0.38	0.31	0.39
<i>p</i>	0.02	<0.01	0.01	0.02

^a Among respondents with children old enough to have chosen the farm as a career

As there is only a weak suggestion of association between definition of good farming and conservation practice, no significance can be attributed to the former as a factor inter-

vening between community ties and conservation practice. It appears that there has been no significant process of redefinition of good farming into terms clearly associated with conservation.

The effect of Landcare group membership can be examined for only two of the three communities, as no Landcare group had been established in the third. In those two areas, 28.2% of respondents stated that they were members of Landcare groups. This is a similar proportion to that found in a much larger survey of broadacre farms (Ockerby and Roper 1994). For comparison with the results discussed above regarding succession, only those farms with children old enough to take on a farm are included in the analysis. Neighbours visited and length of local residence both indicate some correlation with Landcare membership ($r = 0.35$, $p = 0.01$ and $r = 0.20$, $p = 0.10$, respectively). However, Landcare membership shows only weak and insignificant correlation with stated extent of conservation activity ($r = 0.12$, $p = 0.32$). This result is broadly consistent with earlier research. When Landcare is 'partialled out', the Pearson correlation coefficient for neighbours visited and stated extent of conservation activity falls only marginally from 0.35 to 0.33, and that for length of local residence falls from 0.20 to 0.13. Proposition 7 receives support only to the extent that there is evidence of intervention of succession between community ties and stated conservation activity.

Conclusion

Cultural influences on farming are complex and interrelated among themselves and with structural features. The view which focuses on personal characteristics and traditional habits of farm operation and sees them as barriers to the adoption of conservation farming is inadequate. So too is the perspective on community ties and organisation which illuminates them only as paths for communication and means of bringing about more informed decision-making by farmers. When the cultural conditions in which decisions are made, rather than the decision processes of individuals, are examined, a different if not contradictory interpretation emerges. The social networks which could be seen as potential conduits for innovative ideas become something much more: they are relationships in which ideas and conditions are interpreted, and meanings are transmitted through cultural tradition. The process of transmission of both innovative ideas and traditional values associated with farm practices is only one aspect of a culture which influences and is influenced by all social action in space and time. The process can be fully understood only by means of ethnographic study (see accompanying paper by Emily Phillips for example). This research has attempted rather to tackle the relationships among the cultural and structural conditions in which information is passed and actions taken.

Stepping beyond the farmer's decision-making introduces much complexity. This research has attempted to specify and account for some significant cultural practices by starting from the concept of cultural tradition and its known attributes in the farming context and relating them to conservation farming practice. From this study, there is evidence that cultural tradition is significant in terms of community ties, because these ties help to maintain the tradition of actual, rather than just valued, transfer of farms from older to younger generations. Traditional expectations for handing on a farm may be waning. Moreover, farmers face the constraints of cost and time regardless of their commitment to 'setting up their [usually] sons' on their farm. There might be other explanations for the lack of significance attributed to expectations of succession, including a constellation of traditional beliefs such as scepticism about conservation farming discouraging its use, even when succession is highly valued and expected. The small size of the sample for our study prevents exploration of such factors, although there is some evidence of scepticism. But as the expectation of succession is apparent in only about half the sample studied, and its continuing decline appears likely, it may have little significance.

While the presence of a successor is important to farm practice, the contribution of successors to the use of conservation techniques has yet to be examined. Such examination might proceed by considering either injection of new ideas or simply contributions to the farm labour force, as explanations for the greater stated use of conservation techniques on farms which have successors. The latter factor gains some support from the finding that the cost 'barrier' was more frequently cited by those without successors, but is weakened a little by the similarity in farm equity between those who did and those who did not cite cost as a preventative factor.

There is little evidence of a linkage between good farming and Landcare membership, suggesting that extension through this medium is not fostering change. This is not to say that it cannot, but it will require a broader approach to extension than either traditional methods or the growth of group-based methods. But it should not be concluded from this study that extension has failed. It has not explored the communication patterns relevant to the extension of conservation farming and does not claim that they are insignificant, either theoretically or empirically. It has added a cultural dimension to the frameworks used to explain use of conservation farming techniques. The provision of information and advice by extension is not devalued by a cultural model. Rather, the cultural model calls for extension to acknowledge and attend to its cultural context. It implies that extension should operate in the cultural dimension and see itself in a broader role: as a medium for cultural change. Working only with individuals it runs the risk of blaming them for not following extension agency prescriptions, and misses significant targets: social and cultural factors underlying continuity and change. Group extension methods offer one step past individualism in that they attempt to harness interactive ele-

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ments of people working and sharing together. However, extension should go further by addressing conservation farming at the level of cultural tradition.

At the macro-level, this research should not divert attention from the structural context of sustainability and conservation. While micro-level structural conditions, as exemplified by farm equity in this research, have relatively little impact, macro-structural conditions are related to the process in which farm succession and inheritance do and do not occur. While little is known about the practice of farm succession in Australia, it seems very likely that the terms of trade for agriculture have discouraged it and will continue to do so. These processes are, however, beyond the reach of micro-level extension, being part of an increasingly globalised agri-food system.

The processes through which community ties, as indicators of tradition, become associated with moves towards less traditional farming methods require analysis of the interpretative processes of farmers. Some previous approaches to this problem have drawn on rational action models, but the variety and complexity of the conditions in which rationality might be defined render them less useful. There may be an element of rationality apparent in decisions to use conservation practices more extensively when the labour and skills of an additional family member become available, but this would offer a narrow perspective, leaving out the background factors and the interpretative processes required for that decision. Many factors external to individuals are involved. Moreover, the interpretation is carried on in the context of social relationships on the farm, in the local community and beyond. Not all family members will necessarily agree on which techniques should be applied and how extensively they should be used, just as not all community members will appraise new techniques equally.

Subjectivity among farmers in their interpretation of conservation farming techniques is apparent, although most farmers appear to understand them and are not sceptical about them. Questions about the real extent of adoption of conservation farming practice remain open, although the findings of this survey are loosely similar to those of others which sought to measure some prescribed indicators of frequency of adoption. No response given to the question about type of conservation technique used could be deemed to be incorrect. As knowledge of conservation techniques was pervasive across the communities studied, one might propose that perception of use is a reliable indicator of actual use. But this would risk missing an important point for those seeking to increase adoption: the subjects for extension should be those who do not see themselves as extensive users, not just those who lack knowledge or have not yet decided to adopt. Extension workers should appreciate that farmers are subject to many forces and that they will continue to define both conservation and good farming using the constraints and resources offered by their cultural and structural situations, which they in part construct. It is therefore imperative that

extension takes a planning approach to adoption of conservation practices, taking into account the breadth of factors affecting farm practices and the ways in which communities construct and carry out those practices.

No attempt is made to reduce all micro-level explanation for the use of conservation techniques to cultural factors. Although the small sample size is a significant constraint, we emphasise the capacity of the regression to explain a substantial proportion of the variance in stated extent of use. The range of important factors appears virtually infinite, because it could include items as diverse as biophysical features of the farm and the abilities of farm operators. More significantly, however, stronger relationships appear between conservation and some attributes of cultural tradition—succession and community ties—than between conservation and structural and demographic factors—equity, age, and education. Of all these factors, succession has the greatest impact on conservation.

The significance of succession raises important questions about the direction of agricultural change in the Riverina and in Australia more widely. If farm succession declines, the use of conservation farming techniques may be inhibited. Two factors appear to be important. One is the general decline in the terms of trade for agriculture, with the perception that this trend will continue. The other is the concomitant decline in the community ties which create some of the conditions in which succession is fostered. There is a threat of a downward spiral. As fewer members of the younger generation choose their family's farm as a career, so the community bonds which provide a basis for the next generation's succession are weakened, and so a basis for succession is further eroded. Associated with this, one could expect that the use of conservation farming techniques will also suffer downward pressure. Verification of this finding using a larger-scale study would be valuable, as the implications for extension and Australian agriculture are profound.

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Social and Cultural Factors that Influence the Adoption of Sustainable Farm Practices

Emily Phillips

Introduction

There is a large body of sociological theory which seeks to explain farmer behaviour. However, much of it follows the precepts of rational action theory to develop predictive models which while, sometimes proving accurate, are not so good at explaining behaviour in meaningful ways. They also fail to address aspects of farm practice that have been recognised for some time. In particular, they fail to account for cultural and traditional factors that influence farm practice. An ethnographically based approach, that focuses on culture and practice is able to overcome this problem through a focus on the values and beliefs of farmers, and the ways they are expressed in their everyday lives and social relations. This approach draws attention to the processes through which some behaviours become accepted as legitimate and defined as good. In this way they create and recreate, constrain and enable, certain farming practice.

An ethnographic interview survey of 104 farm people on 57 farms was conducted in two communities in the Riverina region of New South Wales. The sample was obtained by identifying a small number of farmers in each community and asking them for the names of other members of the community until all families recognised as community members had been identified. Included were some families who did not consider themselves to be members of the communities were included, but were considered so by others. Interviews were carried out in late 1994. Family members were interviewed together. Separate responses were recorded for each member and discussion was encouraged. This survey was preceded a period of intensive involvement on 10 farms in these areas, by which the parameters of local cultures as they relate to farm practice were established.

This chapter describes how a picture of the systems of social standing in these two communities developed during the process of ethnographic fieldwork through both phases of data collection. This picture is of a farming culture that is particularly divided hierarchically in terms of 'good' farming practice, and the relevant cultural and symbolic attributes that farmers find are required to achieve this. This is a social system that rewards 'good' farming practice, thus encouraging farmers to farm in certain approved ways. However, this

is not simply a static cultural blueprint for farming practice. The construction of 'good' farming practice is found to change over time, and to be contested by different farmers. Moreover, cultural and symbolic 'capital' invests certain farmers with the power to define 'good' farming practices.

Social Stratification and Social Standing in Rural Areas

There has been a great deal of sociological research on the importance of social structure in rural areas. It is possible to divide the contributors to the literature on the subject into two camps: those who have drawn on the political economy of rural society to debate the importance of class in farming communities; and those who have focused largely on the everyday lives of people to analyse social hierarchies among members of local communities. The first camp can be dealt with somewhat briefly. Interest in the importance of class in rural society has been spearheaded by an ongoing debate in the rural sociology literature. At risk of over-simplification, the debate centres essentially around questions of whether farmers constitute a class in themselves, or whether they occupy shifting and contradictory class positions (Mann and Dickenson 1987). This is cross-cut and further complicated by debates in the discipline over the probable persistence or decline of family-based agriculture. This debate tells us little about the internal structure of farming communities.

Studies that have focused on social hierarchies, or stratification within rural communities, have, on the whole, been outside the political economy framework and have paid more attention to the internal structures and dynamics of rural communities. Within the Australian community-studies literature, a number of investigations have offered analysis of the systems of structure and standing in rural communities. None of these studies provides either a theoretically or empirically adequate analysis of local systems of social standing.

An early study by Oeser and Emery (1954) outlines the system of class and status in 'Mallee Town' in the north-western corner of Victoria. Oeser and Emery argue that Mallee Town is organised into the four class divisions of farmers, businessmen [sic], white-collar workers and labourers,

which occupy positions of relative status in the local hierarchy. Status is accrued through high economic position, and since Mallee Town is to a large extent dependent on the farming community for income, farmers gain the highest status as an occupational group. However, while the link between class and status is somewhat crude, Oeser and Emery make an even larger, and essentially unexplained, theoretical jump in their assertion that farmers hold the most ideological power; '...an analysis of the political ideologies and organisations within this community showed that the prevalence and dominance of political conservatism arose from the dominant form of rural production, ie. by individual self-employed producers' (Oeser and Emery 1954).

Similarly puzzling is Nalson's (1982) attempt to outline a system of community prestige ranking, based the position of individuals within this system. Nalson (1982) defines nine criteria for prestige which cover farming type/occupation, nature of land ownership, length of residence in area, capital worth, income, ethnicity/race, membership of local organisations, holding public office, and education. The central problem is that Nalson does not make any attempt to generalise from the individual interviews to identify a system of standing or stratification in the community as a whole. Instead his work results in a 'formula for labelling individuals... rather than a schema for identifying classes' (Lawrence 1986).

More sophisticated theoretical analyses of local stratification have come from the work of Wild (1978, 1983) and Dempsey (1990). Wild and Dempsey both analyse a rural community in order to identify its class structure, and both find that features such as occupation, property ownership and income delineate social position. In 'Bradstow' Wild identifies six central groups ranging from wealthy grazing families through the *nouveau riche*, successful business people, tradespersons and shopkeepers, wage earners, and lastly the group of 'no hoppers' (1974). Both Wild and Dempsey (1990) find that status factors are more important than class in defining position and social inequality. Like Wild, Dempsey's (1990) work in 'Smalltown' identified six strata that were delineated by occupation, but contrasts markedly in being unable to find such a clearly defined and widely agreed upon system of ranking.

In addition to class analysis, Poiner (1979, 1990) and James (1981) draw attention to gender as a stratifying feature of rural communities. Poiner (1990) demonstrates the importance of the relationship between gender and local social standing in her assertions that rural women conform to existing gender stereotypes in order to bolster the standing of their husbands, and tend to support conservative family orientated policies in an attempt to 'return prestige to the whole family, but especially to men' (1990). In a similar vein, Mahar (1991) explores the moral economy of rural women in a small New Zealand town and found that they were able to accrue status and social standing only through the traditionally female domain of community work and contributing

to the reproduction of the moral community. Hatch (1992) outlines separate systems of standing for men and women, finding that women gain social standing from domestic and community achievements, while simultaneously reinforcing the public and work-based achievements of men.

While emphasis on political economy in the rural society literature has been on systems of local stratification that focus on external measures rather than internally and locally defined cultural systems, the community studies literature has concentrated to a much larger degree on local social constructions. The work of Oxley (1974) is a particularly good example of this attention to locally specific detail. Drawing on a background in anthropology and extended fieldwork in the community described, Oxley concludes that, behind the veneer of egalitarian ethos there lies a complex structure of social organisation. Oxley divides the rural towns into upper, middle and lower strata, and discusses the relationship between this widely accepted hierarchical structure and the pervading ethos of egalitarianism in voluntary and leisure organisations. He finds that structures of hierarchy and egalitarianism are able to coexist as they are articulated differently in different social contexts. Certain types of voluntary organisations tend to reinforce structures, whereas others symbolise ideas of equality.

However, while accounts like that of Oxley (1974) are extremely thorough in their attention to ethnographic detail, they are generally not so good at describing the relationships between rural town and country structures. Indeed, the community studies literature is limited greatly in its conceptualisation of the agricultural or farming components of rural community structures. Oxley (1974) conceptualises the farming community as simply comprising 'graziers'. 'Graziers' are divided into an upper and lower stratum. The upper stratum 'have considerable wealth and generations of wealth behind them. They usually live in imposing homesteads and live very comfortably. They belong to exclusive clubs... and their children go to the best private schools' (1974). The lower stratum graziers are generally part-time farmers who live closer to town and who 'participate in the informal life of club and hotel bars' (1974:89). It is hard to imagine where this hierarchy leaves the small-scale family farmers to be discussed here. As Lawrence (1987) argues, the term *grazier* has a very specific meaning in Australia; 'raising sheep on pastures—rather than tilling the soil', and therefore Oxley has missed altogether the important category of family farmer. A similar problem is found in the work of Wild (1978), who fails to theorise adequately the position or structure of the rural population, despite mentioning repeatedly the importance of the rural population to the economy of 'Bradstow'.

This lack of attention to the place of farmers in the social structure is a problem that plagues Australian rural community studies. The community studies literature is able to account very well for local social structures and systems of standing in rural towns. But this essentially urban bias, which,

if they address farming populations at all, creates categories for them that are so simplistic as to render the findings somewhat meaningless for the rural hinterlands. Indeed, the approaches and conclusions of the studies discussed here are of only limited application to the populations of small farming communities such as that to be analysed later. Part of the problem may lie in the difficulty of applying the stratification and class type analysis to a group that does not contain a range of different occupations. While the political economy literature would tell us that all farmers are located differentially with regard to capital, their basic means of production essentially similar. It is thus much easier to apply a stratification analysis to different occupational groups of a town, and contrast this with the rural hinterland, than it is to try and discern a pattern of stratification in a farming district.

Drawing on the work of Hatch (1992) and Mahar (1991), this chapter attempts to solve the problem by focusing on the social standing of farmers in their own farming community as it sets about its analysis of farming practice. Hatch's 1992 monograph 'Respectable Lives' is one of the few pieces of work attempting to describe the systems of social standing in farming communities. While a good deal of the book is devoted to the relationship of the farming community to the town, in terms of the occupational hierarchy and the relative importance of farming within it, Hatch also describes systems of standing within the farming community. Hatch (1992) argues that the farmers in the southern New Zealand community of South Downs care very much about their social respectability as measured through the criterion of wealth, farming ability and refinement. This local system of social standing and the resulting conceptions of self are the reflection of cultural and historical processes that are specific to this agricultural community, and can therefore only be understood within this specific cultural context (Hatch 1992). Mahar (1991) offers a similar analysis of a rural community in northern New Zealand. Elite rural women are shown to use their economic position to participate in community activities and commit to community service in order to reproduce the structure of their class within the farming community.

The Australian and New Zealand community studies literature highlights the importance of social standing in rural communities. However, much of the literature struggles to place the farming or agricultural component of the community within this structure. The work of Hatch (1992) and Mahar (1991) goes a long way toward this and is a useful theoretical starting point for an understanding of social standing in farming communities. However, before a theoretical conceptualisation of social standing is developed, it should be pointed out that the central interest of this research does not lie in a theoretical problem alone. Indeed, from a very early point in the ethnographic fieldwork, it became clear that issues of social standing were of central importance in Redwood and Milldale.

The Importance of Social Standing in Redwood and Milldale

20th February 1995

I arrived at the farm mid morning and found Craig in a bit of a flap. About four months ago, an international chemical company which was considering locating nearby had asked local farmers if they could take photographs of their farms to be included in the company's annual report to demonstrate the beauty of the rural area in which they had chosen to locate. Today Craig had received a copy of the report and had found a picture of his farm on the cover. The photograph was taken looking up a gently sloping hill and showed three paddocks. Green lucerne pasture was juxtaposed with a crop of bright yellow flowing canola, and a large expanse of vivid purple flowers. I commented that the visual effect of the green, yellow and purple was quite breathtakingly beautiful, thinking that Craig would be proud to have his farm make the cover. However, Craig was furious. He explained to me that the purple flower in the photograph was in fact a weed called Patterson's Curse which had got out of control on his property last season and that it is widely frowned upon to have weeds on a farm. Worst of all, copies of the report had been circulated to all the local farmers.

[From field-notes]

This story outlined is just one of many from the fieldwork site that could be used to illustrate the importance of social standing in a farming community. It demonstrates two very important underlying principles. The first is that economies of social standing are a central feature of the two farming communities. Craig was obviously not pleased to have weeds on his property from both a personal satisfaction and an agronomic point of view. However, his most vehemently expressed concern was the social shame of having a weed problem. Also, since the report had been circulated around the local district, his mistakes would be seen by all the local farmers. Craig was essentially concerned that his reputation or social standing with the local farmers would be tarnished through the circulation of the photograph in the district.

The second important principle revealed by this story is the culturally specific nature of Craig's reaction. To an outsider such as the chemical company or a researcher such as myself, the photograph displaying the Patterson's Curse was simply a visually very attractive image. As a farmer, Craig read this photograph very differently and instead saw it a symbol of bad farming practice. Thus, Craig brought to the experience the local knowledge that told him, and other farmers in the area, that this purple flower is a weed. Moreover, Craig also brought a cultural construction of good farming practice that considers weeds to equate with bad management, for while weeds are to some extent an agronomic problem, the vigour with which many farmers try to eradicate all weeds on their property is to a large extent a social and cultural construction.

There are obviously systems and structures of social standing in operation here. Craig has articulated a strong concern about the perceptions that other farmers in the district may have of him. Moreover, he has also suggested that a central criterion of this system of social standing may have to do with ability as a farmer. Clearly, two main questions need to be answered in attempting to explore the social standing hierarchy alluded to. Does everyone in a farming community recognise the existence of social standing? And what are the criteria that enable a person to gain standing in a community?

Occupation and Social Standing

The Australian community studies literature identifies occupation as an important source of social standing in rural communities. As outlined earlier, Oeser and Emery (1954) and Nalson (1982) to a large degree, and Wild (1974), Dempsey (1990) and Poiner (1990) to a lesser degree, all base their analysis of standing in rural communities on occupational criteria, arguing that these are important base determinants of class and social position. This may be true in rural towns, but the application of this perspective to farming communities is somewhat less fruitful.

In both Redwood and Milldale all residents are involved to some degree in running their family farm. This is not to say that there is no other activity undertaken to bring income into the areas. In Redwood, approximately 12% of men and 25% of women worked off farm in some capacity to supplement their farm income. In the case of the men this was invariably in providing contract services in such things as wool classing, harvesting and chemical spraying in other districts. Off-farm work undertaken by women in Redwood ranged from casual clerical help to school counselling. In Milldale, 40% of men and 21% of women worked off-farm. In the case of the men this was again invariably in a farming-related capacity, with the women predominantly occupying part to full-time teaching jobs. Thus, all men and most women in Redwood and Milldale are employed primarily in farming.

More important, however, is how the people themselves view their occupational identity. When asked if they viewed themselves primarily as farmers, all men and almost all women agreed. Only two people said that they did not see themselves primarily as farmers, both of them Milldale women who worked close to full time off-farm, and who had come from large cities and married into farming. The only situation in which occupation was ever brought into play in status discussions had to do with the perceptions of some male farmers that having a wife who worked off-farm lowered their personal status. However, on the whole, while there is clearly some diversity in second occupation in Milldale and Redwood, there is little evidence to suggest that it has any real significance in social standing.

Wealth and Social Standing

Wealth is a somewhat more complex issue than occupation. The Australian community studies literature considers wealth to be a central concern, particularly as it intersects with occupation, in contributing to class distinctions. On this basis, I entered the field expecting to find differences in wealth as both a feature of stratification and an important criterion of social standing.

Attempts in the agricultural extension literature to describe the characteristics of farm communities have tended to use farm equity as a measure of wealth. The equity level of a farm is measured by calculating the total value of the farm (adding the value of the land, fixed improvements and houses, livestock, machinery and equipment and any other capital assets), subtracting any farm debt, and then putting the remainder over the total value of the farm as previously calculated. Therefore, an equity level estimates the financial situation of a farm by calculating the proportion of the farm that is owned. Collecting equity data from farmers is a relatively easy business as it is a standard measure that farmers are required to use in their annual reports to banks. Almost all the farmers interviewed knew their equity level. It is also a less threatening measure than asking farmers for detail about their financial position, about which they are generally very coy.

Table 1 gives farm equity data for Milldale and Redwood. Interviews in the two districts suggest that while, equity analysis generates numeric data, local interpretation should be considered when attempting to use this data. Farmers in both Milldale and Redwood appeared to agree that equity could be considered to fall into four main groups. Above 85% is considered good equity, from 70 to 80% is considered acceptable, from 50 to 70% is very worrying, and anything below 50% spells financial ruin. If this more qualitative analysis is considered, then both Redwood and Milldale appear to have roughly three-quarters of their farms falling in the good equity group, suggesting that in both districts there is a significant core of financially stable farms. The other interesting trend concerns the lower end of the equity scale. In Redwood, while the top three-quarters of the population have good equity, the other quarter of the population all fall into the acceptable equity level category. This indicates that in Redwood there are few significant debt problems. In Milldale, however, 1 in 8 farms fall into the 'worrying' equity level group, demonstrating a significant level of debt in the district.

The farm equity figures for Redwood and Milldale are more useful when they are placed in social and historical context. Patterns of land-holding varied between Redwood and Milldale, with Redwood showing lower levels of land turnover and a greater history of succession and family consolidation of land ownership over the generations. While this was also true of some farms in Milldale, land in the district generally changed hands more often and there was a pattern of newcomers buying into the district. In this context, the differences in equity levels make more sense as the more

stable settlement pattern of Redwood has allowed for financial consolidation.

Table 1: Equity level of farms in Redwood and Milldale as a percentage of the total population of each district.

Equity level (%)	Redwood farms (%)	Milldale farms (%)
50		13
70	6	13
75	9	
77	12	
85	9	17
87	6	
90	3	
95	20	
100	35	58
TOTAL	100	100

Farm equity measures are of only limited use, however. While wealth as indicated by equity is relatively easy to measure, the continuous distribution of the data means that there is no easy way to draw lines between people on the basis of how much they have. More importantly, so-called objective wealth measures are of little use when trying to assess to what extent wealth is considered to be a criterion of social standing. What is required here is an investigation of how the people of Redwood and Milldale themselves define and relate to notions of wealth. Moreover, what matters most of all is not simply how much wealth people have, but how this wealth is acquired and how it is used.

In the formal interviews conducted with farmers and at many times during informal fieldwork conversations, farmers were asked whether they perceived differences in wealth in their community. Without exception, farmers in Milldale all felt that there were significant wealth differences in the district. In Redwood, most farmers agreed that there were small differences in wealth in the community, but this was down-played. When farmers were asked how important it was to be wealthy in their community the responses followed a similar pattern. In Milldale, about two thirds of farmers thought that being wealthy gave you social standing. In Redwood, however, almost all farmers denied the importance of wealth. On a surface level this is clearly related to the fact that is a larger spread of farm equity levels in Milldale and thus it is to be expected that wealth differences should be accorded greater significance. However, the situation is a lot more complex. Wealth is conceptualised and measured somewhat differently in the two farming districts, and has differing levels of social status attached to its accumulation.

For two very important reasons, farmers had difficulty discussing wealth and its relationship to social standing. The first had to do with issues of how to measure wealth. When asked to discuss their own financial situation most farmers

were coy and many claimed not to know actual figures. When asked to discuss the financial situations of other farmers in the district, most farmers threw up their hands in horror and despair. At first I interpreted this as an indication that they considered it bad form to be asked questions about wealth, presuming that wealth was a touchy and personal subject. While this was to some extent the case, it soon became clear that a large part of the problem stemmed from the fact that I was misinterpreting their responses. Rather than showing dismay and embarrassment at the questions, many farmers were trying to tell me that it is extremely hard for farmers to judge the wealth of one another. This difficulty is the result of a number of factors. It is very hard to tell how well or otherwise a farm is without knowing their financial position. As one farmer explained it:

You can't put your hand in a man's pocket to see what's going on, can you? . . . Some seem to be doing it better on the surface but whether they are or not is another thing

In order to judge their colleagues, farmers have to rely to a large extent on what they can see and what others will tell them. The state of crops and livestock says little about the financial state of a farm. While it is fair to presume that a good crop will fetch good prices, it may have had twice as much fertiliser and chemical applied to make it as good as it is, and thus the profits are seriously eroded. In other words, the view over the fence provides the farmer with only a partial view of what actually happens financially on the neighbouring farm. Added to this is the problem of life cycle. The financial position of family farms is to a large extent dependent on the stage of life cycle of the farm. Obviously a young family which has recently bought into an area cannot be judged using the same criteria as a couple near retirement age who have had a working lifetime to accrue and consolidate their assets. Thus, farmers felt that while they could identify indicators of wealth, they were unsure of the merit of these in providing a realistic assessment of the financial position of the farm.

There is, however, a second and more important reason why farmers appeared to show reluctance to discuss issues of wealth. This has to do with the relative importance of wealth as a criterion of social standing when compared with other criteria. From a fairly early stage of fieldwork it became clear that when I asked questions about wealth I often received answers that appeared to have little to do with wealth as I saw it. When I asked one farmer how he saw wealth accumulation in the district he replied:

I think you might go three or four generations and the farmers gradually get better and then you'll find someone who decides that they are just going to sit down and do nothing and the whole thing falls down around their ears and they finish selling up.

Others comments followed a similar pattern. Almost invariably any discussions of wealth and social standing turned into a discussion of farming ability. While it took me a while

to see it, I gradually began to realise that they were telling me that farming ability was in fact the most important criterion for social standing in farming districts. This is not to say that wealth and a whole host of other criteria weren't also important, but they were often of lesser importance and in many cases only had meaning in relation to the central criterion of farming ability.

Social Standing and Farming Ability

The importance of farming ability as a criterion of social standing became apparent as during a number of early fieldwork experiences. Aside from the more obvious patterns appearing in formal interviews, the importance of being seen to be a good farmer also became apparent during informal discussions.

One of the earliest impressions gained from the fieldwork conducted in Milldale and Redwood was the extent to which farmers were concerned with what other farmers were doing on their farms. In particular, I was amazed at the lengths that farmers would go to get a glimpse of a neighbour's farm. The following is an extract from field notes:

Tom had to drive into town today to get a spare part for the tractor. I went along for the ride. We drove to town along the main road and Tom pointed out all the farms along the way. He evaluated each one and compared the sight of the crops with his own. On the way back from town we drove along the backroads. Tom said that it is common practice to drive into town one way and home another so that it is possible to get two different views of your neighbour's farms.

Other farmers regularly bemoaned the visibility of their farms to their neighbours. As one farmer explained:

...the worst thing about my farm is that it has road on all four sides and so my neighbours can see everything that I do and so there is no point in hiding the experiment in the back paddock because they can see everything.

As I began to get to know a few farmers in each district, I would ask them to recommend others in the area whom I might talk to. The offer of the name of another farmer whom I might visit would generally lead to a comment justifying the choice, and this would invariably involve whether or not they were considered to be a 'good' farmer. The same situation occurred at almost any time the name of another farmer in the district was mentioned. Mention of the name of another farmer would almost always elicit a judgment as to whether or not they were considered to be 'good' farmers. Thus, despite the fact that the farmers knew that agronomic considerations were only a small part of my study, they still offered the 'good' farmer criterion as the most important consideration.

The importance of this criterion is also highlighted by the ease with which all farmers interviewed were able to discuss the subject. All the farmers interviewed said that they thought

their district contained some of the best farmers. As one Milldale farmer explained;

I would say that there wouldn't be any other district in the area that could say that they were harder workers and were more involved in trying to get results from their farm than this area. I've only taken it from agents, the blokes that go around the areas, deal in stock, and people buying grain. When you meet one of them at a function or anything and they ask where is your farm?... I say well I am right in the middle of Milldale, and they say oh you are lucky you know. That is the best producing country around, and I say its not because of the country – it's because of the farmers, because they are all dedicated.

More importantly, however, all the farmers interviewed were able to comprehend a local hierarchy according to farming ability. This is in stark contrast to the questions regarding wealth as a differentiating characteristic, which generated confused answers. Moreover, all farmers interviewed were able to rank the individual farmers around them according to their farming ability. This generally involved labelling them either a 'good' or 'bad' farmer according to a set of ascribed characteristics.

It appears that farming ability is considered to be of central importance for a number of reasons. All the people in the districts of Milldale and Redwood are farmers to some degree, and therefore it is something that they all have in common. However, more importantly, farming ability is something that farmers seem to think is relatively easy to judge. Many farmers explained that since farming is such a visible occupation and everyone knows what everyone else is doing in the district, assessing the farming ability of a neighbour is not too hard. However, this ease of distinction appears only to operate within the district, as most farmers were able to rank the abilities of only those farmers within their own district. When asked to comment on a farmer in a neighbouring district, most farmers claimed that they did not see enough of this person or see enough of what they were doing to make a judgment. When asked to list farmers whom they thought were 'good', farmers invariably listed other farmers in their own district. Indeed, even between two areas as close together as Redwood and Milldale, I was surprised to find that many farmers did not even know the names of all the farmers in the neighbouring area. This suggests that to some extent this system of social standing is locally specific.¹

Criteria of 'Good' Farming

Certain criteria are used by farmers in Redwood and Milldale to judge whether or not other farmers are to be considered

¹ This is not of course to suggest that there is no connection or overlap with wider farming culture. Indeed, changes in agriculture at both national and global levels have huge impacts on the practices of family farmers and thus the cultural framework of their local area.

'good' farmers. As one would expect, some of these criteria centre on the practices of individual farmers on their farms. In both Milldale and Redwood, the appearance of crops and stock was considered to be a very important determinant of a good farmer:

You'll find their crops are always the best as they can get more than likely. The stock are always good, some good farmers, some blokes farm better their crops are always better than their sheep and some are the other way around, but overall good crops and stock.

Good stock, if the sheep are rubbing up and down the fences he mustn't have dipped his sheep as they have lice problems. If you have sheep running around and they are all daggy and dirty, and even if you are not a farmer you can tell they aren't looking healthy and things like that.

Crops and stock are widely believed to be good indicators of farming ability for a number of reasons. They are very visible indicators that can be viewed from off the farm by everyone. They are also something that everyone in the district knows about and so feels that they can make a fair judgment. Most importantly, however, there is an idea that everyone starts from essentially the same level playing field in growing crops or stock. Everyone in a district will receive approximately the same weather conditions and is working with roughly the same soil. Thus, any significant differences in crops and stock are viewed as the result of the practices, skills and ability of the grower.

Farmers in both Redwood and Milldale stressed the importance of good farm management as a criterion of 'good' farming. There were, however, some significant differences in the emphasis placed on different types of management practices. In Milldale the emphasis was placed on efficiency and financial management. As one farmer explained;

You see a few guys do ordinary things and you think why did they do that. I think eventually it comes back to management really and even knowing your bookwork and having a person in the family that is good at computers.

In Redwood on the other hand, farmers expressed the importance of 'doing things at the right time'. A good example of this can be seen in the sort of comments that many Redwood farmers made about the only new farmer in the district:

He does weird things like going out and ploughing up a paddock after only 15 points of rain. Here we tend to wait until 25 points, and then he wonders why he grows nothing on it!

Other examples included stories about poor management on Redwood farms:

"There's a few here that I reckon are poor managers. You know when this year you got your crop in as soon as you could and some of the blokes were busy, a couple of fellows here were busy spraying, or one bloke went fishing and decided to go on a holiday. It wasn't worrying

me but I could see we were busy finishing here and one other fellow was still busy trying to work his country up. I don't know what he was doing.

The same sort of patterns can be seen in the attitudes of farmers in Redwood and Milldale to the importance of hard work. In both Redwood and Milldale 'good' farmers were considered to be those who worked hard. However, there were differences in interpretation regarding the nature of this hard work. In Redwood, hard work was generally defined as sheer effort and the number of hours put in. In Milldale, hard work was defined more in terms of doing the amount of work required and not wasting time. In other words, in Milldale the efficiency of the work done and good time management were stressed as more important.

While these are differences in interpretation, there are some pronounced differences between Redwood and Milldale in the criteria used to determine good farming. In Redwood, three factors stand out above all others as the most commonly expressed criteria for 'good' farming: neatness, financial security and establishment. The importance of having a neat and tidy farm in Redwood cannot be overstressed:

You know you look around at the sheds and they're nice and tidy, your plant is you know in reasonable order under cover, we always try to keep our plant under cover. . . The house is neat I don't mean that its got to be the brick veneer home built yesterday, and most people around here take pride in what they are doing. You go into other areas and you see their headers pulled out of their paddocks where they were last year and under a tree. I saw an air seeder with the box not cleaned out sitting out in the grass, the crop was growing out of the air seeder and this type of thing. To me, I wouldn't class them as good farmers sort of thing and it doesn't take a lot of time to put something in the shed.

You go into some places and there might be part of a tree blown down and they have left it there and it has all rotted and other people would have picked it up. . . You might get to the front gate and there is a gate it's either dragging or lost its bottom hinge, can't get it undone, its tied up with wire or string"

Farmers in Redwood could all tell me who had the neatest farm in the district and who could plough the straightest:

Tony has probably got the neatest farm in the district. . . terrific fences, beautiful sheds. Bob can put in the straightest plough line. . .

While all farmers interviewed had some degree of interest in how others perceived the appearance of their farm, this obsession with neatness in Redwood stood out. It is to some degree grounded in the history of the district. Redwood has a history of farming competitions. In particular, it used to have a competition to see who could plough the straightest. Though it is over 60 years since the last of these competitions, the culture of farming that they created has to some degree persisted. General tidiness on the farm is also tied up with notions of hard work. As many farmers explained,

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since tidying up is the last thing that is done each day and the farmer is usually tired by this stage, those who manage to maintain a tidy farm show a huge dedication to hard work. Fences were widely agreed to be a particularly good measure of this, since fencing is generally not a crucial job when compared with things that have to be done immediately, such as sowing a crop at a certain time or spraying chemical on a still day. Thus, good fencing indicates dedication and hard work:

Well to me it just degrades a farm. If you drive along and a fence is down you think oh he's a bit lazy if you can't be bothered to get out and do a bit of work. Whereas if there is a wire broken or a fence down I will go out and fix it because I know if my sheep get out and get infected well I will have to destroy them or sell them or do something with them so I try to keep all my stock in... It's just to try and keep the farm neat and not run down and that doesn't take a lot of money. We like to keep the place looking neat and tidy and not have stuff strewn everywhere.

Finally, farmers expressed that tidiness is also one way in which it is possible to distinguish their farms from their neighbours in a situation where distinctions are often hard to make since most of them tend to grow the same crops and stock.

The criteria of financial security and establishment are also of crucial importance in Redwood. This was typified by comments such as the following;

...if they've been handed down a good size property in this area and they're a fairly good manager well those are the people that are doing well and are good farmers.

Generally the good farmers are the ones who have had the property handed down to them because they are the ones who know how the weather, the climate works around here. The mistakes have already been made for them, they know what works and what doesn't work usually.

Obviously what is meant here is that inheriting a property gives a sound financial base from which to begin farming and thus should make managing a farm somewhat easier. However, the most interesting aspect of the focus on financial security and establishment is the element of tradition that it introduces to the construction of 'good' farming practice in Redwood. Farmers tended to emphasise the importance of a strong local knowledge base in farming and thus the importance of handing down the farm and the knowledge accumulated and passed to the next generation. The emphasis on establishment and security in Redwood is to some extent the reflection of the wider social culture in that district. The length of residence of most of the families currently farming in Redwood has clearly created a climate in which longevity is considered to be important. This is also tied up with the largely Methodist tradition of the district which emphasises hard work and frugality and which encourages the accumulation of a sound financial base. Emery and Oeser (1954) found that the Methodist component of the town in

their study stood for 'hard work and the need to help each other'. While it may be a somewhat extreme position to assume that this is the only factor influencing the development of conservative attitudes in Redwood, there is clearly an element of Methodist culture remaining. This is a position that is supported by the persistence of the local Methodist church in Redwood, despite the decline of rural churches in almost all the surrounding districts.

While tidiness, establishment and financial security are mentioned by some Milldale farmers, they are not factors that appear to be strong criteria for 'good' farming in the district. Farmers in Milldale instead tended to stress the importance of knowledge, progressiveness and profit as essential characteristics of 'good' farming. In terms of knowledge, farmers in Milldale stressed the importance of both traditional and modern knowledge as crucial to being a 'good' farmer. In particular, importance was placed on being open to new ideas and willing to accept challenges to traditional sources of knowledge. Thus, ideas about knowledge and progressiveness tend to be tied up together:

In the case of Kevin, he seems to be a pretty good farmer because he's a fairly progressive type fellow. He's been involved with Ag. departments and all those sort of things.

The importance of profit was one of the most commonly expressed conditions of being considered a 'good' farmer in Milldale. As one farmer commented;

Well a good farmer looks after the land to produce good profits, all those people I mentioned would produce good profits.

However, the problem with a criterion such as profit is that, as many farmers expressed, it is difficult to measure and often requires contradictory behaviour:

Some would be considered top farmers and the rest would be average. I think the top farmers, well they appear to be top ones and they get good results but you don't hear the bad results that they have too much. They tend to have bigger yields but when you sit down and look at the costs on what they had to put in to get that yield. I think you'll find that they're not much better off than anyone else.

Thus, while profit is to some degree measured by size of yields, farmers are somewhat sceptical about the reliability of this. Other indicators of profit that seem to be perhaps more important are new machinery and sheds. Farmers in Milldale indicated very strongly that keeping up with new machinery and making capital improvements on farms such as building new sheds were very important as an indicator of a farm that is going well.

Finally, it should be mentioned that in both Milldale and Redwood farmers can also gain some degree of social standing for being especially good at one particular aspect of farming. In both districts certain members of the community were widely recognised for their expertise in such specialities as

producing top lambs, producing excellent wool, technical or mechanical expertise, being especially innovative or being a particularly hard worker. However, the farmers who are repeatedly referred to as the really 'good' farmers appear to be good all-rounders who cannot be significantly faulted on any aspect of their enterprise.

The criteria of 'good' farming defined by the farmers of Milldale and Redwood, highlight both the local specificities of the two districts and the general facets of farming culture that contribute to this system of standing. Both Milldale and Redwood exhibit a system of social standing that places 'good' farming at the centre. Many of the criteria that are used to assess whether or not a farmer can be considered to be a 'good' farmer are common to both districts. These are probably criteria that reflect wider farming culture. However, there are also some characteristics that are particularly emphasised in each of the districts. Having schematically outlined the main criteria for 'good' farming that are applied in each district, it is important to explore how this system of social standing operates. In particular, the question now becomes: to what extent do the particularities of each district influence the actual everyday practices of individual farmers?

Social Standing and Farm Practice

In order to gain this capital or prestige, farmers must farm in certain prescribed and approved ways. These processes can be clearly seen at work in the fieldwork and interview data discussed previously. In both Milldale and Redwood certain criteria determine the allocation of the label of 'good' farmer and the hierarchy of social standing. Farmers are clearly aware of these criteria and judge one another's farming ability. Farmers in Redwood and Milldale are encouraged to farm according to the culturally prescribed criteria of the district.

Strategic Farm Practice

However, social relations do not simply set out cultural rules that must be followed. That type of formulation would imply a static construction of farming practice that would never change. This is clearly not the case, as farmers in both Redwood and Milldale described constant and far-reaching changes in their farming practice. Many of these changes have been spearheaded by forces outside the local farming communities and are the result of both national and global processes (see Phillips 1996). Many changes are also the result of local processes. In both Redwood and Milldale, the criteria outlined previously form the broad framework of 'good' farming practice. However, the details of individual practice within this framework clearly differ from farm to farm. Moreover, there are some farmers whose practices stand in direct contradiction to the widely accepted practices of the district. There is one farmer in particular in Redwood who advocated quite different practices to most of the

other farmers in the district. Other farmers in Redwood discussed the differences between their farm practice and that of Bob quite openly. However, their discussion clearly highlighted a tension between Bob's practice and the rest of the district. This tension increased when Bob won a State-wide competition for his wheat crop. This winning crop had been grown using a new direct drill technology that was not widely accepted in the area. However, as one of the local farmers was quick to point out, the only reason that this technology produced such a good crop was that traditional methods that are accepted in the district were also used:

That crop wasn't actually direct drilled. There was a story there and sometimes as you might have guessed or you know sometimes it sort of gets lost when it actually gets in to the media. And the true story, all the locals know the true story... Well actually last year that was a failed pea crop because of the blight disease and it became overgrown with skeleton weed. The paddock was a real mess and the only way that Bob could get it was to disc all this rubbish in. The stock were needed because the skeleton weed got so old and so it was disced and though he might have made, well you might be able to call it minimum till because of the way he sowed it and he possibly didn't work it as much as he would have 20 years ago, but really in the true sense it wasn't direct drill and wasn't what I could call minimum till which is maybe one scratch up not long before you sow and possibly green fallowed chemically before that. It didn't sort of fall into that category. Although Bob has of course bought a machine that can go into that type of farming and everyone is looking very keenly at the results.

Because in a good year our crops can get up to that Bob standard of 8 tonnes a hectare not that most of us weren't quite happy if we can get up to 6 tonnes a hectare which I think is still a fairly good crop... As far as putting on extra nitrogen topdressing nitrogen I would say yeah he pushed it further than anyone else in the district. Of course we have all looked with interest at what he has been doing.

Other farmers also commented extensively on Bob and the degree to which he deviates from the dominant definition of 'good' farming practice.

Most farmers around here do the same, well they've farmed the same way really, well you've possibly been where they are, but Bob, well Bob is very professional really; he does have good crops and yields and so forth but then again I shouldn't say it but he could be running his farm down. The amount of spray he uses that would have to have some effect, but that's his way of doing it, not mine.

A similar situation occurred in Milldale when an old farmer who was widely considered to be a very traditional and a somewhat backward farmer won a wheat competition. The farmer himself was quite aware of the stir that he had caused:

I am surrounded by farmers that are very good farmers that are pushing their ground all the time and their

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capacity to grow everything and its a little bit like a competition which I don't enter and that is why a lot of them were a bit dubious about me winning this competition. They were, I have seen their reaction and one bloke even said it, what the bloody hell, how could he get it? He doesn't do what we do. But the ground that I have got is never flogged out, so therefore the quality of wheat that I have got is better and that would be the reason.

As these examples demonstrate, farmers not only gain prestige by articulating socially-rewarding practices, they also constantly redefine this practice through articulating different and competing models. This tension between following the rewarded practice and attempting to define 'good' practice through influencing different practices is captured in one Milldale farmers description of a 'good' farmer in his district:

Jim is an individual and does what he wants, although he keeps an eye on what everyone else is doing.

Thus, rather than simply following a cultural prescription, farmers are constantly engaged in strategic farming to gain the community recognition required to define their farming practice as 'good' farming. The construction of farm practice takes place in a context of power relations at local and societal levels. Cultural, symbolic and economic 'capital' invest certain farmers with the power to define 'good' or more acceptable farming practices and thus influence the practices that farmers choose in order to gain this capital.

The relationship between practice and social standing is illustrated by the following example of a farmer's claim to social standing:

...most flattering if that does happen, yeah. Then you think yeah, I must be doing the right thing, yeah I'm a good farmer because yes they are going to try and do the same thing and that, well that's happened with my neighbours this year... As it happened we have had two good years establishing lucerne pastures and every paddock I have got out [of rotation] is a lucerne paddock and they haven't got any lucerne in their paddocks and their paddocks are bare and if I leave the sheep off mine it comes green in a week and yeah, they've already decided that next year they are going to sow lucerne next year.

Conclusion

This analysis casts a different light upon the traditional notion of the diffusion of innovations along networks of socially interacting farmers. The networks are sites of competition and hierarchy, competition not just to be seen as either a 'good farmer' or an innovator, but also to define 'good' farming practice. Sustainable practices, like all others, are subject to such definition and redefinition through processes in which sources of prestige are created and sought. Practices which are defined outside the local community as

innovative or sustainable indicates, subject to individual motivation to maintain a traditional definition of good farming. In this way, innovations can be redefined as means by which others attempt to obtain social standing and usurp the position of farmers further up the traditional hierarchy.

The legitimization of sustainable practices is therefore highly contingent on localised cultural tradition and the social hierarchies associated with that tradition. Those seeking to extend the adoption of sustainable practices should be aware of the factors which farm practices are contingent upon. Sustainable practices should be seen as much more than ways of operating a farm or applying innovative techniques and technology. They are social practices, and thus are also means by which some people can challenge others in the local social order. Through this process farm practices take on a broad range of meanings which extension agents should be aware of.

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Case Study 2

Decision Support for Sustainable Management of Grazing Lands

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Decision Support for Sustainable Management of Grazing Lands

Abstract

This report presents a history and discussion of the effectiveness of an interorganisational R&D project that focused on the collaborative development of a decision support system (DSS) for sustainable use and management of the extensive grazing lands of northern Australia.

The fragmentation of responsibilities and the diversity of approaches relating to resource management and environmental stewardship across multiple stakeholder groups can provide fundamental barriers to the adoption of integrated action to collectively address sustainability issues. Most importantly, this situation inhibits the facilitation of environmental stewardship at all levels of resource management (ie. the farm to region). This study demonstrated that DSS technology innovations can create opportunities to foster communication and integrated action across a range of diverse stakeholder groups. The report focuses on increased learning in relation to the management of such projects whose objectives include an effective technology transfer program. In particular, the lessons learned are examined in terms of: (a) the technological design and implementation of a complex system innovation development process, and (b) the management and evaluation of science-based R&D on information technology innovation for sustainable resource use and management.

An iterative and evolutionary R&D process emerged through a facilitated participatory process of stakeholder interactions focused on joint activities to develop a technology innovation. This process required an enduring R&D cooperative alliance, which was based on a long term purposeful relationship that fostered active stakeholder participation, and facilitated the emergence of trust amongst the partners. The collaborative relationships were most effective where the partners had similar values, beliefs, and cultures. On-going management of the relationship required sustained work and commitment of all parties throughout the R&D process. However, participation alone was not sufficient. Stakeholders needed to be able to affect decisions relating to the innovation development process.

Although the target audience was clearly identified early in the R&D process, designation of the actual end users changed over the life of the project, as the issues being addressed were more clearly defined and the roles of stakeholders in relation to the issue evolved. The technology innovation development approach was able to manage these changes in primary stakeholders and their multiple objectives over the course of the project.

The situational context in which each of the stakeholder groups/end users as well as the system developers were operating changed independently of both the changes in the R&D problem being addressed and stakeholder and system developer control. An iterative and prototyping approach to the DSS technology innovation development process provided a capability for constant adaptation to changes in targeted stakeholder needs, as well as technological advancements that occur over the life of the project. This approach proved to be effective for experts, stakeholders, and system developers to reassess and confirm the objectives of the DSS technology development in an on-going way. In particular,

it provided effective feedback cycles to enhance mutual learning by technology developers and R&D stakeholders alike. Therefore, innovation in technology development occurred through a host of small incremental improvements that provided a basis for accumulated learning processes.

Although there were significant benefits realised from the participatory approach to the interorganisational R&D cooperation, there were costs along the way. These included the escalation in commitment of time and financial resources to substantial interactive processes with multiple stakeholders by the DSS developers, the need to resolve ensuing conflicts, and the need to accommodate the conflicts amongst some key stakeholders.

The initial scoping phase was important in negotiating effective participatory relationships with the key collaborators, to scoping the key issues from their perspective, and to defining agreed objectives. But it is significant that these relationships and the agreed objectives changed as part of the collaborative process. Moreover the multiple, and sometimes conflicting, agendas of multiple funders meant an escalation of commitment to specific aspects of a project well beyond that which was originally anticipated, and led in part to episodic conflicts of interest emerging amongst stakeholder groups, system developers, and the agendas of some funding groups.

The study has clearly demonstrated that approaches to evaluation of the effectiveness of the R&D process need to be multi-faceted, encompassing not only technical and institutional impacts but, most importantly, less tangible outcomes. These less tangible outcomes included stakeholder learning processes and behavioral change, and learning impacts on the interorganisational environments. Moreover, the study showed that the R&D assessment process needed to be considered in the context of the broader evolving situational factors relating to the social and political environment. With no universal assessment standards and importance being placed on generating an effective technology innovation development process, value trade-offs were inherent to the evaluation processes.

The perceived usefulness of the DSS by key stakeholders was found to be influenced by (a) the degree of active user/stakeholder involvement in the system innovation development process; (b) the use of iterative and evolutionary development methodologies; (c) the DSS functionality; and (d) stakeholder 'learning' experiences during the R&D process.

These findings invoke a new paradigm for the role of science-based decision support technology innovations in sustainable resource management. This paradigm encompasses a shift from a primary concentration on the correct solution, or a limited choice of management options, in tactical decision-making (problem solving) to one that uses a focus on tactical decision-making as a tool to provide a process for interaction. This process is one in which (a) increased learning about the decision environment and the problem context can take place; and (b) impacts on the organisational environments within which the stakeholders groups operate and interact are facilitated. A model of this new paradigm that incorporates these findings is presented.

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Acknowledgments

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Appendixes

- 1 List of papers prepared as part of this project
- 2 Critique: Landassess DSS—a biological scientist's perspective, by Andrew Ash, CSIRO Tropical Agriculture

I Background

I.1 Introduction

This report presents a history and discussion of the CTC1 project, Decision Support for Sustainable Grazing Management, which involved the development of a decision support system (DSS) called Landassess DSS. The presentation focuses on increased learning in relation to the management of such projects, whose objectives include an effective technology transfer program.

The CTC1 project has successfully achieved its original stated objectives. These objectives were to develop and demonstrate the effectiveness of a prototype Landassess DSS to key stakeholder groups within the Northern Territory (NT) Government agencies with responsibilities relating to the management of pastoral lands. The DSS has been delivered to, and accepted by, these stakeholders; to that extent the CSIRO R&D team's role as developers of a prototype DSS has been fulfilled.

This report first reviews the initial scoping of the project and its implications to the CTC1 project implementation process (Chapter 1). It then describes the dynamic institutional and policy context within which the project was implemented, and its influence on the R&D (Chapter 2). The project's overall approach and related methodologies are summarised (Chapters 3 and 4) and the evolving implementation processes are described briefly (Chapter 5). The report then examines the lessons learned:

- at the level of technological design, development and implementation of a complex systems innovation development process (Chapter 6); and
- at the level of managing science-based R&D on information technology innovation for sustainable grazing management (Chapter 7).

Issues relating to the evaluation of DSS effectiveness are examined in Chapter 8. Finally, based on these learnings, recommendations on a new paradigm shift for the role of science-based decision support technology are made (Chapter 9).

I.2 Scoping activities before CTC1

The CTC1 project originated as part of the CSIRO Multi-Divisional program (MDP) initiative on Land and Water Care (LW&C). The MDP funding was for four years from 1990–91 through the “1989 May Statement” funds provided by the Federal Government to CSIRO. The scoping activities of the project, that is, work in the period before funds were obtained from the LWRRDC, GRDC, and RIRDC joint program on “Adoption of Technologies for the Sustainable Management of Grazing and Cropping Industries”, had three distinct phases:

- i. June 1989–June 1990: initial problem identification with potential collaborators; initial scoping of DSS requirements and system design considerations; identification of potential stakeholders; assessment of data availability; and initial funding negotiations. This involved the short-term inputs of three scientists (ie. climatologist, system analyst, resource integrator/geomorphologist).
- ii. July 1990–January 1991: scoping of system design, methods and techniques; acquisition of available resource data and GIS coverages; and furthering of the collaborative relationship. This involved a research team of one research scientist (pasture ecology), one programmer, a GIS specialist, plus the short-term inputs from three other scientists (climatologist, soil scientist, resource integrator/geomorphologist) and a system analyst.
- iii. February 1991–March 1992: major project redesign with staff and leadership changes. This included refining the project objectives to match the reduced skills/resource base available, establishing a conceptual framework for the DSS, identifying and developing an integrating framework for the assessment of pasture condition and the evaluation of grazing management options, and commencing active participation of key stakeholders in the system development process. This also involved a reduced research team of one programmer/system analyst, part-time involvement of resource integrator/geomorphologist, and part-time inputs of a GIS specialist and a soil scientist.

The project's stated objective at its inception in 1990 was: ... to develop a computer-based DSS to aid in the assessment of land and pasture status within the Northern Territory (NT), particularly, assessing the risk of degradation of grazing lands currently in good condition.

The project sought from an early stage to undertake a collaborative approach to the R&D with the NT Government agencies which had responsibilities relating to the management of pastoral lands, and with other community based groups, such as Landcare groups, and the pastoral industry. Following initial negotiations in 1990, a collaborative agreement was established with officers of the Land Conservation section of the Conservation Commission of Northern Territory (CCNT) and, in June 1991, with the Pastoral Lands Branch of the Department of Lands and Housing (DL&H).

The initial scoping of the project through a review of formal documents and scientific literature, and a series of informal interviews with senior management of potential stakeholder groups, identified a public perception of significant past degradation of the extensive grazing lands of northern Australia, and the consequent need for their sustainable management. Moreover, a number of new pressures on land managers were identified as causes of concern in the industry and the NT Government. These included:

- the implementation of disease control and eradication programs (the Brucellosis and Tuberculosis Eradication Campaign, BTEC) which imposed stringent herd management requirements involving increased investment in infrastructure (eg. fencing, permanent watering points);
- the increasing uptake of new technologies (such as the introduction of genetically better adapted stock, supplementary feeding, permanent watering points), which were changing the spatial and temporal distribution of grazing pressure on the resource base; and
- industry expectations of planned legislative changes to the covenants on pasture land tenure in NT (ie. a new *Pastoral Land Act* requiring demonstration of sustainable use of the pasture resource), that was at that time seen by property owners as threatening the viability of the industry.

A major difficulty apparent with the impending introduction of the new *Pastoral Land Act* in 1992 was that although the Act would place the onus on land managers to demonstrate sustainable use of their pastoral lands, there was no generally accepted system of appraising the sustainability of agricultural activities. Approaches to assessing and monitoring sustainability were, and remain, relatively poorly developed and untested (Hamblin 1992; SCARM 1993). Although each State had introduced ground-based monitoring systems, and methods have been developed to assess and monitor rangeland condition using remote sensing (eg. Pickup 1989), there was no effective linking of the results of this monitoring to the practical management activities of producers.

Some of the key questions and concerns raised by stakeholders during these initial 1990–91 scoping activities were:

- There are no objective methods for assessing the sustainable carrying capacity of a paddock.
- What are the critical criteria for assessing land capability within rangelands?
- What is the variability in land capability across the landscape within a management unit (eg. paddock, property)?
- There is no knowledge on threshold levels—that is, given a specified management strategy, how long before the land resource becomes degraded?
- We know how to manage cattle but not pastures. There is a need for more informed advice for managers on risks associated with grazing land management.
- Animal production is a poor measure of the health of the pasture resource. What are the early signs of land degradation?
- Are we shifting grazing pressure to another part of the landscape with the adoption of new technologies?

- BTEC has provided the opportunity for the development of more intensive management systems for the beef industry in northern Australia.

As an outcome of preliminary informal interviews and workshops conducted in 1990 and 1991 with scientific experts and resource managers from government, research agencies and industry, it was concluded that land management agencies of the NT Government needed a system that integrated all the currently available data and expert knowledge, so that more informed management advice and land use policy decisions could be made. At that time, existing decision aids for the pastoral industry (eg. RangePack) focused on herd management and short term profitability rather than on land resource management for longer term sustainability of animal production. Moreover, they provided essentially point-based assessments with considerable and complex input data requirements, and they did not address the management of spatial variability across the landscape. Landassess DSS (decision-support system) was proposed which would assist users to:

- identify the current state of health of a pasture management unit (eg. paddock, property); and
- evaluate the risk to the land resource base from the adoption of alternative grazing management strategies.

The proposed project sought to address these issues through the collaborative development of advanced information technology to link existing databases relating to the land resources, property cadastre, and infrastructure with simple models and an expert knowledge-base in a DSS and geographic information system (GIS) framework. The interactive scoping process conducted in 1990–91 with key stakeholder groups also highlighted that risk assessment should include an evaluation of the economic costs and benefits associated with alternative management options.

The Scott Creek/Manbulloo area, near Katherine, NT, was chosen to develop a prototype DSS for the sustainable management of the monsoonal tallgrass grazing lands of NT with the NT Government as project collaborators. This study location was chosen on the basis of:

- the availability of suitable land resource and property cadastral information in a digital spatial form (ie. GIS format).
- the availability of “a bank of knowledge” relating to the land resources and grazing management systems from scientists and other experts within CSIRO and NT Government agencies.
- the target area had good physical access and cooperative property managers.
- the strong support and interest of the NT collaborating agencies, in particular CCNT.

Links were established with the managing agent for the Scott Creek property near Katherine and the coordinator of

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the Landcare group in the target region, ie. the Victoria River Conservation Association (VRCA). In 1990–91, officers from the Northern Territory Department of Primary Industries and Fisheries (DPI&F) were also consulted and participated in some early workshops, but did not wish to enter into a collaborative agreement with the project.

The key stakeholders of the project were perceived in 1991 as State/Territory regulatory and advisory land management agencies, Landcare groups, pastoral companies, industry R&D corporations, and other researchers.

1.3 Implications of the scoping activities

The key implications of the scoping activities undertaken before CTCI started were as follows.

- Within the extensive native pasture environments of northern Australia, widespread land degradation was seen as threatening sustainability. This degradation of the grazing land was the responsibility of numerous, and regularly changing, property managers on primarily leasehold land.
- Although these lands have long been used by the grazing industry (for over 100 years in some areas), little was known about the cumulative impact of grazing and how to manage it. Moreover, the increasing uptake of new “technologies” (such as fencing of paddocks, provision of permanent water supplies, new more drought resistant cattle breeds, and feed supplementation) was changing the spatial and temporal impact of grazing on the land.
- With the rising public concern during 1989–1991 for resource conservation and environmental quality, and the impending stewardship requirements of a new *Pastoral Land Act*, decision-making processes in grazing resource management were becoming increasingly complex. The ability to assimilate pertinent information to support or facilitate the decision-making process at both policy and enterprise levels was emerging as a potential limiting factor. To address these concerns and meet their stewardship responsibilities, there was a need for NT agencies to determine the current status of grazing lands and monitor change. This required substantial integration of data and information. However, there were significant problems relating to non-uniformity of scale and precision, and numerous large “disconnected” data sets. There was an urgent need therefore for integration of all that was known about the pastoral system. This appeared to require *an interdisciplinary approach* at “natural” scales relevant to the decision-making of land resource managers. This approach would need to transcend traditional agricultural and biological research. It would also require approaches that allowed integration of currently disparate quantitative and

qualitative data and information sources to enable spatial and temporal aggregation, modelling, and evaluation of management options.

- In relation to these resource use management systems, there was a lack of methods/means for (a) the identification or early signs of potential sustainability problems, and (b) the evaluation of the potential effects of management options and/or implications for future use. Given the lack of understanding of a number of aspects of the problem (such as indicators of sustainable grazing management systems) and the complexity of the sustainability issues being addressed, the needs of the key stakeholders of the R&D could not be precisely defined in advance, so *an evolutionary process of DSS system development* was required involving *active participation* of key stakeholders/end-users of the proposed DSS.
- The project required a *customer-focus* which involved co-operating with multiple agencies/end-users with diverse responsibilities and ‘cultural’ backgrounds, and different perspectives and knowledge of the problem. The involvement of each of these agencies in the project was driven by quite different and *multiple objectives*. These multiple objectives meant that: (a) at times there would be the potential for significant conflicts of interest amongst collaborators and with the developers, and (b) there were *multiple criteria for evaluation* of the value of the technology innovation and its impact.
- *Management of end-user expectations* would be an on-going need particularly given the relatively long time frame required for system development.

A further outcome of these early scoping activities was the realisation that more funding would be needed outside the normal CSIRO appropriation. This would support closer interaction with the collaborating agencies who were geographically dispersed between Darwin, Katherine and Brisbane.

The Land Resource Management Group of the CSIRO Division of Tropical Crops and Pastures based in Brisbane, in collaboration with the Darwin-based Land Conservation section of CCNT and the Pastoral Lands Branch of DI&H, approached LWRRDC for additional funding support in late 1991. The project was subsequently approved for funding as one of the five projects comprising the LWRRDC/GRDC/RIRDC program, “Adoption of Technologies for the Sustainable Management of Grazing and Cropping Industries”. This program was funded for three years from 1992/93. The key issues that were raised within the initial negotiations in the first half of 1992 for this additional funding were:

- The role and effectiveness of agricultural DSSs and other computer-based technology innovations were being strongly questioned by R&D funding agencies and others, so that there was a need to:

- (a) better define their role in sustainable resource management, and
- (b) develop improved methods to evaluate such innovations.
- Given these concerns, and that the project now had multiple funding sources, the DTCP researchers were now committed to meeting multiple, and sometimes conflicting, agendas, namely:
 - (a) NT collaborating agencies,
 - (b) CSIRO Multi-divisional Program on Land and Water Care, and
 - (c) IWRDC/GRDC/RIRDC program on “Adoption of Technologies for the Sustainable Management of Grazing and Cropping Industries”.

The new funding enabled additional staffing of the research team, ie. a part-time programmer and short-term involvement of an economist, and increased operational resources. However it also meant that the project staff would be responsible, not only for the development of the DSS, but also for extrapolating their experiences to DSS technology R&D processes in general.

1.4 Project objectives

The primary CTC1 objective was to contribute to the goals of the Adoption of Sustainable Resource Practices Program. Specifically, CTC1 sought to do the following.

- Develop methods for a computer-based decision support system (DSS) to assist resource managers/users to formulate and evaluate alternative grazing management strategies for the sustainable management of the northern Australian native pastures. The DSS will enable resource managers/users to:
 - (a) assess the current state of health of a grazing management unit (eg. paddock, property);
 - (b) evaluate the potential risks to the land resource base from the interaction of alternate grazing management strategies; and
 - (c) assess the economic costs and benefits/risks to the resource user.
- Establish a prototype Landassess DSS for the Scott Creek/Manbulloo area of the monsoonal tallgrass woodlands near Katherine, NT, and to demonstrate the technology.
- Implement an effective transfer program to facilitate adoption of the technology.

2 Situational context: a dynamic influence

“... the interaction of technology and organisations is a function of the different actors and socio-historical contexts implicated in its development and use”

Orlikowski, 1992, p.405

Recent R&D from diverse research fields has emphasised the context in which policies, programs and institutions are operating strongly affects R&D implementation. These research fields include evaluation research (eg. Ormala 1994), information systems development (eg. Newman and Sabherwal 1989, DeLone and McLean 1992, Adelman 1992, Willcocks and Margetts 1994), DSS and other advanced information technology development (eg. Orlikowski and Robey 1992, Orlikowski 1992, Pinto and Azad 1994, Angehrn and Jelassi 1994), and organisational theory (eg. Altschuld and Zhang 1995).

Contextual factors are themselves dynamic (Newman and Sabherwal 1989, Ormala 1994, Willcocks and Margetts 1994) and specific to each organisation (Kaufman and Weill 1989). Willcocks and Margetts (1994) distinguish between two types of contextual factors:

- external – that is “the givens that the organisation and its members need to respond to and accommodate”, such as: politics and government policy; departmental guidelines, procedures and funding arrangements; and
- internal – that is “the characteristics of the organisation itself”, such as strategy, structure, management and its culture, including its values, symbols, belief systems and deep assumptions, which have also been found to influence information technology R&D implementation processes (eg. Robey and Rodriguez-Diaz 1989).

Other research on the implementation of information technology R&D projects and research-extension links have emphasised the difficulties imposed by “jurisdictional balkanisation” (Fellman 1994) or “functional specialisation” of organisations (Nogueira 1990) In other words, fundamental divisions of responsibility between agencies are barriers to the adoption of technologies and the facilitation of environmental stewardship.

The institutional and policy context of each of the NT collaborative partners strongly influenced the DSS development process, and ultimately the Landassess DSS product itself. Also, there were significant changes in these contextual factors for each of the organisations involved over the life of the project, of which some were positive and some negative. The evolution of the policy context and the changing roles and responsibilities of the collaborating partners are briefly outlined in the following sections. The R&D process itself is described in Section 6 of this report.

Note: the origin of quotes of individuals who participated in the evaluation processes of this project (see Chapter 4) are presented as a position and organisation of the individual.

2.1 Policy context

Many national and Territory policies and inquiries influenced the initial scoping of the Landassess DSS project and the shape and direction of both the research focus (particularly in the period 1989–92) and the subsequent system innovation development process.

2.1.1 Federal policies relevant to sustainable land use and management

The World Commission on Environment and Development produced the Brundtland Report “Our Common Future” in 1987. It strongly emphasised the concept of sustainable development. In response to this international initiative, the federal government set up a working group that identified the national objective for agricultural sustainability as “*the use of farming practices and systems which maintain or enhance*”:

- the economic viability of agricultural production;
- the natural resource base; and
- other ecosystems which are influenced by agricultural activities. (SCA 1991)

The concept of sustainability and its implications for land use and management were topical in public and research forums at the time of this project’s inception. Other initiatives that influenced the initial scoping of the CTC1 project included:

- a national review of land degradation in Australia (Woods 1983) which recognised for the first time the spatial extent and severity of both soil and vegetation degradation at a national level;
- a House of Representatives Standing Committee on Environment, Recreation and Arts inquiry on land degradation (The Parliament of the Commonwealth of Australia 1989) which commenced in December 1987 with particular reference to: (a) on-going causes of land degradation; (b) effectiveness of policies, programs and practices designed to alleviate land degradation; and (c) measures required to protect the environmental and productive values of land.; and
- the national Decade of Landcare Plan (1990–2000) which aims to improve management of natural resources by increasing awareness and participation among rural and urban communities.

Extracts from reports on these latter two initiatives follow.

House of Representatives Inquiry on Land Degradation, 1989

The committee reported that:

Early signs of land degradation are not easy to detect or quantify and are masked by management activities, land use changes or seasonal conditions. Research into farmer perceptions of the impact of erosion on productivity suggests that the problem lies not so much in convincing farmers that soil conservation is important as in convincing them that their own land is being degraded. Unless landholders can see that land degradation affects their own properties it is unlikely that they will either voluntarily undertake preventative management of their land or support development and implementation of performance standards, or coercive government regulation.

The Parliament of the Commonwealth of Australia 1989, p.23

It also identified numerous factors which have contributed to land degradation in the past, and which were limiting the introduction of sustainable agriculture, in particular:

- Lack of awareness of land degradation as a problem,
- Lack of understanding of soil processes,
- Uncritical application of inappropriate land use practices,
- Land tenure that encourages non-sustainable land use or inhibits change,
- Economic factors including lack of incentives,
- Deficiencies in extension services,
- Lack of information sources and databases,
- Inadequate training and education of land managers,
- Indirect consequences of government policies, and
- Lack of a national approach to a forward strategy.

It perceived that:

“A lack of information will be a further constraint to the adoption of sustainable agriculture. There is a need to develop information sources and databases which extension officers and farmers can draw on. There is also a need to ensure that the results of research are made accessible and relevant to practitioners.”

The Parliament of the Commonwealth of Australia 1989, p. 32

It also considered that:

“The whole farm planning approach could be a significant element in strategies to prevent and repair land degradation. However it notes that it would be difficult to achieve widespread acceptance of this approach unless farmers are provided with good information and technical assistance. It will also be necessary to show farmers the benefits of this approach including the positive economic returns. Government agencies have a role to play in this

area but they are not yet necessarily in a position to provide the type of advice which integrates principles from a variety of sources and emphasises both the economic and ecological advantages.”

The Parliament of the Commonwealth of Australia 1989, p. 115

The Decade of Landcare Plan goals

- That the whole community be aware of the problem of land degradation and the benefits of sustainable land use.
- Continuing development and implementation of sustainable land use principles and practices.
- All public and private land users and land managers understanding the principles of sustainable land use and applying them in their use and management decisions.
- All Australians working together in partnership for sustainable land use.
- Effective and appropriate economic, legislative and policy mechanisms in place to facilitate the achievement of sustainable land use.

2.1.2 Northern Territory policies relevant to pastoral land management

In response to national and international concerns such as those outlined above, the NT Government developed a number of approaches, reflected in individual departmental policies. The main examples were: NT

- the NT Conservation Strategy, which was initiated in 1990 and eventually publicly released in 1994;
- Landcare NT launched in 1990;
- the NT Decade of Landcare Plan, which was finally released in 1992; and
- the Pastoral Land Act passed by the NT Government in June 1992.

These policies evolved over the life of the Landassess DSS project. They had an important influence on the DSS development process, as well as the role and level of involvement of the stakeholders of the R&D.

In 1990, the CCNT initiated a new NT Conservation Strategy. It was in line with the World and National Conservation Strategies and promoted the need for a balance between conservation and sustainable development. It also launched Landcare NT to co-ordinate Landcare activities as well as promote public awareness of Landcare issues and raise sponsorship of relevant activities. A new Landcare group, the Victoria River Conservation Association (VRCA), covered the target region for DSS prototype development.

The NT Decade of Landcare Plan, which was launched in 1992, introduced for the first time a co-ordinated approach to land conservation and protection. It provided a strategic framework for both community participation and allocation

of government resources. The primary focus of the Plan is on maintaining the quality of land resources, protecting and enhancing the land's productive potential, and preventing land degradation. Land degradation was defined as “a set of processes that reduces the quality of land, and consequently the long term productivity of land [including] the soil, water, vegetation, fauna and other natural resources of the environment”.

Following the declaration of the NT as free of Brucellosis and Tuberculosis in 1992—and consequently the Brucellosis and Tuberculosis Eradication Program (BTEP) moving into a monitoring phase—the NT Government introduced a new Pastoral Land Act in June 1992. The goals of the new Act emphasised good land management, maintenance of renewable resources, and sustaining the land's productive capacity. The objects of the Act are:

- To provide a form of tenure for Crown land that facilitates the sustainable use of land for pastoral purposes and the economic viability of the pastoral industry
- To provide for
 - (a) the monitoring of pastoral land so as to detect and assess any change in its condition;
 - (b) the prevention or minimisation of degradation of or other damage to the land and its indigenous plant and animal life; and
 - (c) the rehabilitation of the land in cases of degradation or other damage.
- To recognise the right of Aborigines to follow traditional pursuits on pastoral land
- To provide reasonable access for the public to and through pastoral land to perennial waters and places of public interest
- To provide a procedure to establish Aboriginal community living areas on pastoral land.

Thus the Minister, the Pastoral Land Board, and lessees had to ensure that land held under pastoral lease was used sustainably. The emphasis was on voluntary and co-operative landcare and management with the main responsibility to care for the land being placed with the pastoralist, given the support of Landcare groups and government advisory services. The Act effectively improved security for lessees (by converting most pastoral leases to perpetual leases) in return for complying with land care covenants, maintaining the pastoral business, improving infrastructure, and monitoring the condition of pastoral land.

The Act heralded a new era in pastoral land management in the NT by abolishing the old prescriptive development covenants on pastoral leases. These had required, for example, the development of buildings, fences, waters and yards, and a minimum number of cattle being carried on the property. The OIC of the Pastoral Lands Branch, DL&H, noted that:

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DL&H were now operating under a radically new Act developed at the start of the decade. Previously the Crown Land Act had been very prescriptive including legal liability, covenants ... for example, it imposed default actions that often did not produce the desired result. The new Pastoral Land Act now wants to foster environmentally friendly sustainable land use ... education and awareness were high on the agenda during the development of the Act ... and an emphasis placed on monitoring.

Initially there was considerable anxiety in the industry but, by 1995, there was a noticeable shift in the pastoral industry's attitude to the new Act. For example the OIC/Executive Officer Land Conservation, CCNT, remarked in November 1994 that:

... the pastoral industry and landholders are now fairly keen on monitoring.

During the DSS Evaluation Workshops held in November 1994, the pastoral inspectors of the Pastoral Lands Branch, DL&H perceived a positive change in attitude by the pastoral industry:

... our role is more an 'extension' role than a 'policeman' role now. We aim to work with the pastoralists to manage the resource base but while maintaining productivity. The majority of land managers are now supportive of the monitoring system. There is much less resistance now than initially, with some managers starting to ring us up ... The DL&H process has been participatory ... encouraging pastoralists to be present when we set up sites and when we are recording.

Approximately 95% of the effort to date has been on education. A lot of pastoralists are now requesting assistance in putting monitoring sites in areas that they are interested in ... People in dry country want monitoring to begin while the country is at its worst so they can use the 'improvement' to demonstrate to outsiders that they are on top of things.

Although the implementation of the Act is progressing gradually, there is however an on-going policy conflict over which Act is to be "the primary or master Act" over pasture leases, ie. the proposed new Soil Conservation Act or the Pastoral Land Act. The former Managing Agent of Scott Creek property and a member of the Pastoral Land Board remarked that the three-year conflict:

... has still not been resolved ... The new Pastoral Land Act is meant to be a one-stop shop for the pastoral lands ... the Soil Conservation Act has to take on all the other lands as well, but in doing that you can encompass pastoral lands too as far as regulation and controls and serving notices on people.

2.2 Institutional contexts of the R&D partners

Over the five-year life of the project, the institutional contexts of each of the four R&D partners for the CTCI project—ie. the three NT Government agencies based in

Darwin, and the CSIRO research group based in Brisbane—were subject to significant structural and functional change. These changes markedly influenced the DSS development process, the staffing and financial resourcing of the project, and the ultimate success of the DSS product.

The following sections briefly examine:

- the changing roles and responsibilities of each of the NT Government departments;
- some of the ensuing conflicts; and
- the changes in the situational context in which the CSIRO researchers and developers of Landassess DSS were operating.

2.2.1 Conservation Commission of the Northern Territory

The CCNT was established in 1980 with a broad charter to ensure that economic development of the Territory is compatible with the use and conservation of its natural resources. It provided advice on environmental and land management matters to other departments in the NT Public Service, as well as to private land users in the Territory. To carry out its obligations as set out in the Legislative Charter, CCNT adopted a number of objectives which in 1990, when the Landassess DSS project started, included:

- meet the needs of present and future generations for the conservation of flora, fauna and land resources;
- promote the integration of conservation and development;
- increase community awareness, appreciation and enjoyment of the environment;
- provide government with factual, objective and timely advice including options and alternatives, relating to all areas of the Commission's responsibilities; and
- implement government policies and directions in those areas.

In 1992, CCNT's organisational structure comprised three Divisions (Parks, Wildlife, and Conservation) and two regional sections (Katherine and South). The Land Conservation section of the Conservation Division identified its role as being "to promote the sustainable utilisation of NT's land resources".

CCNT's key responsibilities were the administration of the Soil Conservation and Land Utilisation Act, the National Soil Conservation Programme, and Landcare NT. It also provided advice and material for property management planning (PMP) to pastoral properties and, effectively at this time saw itself as the champion of PMP in the Territory. The OIC/Executive Officer Land Conservation, CCNT, perceived 1992 as "a threshold time" for CCNT:

... we shifted Soil Conservation as a section in CCNT Land Conservation to a Land Management section—a clear

message that the focus was no longer on rehabilitating land but on managing land; and no longer just on collecting soils information, but on vegetation information also.

He remarked that, at this time, CCNT saw preventive planning (and therefore PMP) as part of “the philosophical basis for our existence” and that “the way to preventative planning is through monitoring and understanding the system”. The OIC of Land Management Section within Land Conservation, remarked:

... at that stage, we probably still had this vision of PMP, property management planning, and that we [the three Departments] could all work together and deliver a very good integration extension package to land holders ... We [CCNT] were involved in it [PMP] very heavily. We were trying to push it and this [Landassess] was the way to go. If we understood the resources, if we understood the management constraints, we could all bring it together and deliver it.

Inevitably, however, there was considerable industry concern in NT over the broader public and official focus on land degradation and sustainability. In particular, there was much anxiety over CCNT’s legislative charter in relation to soil conservation, and its emerging role in PMP. The industry lobbied the Government and, in 1993, a Ministerial directive led to CCNT losing the responsibility for PMP to the DPI&F. This was a very significant decision that impacted on the Landassess DSS development process and, in particular, key stakeholder groups of the Landassess DSS R&D. This role was effectively imposed on DPI&F and, as the managing agent for Scott Creek property pointed out, although DPI&F had the responsibility there was considerable doubt that at an operational level, beyond the rhetoric, they would implement it:

DPI&F were told they were to take the front rein ... However, I don’t think they will do it unless they have a major change.

In July 1995, a major Ministerial-level restructuring led to the abolition of the CCNT as a separate organisation. The Land Conservation section and its legislative responsibilities were incorporated in a new department called the Department of Lands, Planning and Environment.

2.2.2 Department of Lands and Housing

Most of the NT in 1990 was pastoral land, covered by Pastoral Leases which were administered by the Pastoral Lands Branch of the Department of Lands and Housing. Leases were issued over extensive areas of land, and were frequently over 2,500 sq. km in area. This historical pastoral land administration system required full development of pastoral land areas including the development of buildings, fences, waters and yards, and carrying a minimum number of cattle.

In 1992, the NT Government introduced a new *Pastoral Land Act*. Although there was extensive consultation and

information sharing with interest groups during the drafting of the legislation, considerable community concern was evident in the early interactions with the pastoral industry by Landassess DSS researchers. The Government wished to change the emphasis to reflect the growing awareness of the community of the need to maintain our natural resources for future generations. The new Act placed emphasis on voluntary and co-operative land care and management. Under the Act, the principal roles of the three main land management agencies in relation to pastoral land management are identified in Table 2.1.

The Act created the Pastoral Land Board. A key responsibility of the Board is to develop the pastoral land monitoring methodologies, based on information collected through ground-truthing and assessment. As technological advances in satellite imagery become available, they are to be used. After consultation with the pastoral industry, the Pastoral Board initiated a two-tiered monitoring system in 1994.

Tier One is a photopoint-based system with pastoralist participation. It is designed to increase knowledge and awareness of plant and pasture behaviour, and aims to assist lessees with management decisions by providing a means of documenting change at specific pasture sites over time. These sites, known as monitoring sites, are installed by officers of the Pastoral Lands Branch, Department of Lands, Housing and Local Government in association with lessees. Lessees are encouraged to visit sites every twelve months and complete the site data sheets.

Tier Two involves monitoring by Government agencies at a regional level using a smaller number of sites, to be known as ‘reference sites’, which wherever possible, will be a cross section of the Tier One monitoring sites. Data on range condition are to be gathered by the Land Conservation section of CCNT using conventional methods. Remote sensing and satellite imagery will augment this information, providing a basis for interpreting reasons for any change detected at either Tier One or Tier Two level. The information obtained from Tier Two monitoring is intended to be used by rangeland officers in interpreting reasons for change and guiding management decisions.

In July 1995, a major Ministerial restructuring led to the abolition of the DL&H. The Pastoral Lands Branch and its legislative responsibilities were incorporated in a new department called the Department of Lands, Planning and Environment.

2.2.3 Department of Primary Industries and Fisheries

DPI&F’s key objectives in 1991 included “to foster the long term, on-going viability of the animal industries in the territory”. DPI&F exercised a regulatory and/or support function in the areas of livestock health and breeding, livestock feeding, livestock movement and weed control.

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Table 2.1 Roles of government agencies under the Pastoral Land Act from 1992 to 1995.

CCNT	DPI&F	DL&H
<ul style="list-style-type: none"> • Soil conservation • NSCP Administration • Feral animals • Land Care • Land resource mapping • Natural resource assessment • Property management planning (land resource mapping) 	<ul style="list-style-type: none"> • Pasture management • Beef production • Disease control • Weed control • Voluntary rangeland assessment & specialist advice • Property management planning (extension) 	<ul style="list-style-type: none"> • Tenure • Lease administration • Periodic inspection • Mapping & plan production • Rent • Infrastructure maintenance • Data collection • Basic photopoint • Coordination • Property management planning (infrastructure and mapping update)

At this time BTEC was a major force for change that had been focusing much of the Department's activity. However, in 1992, the NT was declared free of Brucellosis and Tuberculosis, and BTEC moved into a monitoring phase. By 1993, the prime focus of DPI&F had evolved to be "the principles and practices of sustainable agriculture", with the recognition of "the need to encourage those involved in agricultural pursuits to adopt the PMP concept, with sustainability being the underlying motive". The department's services and functions now included advice and extension on:

- sustainable utilisation of rangelands,
- pasture development and utilisation,
- livestock production systems, and
- animal health.

Importantly, the Department had been appointed as the government lead agency for property management planning (PMP) in the N.T, and a conceptual framework was developed for the process itself.

By 1994, a major reshaping of the organisational structure of the Department occurred in response both to this new direction and also to the changing needs of industry which included:

- a rapid developing livestock trade in SE Asia,
- moving to a monitoring phase of BTEC, and
- increased focus on long-term sustainability of industries.

The new Departmental structure involved ten 'frontline' Divisions including:

- Land Resource Management Division—concerned with maintaining the permanent sustainability of all farming and grazing systems; and

- Katherine Pastoral Division—concerned with maintenance and development of the pastoral industry in the region.

DPI&F's new role and approach was described by the Director, Katherine Region Pastoral Division, DPI&F, at the Landassess DSS evaluation workshops held in November 1994 as:

DPI&F has a leading role in continuing the development of sustainable agricultural systems in NT and economic growth focused on developing links with S.E. Asia. Extension research and overall economic development focus is based on country, cattle, community, clients, cash. The DPI&F philosophy is that people who own the land are the people managing the land, and therefore DPI&F tries to improve pastoralists' skills as best as they can. The integration and delivery of information to land managers on the ground is an important role of DPI&F.

2.2.4 Cultural conflict: within and between government and industry

In 1990, at the start of this Landassess DSS project, these three NT Government agencies had very different organisational cultures and responsibilities concerning the grazing industry and land management.

They engaged in little constructive interaction or information exchange except at the highest level, ie. heads of departments and ministers. At the operational level, particularly at middle management, there was frequently open, and even aggressive, conflict. The OIC/Executive Officer Land Conservation, CCNT, referred to "big cultural problems" between agencies "with philosophically different approaches" to grazing land management, and "different approaches to the management of change". CCNT saw that it had a need to be proactive and that it was "an agent of change". "We were saying we need to change our management to recognise land capability and biological conservation". DPI&F's philosophy, on the other hand, was

based on “changing our ability to provide service based on the economic needs of people. [We] are a Department that reacts to the needs of our constituents, who are primary producers.” Both Departments however have shifted philosophies since then.

In 1990, the Managing Agent of Scott Creek property, who was a member of the CCNT Soil Conservation Advisory Council, doubted whether all three departments (ie. CCNT, DPI&F and DL&H) were “on the same track”. In the three organisations he perceived that there were distinct cultural differences:

They [the three departments] didn't even talk to each other ... except at a very high level they'd be saying “She's right, we're all working together”, and at the very low level, you may have had a couple of mates who had a beer, but anything in between was just not on.

The OIC Pastoral Lands Branch, DL&H, recalled that in 1990 “there was a lot of conflict between organisations, although they all worked for the one government”, and that there was also a lot of change going on in the three organisations at that time:

I think back in those times there was a need for a more collaborative approach on all the projects ... there was quite a lot of change around through the organisations as well ... there was always quite a bit of differing opinion between the heads of our department and DPI&F ... they [DPI&F] were, as one person put it, sitting on the fence.

DPI&F, because of their production and industry-driven focus, were geared by some parts of industry ... There was the Lands Department, who was the policeman, who jumped on us [the pastoralists] for doing bad things. Then the Conservation Commission came along and they were the wreckers and their job was to stop you [the pastoralist] doing anything that you thought was all right ... that [thinking] was probably perpetuated by some of the industry people. ... That's just about broken down now, but there are still some vestiges of it. ... In those days it was red hot.

The Chief Economist of DPI&F recognised the operational conflicts between functionally disaggregated and philosophically different organisations and interest groups in June 1995:

I don't think it's a Landassess problem ... it's an institutional one ... but it's part of government ... we've just accepted there are and will be tensions always between ourselves and the pastoral industries, and there's tension through the pastoral industry with CCNT and Lands, there's tension with us and CCNT, and us and Lands.

The principal implications of such inter-organisational conflicts for the implementation of projects like the CTC1 project relate to the need to address, from project inception and as an on-going process over the life of the project, who the key individuals or stakeholder groups to work with are, and how and when this interaction process should be undertaken.

A key factor influencing these conflicts were the fundamental cultural differences between agencies. The OIC/ Executive Officer Land Conservation, CCNT, in the evaluation interviews described the roles and differing cultures of the three agencies as:

CCNT have a primary charter for land and vegetation conservation, but in delivering to pastoralists/land users they have to take account of their need to be profitable. DPI&F have a primary charter for increasing productivity from land subject to a sustainability constraint, that is if the land manager cannot make a profit without destroying the land resource, the activity would have to be questioned. DHL is responsible for maintaining the status of resources owned by the Crown—ie. a charter to administer leases through the Pastoral Land Act. CCNT and DHL have a legislative mandate, while DPI&F has a policy mandate (ie. to support industry groups).

Culturally the pastoral industry groups had a much closer affinity with the DPI&F, because of its mandate. The Director Katherine Pastoral Division, DPI&F, recognised a lot of concern in DPI&F over the fears held by pastoralists over the potential use of Landassess as a “regulatory tool”. The Chief Economist, DPI&F, also remarked that:

“One of the concerns of the industry, and they are very sensitive to this sort of thing, is being told how to run their properties and they get very concerned about mechanisms that they say could be used against them in a regulatory way. They are particularly sensitive to land management type issues ... and they are particularly sensitive about Lands and Housing and CCNT in that context, and less sensitive and more comfortable with us being the key agents for sustainability.”

By 1995, however, the new Pastoral Land Act was effectively acting as the catalyst forcing the integration of the three land management agencies, at least at a rudimentary operational level. This situation was facilitated by the influence of Landcare and other industry groups who were now expecting integrated advice and were also demanding more interaction among advisors. In July 1995 two of the project's key stakeholder groups, ie. CCNT and DL&H, were integrated into one new Department.

2.2.5 CSIRO Division of Tropical Crops and Pastures

CSIRO, at both research team and organisational levels, influenced the project from time to time throughout its life.

The Landassess DSS project was initiated in 1989 and subsequently implemented by the then Land Assessment Group of the CSIRO Division of Tropical Crops and Pastures (DTCP), based at the Cunningham Laboratories in Brisbane, as part of its research portfolio. At this time, the group had an R&D focus on information systems for land assessment and evaluation. This they used for land use planning and resource management, predominantly in the south-west Pacific. The group underwent significant refocusing of its

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research and staff changes in the first 18 months of the project.

At its inception in 1989/90, the Landassess DSS project was funded through a CSIRO Multi-Divisional Program (MDP) on Land and Water Care (L&WC). This involved projects which were “to be treated and carried out as contracts, not simply regarded as part of the normal run of appropriation-funded CSIRO research”. Landassess DSS project was initially funded for four years “to provide information on the management implications behind an assessment of the extent and rate of current degradation, and to provide a risk assessment of the potential for further degradation”. The Landassess DSS project was to be part of “an integrated package” of three DSSs which was to: (a) be developed under the L&WC project “Decision Support Systems for Assessing and Restoring Degraded Arid and Semi-arid Grazing Lands”, and (b) obtain information from the CSIRO L&WC Sub-program on Rangelands Management.

The low level of funding compared with that requested lead to a “project re-orientation”. Project documentation in April 1990 noted that:

“... resource data required for the development of the DSS itself will now have to come from these institutions [NT Government agencies] rather than internally developed within the project.”

Collaboration in developing the DSS was then sought with CCNT:

“... at the earliest stage both for CCNT as a knowledge-base and in regard to integration of the DSS into CCNT and standardisation of relational database management systems.”

In June 1990, the Land Use Assessment group was directed by senior DTCP management to re-focus its research, and to spend at least 70 per cent of its time “on-shore”, that is within Australia and away from the previous dominant focus in the south-west Pacific. A DTCP pasture ecologist, with considerable R&D experience in the DSS study region joined the group to co-ordinate the MDP work. Five other staff members of the Land Assessment Group were to be part-time advisors. These included a systems analyst, climatologist, soil scientist, geomorphologist, and GIS/information systems specialist. In July 1990, a programmer with a background in artificial intelligence applications was appointed for three years.

By late 1990, a conflict had developed over the proposed research approach between the project co-ordinator and the remainder of the project team and upper DTCP management. This conflict related in part to different perspectives on the modelling approach to be taken (ie. a predominantly ‘process modelling’ approach versus a predominantly ‘rule-based qualitative reasoning’ approach), as well as the expectation of timeframes that the DSS system innovation development process would involve. At this time

as well, the project leader of the Land Use Assessment group advised senior management of his intention to retire. A decision was made to restructure the group’s activities into three separate projects. In February 1991, a new project leader of the Landassess DSS CSIRO MDP project was appointed who had been a member of the initial project team. However staffing resources were now substantially reduced comprising only a programmer, a GIS specialist and a soil scientist. Both the project leader/geomorphologist and soil scientist still had on-going commitments to an “off-shore” project, and the GIS specialist was a temporary part-time appointment for a further six months. Moreover the project now lacked expertise in pasture science, and none of the staff had prior experience with the grazing industry.

At this time, the project had in-principle support from DTCP top management; this continued over the life of the project. Good collaborative links also continued to be maintained with CCNT throughout these difficulties.

These changes to the Landassess project team were followed in early 1992 by a decision of the DTCP Management Committee for major changes in its overall R&D focus. This was in response both to broad public expectations for more ‘relevance’ in agricultural R&D, and to a declining funding base. They involved a shift from a disciplinary science relating to crop and livestock production to an interdisciplinary focus on the environmental aspects of economic development of those rural industries. These changes in focus were also accompanied by a significant downsizing of the Division and a rationalisation of its management structure in early 1993. In this ‘downsizing’ process, the CTC1 project’s soil scientist retired, and the project also had a change in the DTCP program manager within which the CTC1 project was based. Significantly, this latter change led to the project being situated in a DTCP program that provided it with much closer links to pasture ecologists and agronomists with experience in the target study area. Moreover the Landassess project also acquired a new computer programmer/technical officer who contributed half of his time to this project.

Despite these limited resources, the project team essentially met its broadly defined milestones within the CSIRO MDP. In comparison, the other two DSS systems to be developed as part of the proposed integrated MDP DSS package largely involved further development of existing software products, while the Landassess DSS project was a completely new R&D initiative. This meant that the designs of the other two DSSs were constrained to a large degree by the previous software design standards of the original products which they were being built upon. This led to some tension between these other researchers and the Landassess DSS developers because:

- the Landassess DSS developers wished to take advantage of the opportunities provided by emerging information technologies, and not be constrained by the other DSSs’ system design approach or development standards;

- there were no existing end-users/customers for the proposed integrated DSS product of the MDP; and
- Landassess DSS's stakeholders in the NT Government expressed some concerns over working directly with specific members of the other DSS research projects due to their then perceived poor relationship with producers.

In essence, the approaches undertaken by the Landassess DSS Principal Investigator to address these conflicts were to:

- focus the system innovation development process predominantly on meeting the needs and concerns of its key NT stakeholders in the first instance; and
- cooperate with the other DSS developers in the MDP in meetings and workshops to discuss progress and explore potential options, wherever it did not directly compromise meeting the Landassess DSS stakeholder needs.

The Landassess DSS team had support from within DTCP upper management in these approaches, and this effectively meant that the Landassess DSS project did not fully meet its CSIRO L&WC MDP obligations of integration and direct compatibility with the other DSSs being developed.

Support from DTCP upper management was maintained throughout the course of the project, despite strong concern expressed in March 1992 by an Advisory Committee to DTCP. This Advisory Committee mainly represented the pasture and cropping industries. Their major concerns in 1992 were the project's primary focus on land degradation in beef production systems which were not openly recognised by the industry as an issue, and criticism of its close links with the CCNT rather than industry focused agencies. Over the next three years, one of the pastoral industry members of this Committee became supportive of the R&D, while others continued to express strong concern with the project's objectives.

A final presentation was made on Landassess DSS to this DTCP Advisory Committee in April 1995. The other concerned members acknowledged the significant progress the project had made and that they personally would like access to a Landassess DSS application on their properties. However, they still expressed considerable concern over:

- the reliability of the resource data;
- the validity of the DSS's risk assessment capability; and
- the potential for the DSS to be misused by some government agencies to the perceived disadvantage of the beef producers.

2.3 Summary of contextual factors

The implications of the CTC1 project's multi-stakeholder R&D experience are as follows.

- When addressing issues of sustainable management, the necessity for multiple stakeholders provides opportunities for R&D processes to experience episodic conflicts of interests with different stakeholder groups, including end-users and funding bodies.
- The fragmentation of responsibilities relating to environmental stewardship across government agencies potentially provides fundamental barriers to the adoption of new technologies, and can inhibit the facilitation of environmental stewardship at the grazing management level.

Key aspects of the external context for management of projects focusing on R&D on public good issues can be summarised as:

- Multiple stakeholders will be involved. Designation of the actual end-users will change over the course of the project as the issues being addressed become more clearly defined and the roles of stakeholders in relation to the issue/problem context also evolve. The R&D approach taken, therefore, needs to be able to manage changes in primary stakeholders.
- The situational contexts in which each of the stakeholder groups or end-users (as well as the system developers themselves) are operating, may change independently of both the R&D problem being addressed and stakeholder and system developer control. The R&D approach taken by the system developers needs, therefore, to be flexible enough to be able to respond to these changes to ensure the continuing relevance of the research.
- Multiple agendas of multiple funders may mean an escalation of commitment to specific aspects of a project well beyond that which was originally planned. This can result in conflicts of interest emerging amongst stakeholder groups, between system developers and some stakeholder groups, and between developers and some funding groups.

3 Project approach: within a dynamic environment

“When the problem is to know what the problem is, we need more than one perspective.”

Thompson and Warburton 1985, p.33

3.1 Overall project approach

The CTC1 project can be seen as having technical, methodological, and socio-political dimensions. This required a multi-method project approach which attempted to draw on and integrate the strengths of a range of disciplines, including: information systems research, artificial intelligence, systems analysis, land resource science, environmental science, pasture ecology and agronomy, animal science, management science, organisational behaviour, and evaluation research. The project was designed to be:

- collaborative and customer-focused,
- interdisciplinary,
- iterative and evolutionary, and
- evaluative.

The rationale for the first three of these approaches are briefly described below. The rationale for the evaluative approach is described in Chapter 4.

3.2 Interorganisational R&D cooperation: a collaborative approach

3.2.1 A collaborative alliance

Organisations are operating increasingly in complex networks of relationships, both across multiple organisations, and within the organisation itself. With high costs of performing R&D and an increasing market demand for new technologies, individual organisations can gain significant comparative advantage from sustained ‘fruitful’ collaborations or alliance networks (Kanter 1994; Brockhoff and Teichert 1995).

An organisation’s performance, and even survival, frequently depends on linkages with other organisational groups. The formation of interorganisational relationships is a strategy that organisations can use to cope with complexity, uncertainty and turbulence. Increasingly, organisations are entering into interorganisational relationships to conduct R&D on complex environmental and societal problems. The underlying premise of such R&D cooperations is that synergy is possible.

There are many different forms of interorganisational relationships. Interorganisational R&D relationships may include alliances (eg. Gray and Wood 1991; Kanter 1994; McFarlan and Nolan 1995; Bleeke and Ernst 1995), partnerships, joint ventures, consortia (eg. Evan and Olk 1990; Souder 1993), various forms of cooperations (eg. Browning *et al.* 1995; Smith *et al.* 1995; Brockhoff and Teichert 1995), and outsourcing (McFarlan and Nolan 1995). Such relationships have been variously defined as:

- interorganisational effort to address problems too complex and too protracted to be resolved by unilateral organisational action, which are continually reshaped and restructured by actions and symbolic interpretations of the parties involved (Gray and Wood 1991);
- socially contrived mechanisms for collective action (Ring and Van de Ven 1994);
- a political system that serves to integrate differing objectives of the various partners (Brockhoff and Teichert 1995);
- living systems that evolve progressively in their possibilities, that is creating new values together (Kanter 1994); and
- people or groups acting together in a co-ordinated way to pursue shared goals, enjoy an activity, or simply further their relationship (Browning *et al.* 1995).

Interorganisational relationships may be either formal, such as contractual obligations with formal structures of control, or informal, that is voluntaristic and organic (in the sense that informal cultures and systems influence members behaviours) with minimal preparations and few administrative controls (Souder 1993, Smith *et al.* 1995). Moreover, they frequently involve agreements that cannot be “fully specified or controlled by their partners in advance of their execution” (Ring and Van de Ven 1994).

Cooperations involving research organisations for the purposes of conducting R&D have been found to be more ‘loosely coupled’ and have less focused or measurable goals and outcome criteria than other types of interorganisational relationships (Evan and Olk 1990). This has been attributed to the fact that their potential output is generally uncertain, and they frequently have broad societal purposes (Altschuld and Zheng 1995).

The notion of stakeholder participation in R&D to increase relevance of outcomes, the utilisation of research findings, and/or technology diffusion has been widely discussed. The studies and reviews derive from many disciplinary perspectives, including: information systems development (eg. Robey and Farrow 1982; Ives and Olsen 1984; Hirschheim 1985; Baroudi *et al.* 1986; Tait and Vessey 1988), DSS and expert systems development (eg. Eierman *et al.* 1995), program and R&D evaluation (eg. Patton 1987; Greene 1988a, 1988b; Mark and Shortland 1985; Prinsley

1994), and agricultural technology development (eg. Ison 1993, Jiggins and de Zeeuw 1992, Jiggins 1993, Woods *et al.* 1993).

These studies have provided some support for the benefits of stakeholder participation on utilisation and technology diffusion. However, this has been largely through discrete factors (eg. system quality, user satisfaction) related to the use of the technology innovation or research evaluation findings, rather than from the wholesale implementation of participatory approaches (Greene 1988b). Many of the theoretical and operational aspects of participation are poorly understood, such as, stakeholder definition and selection, and the nature and role of meaningful participation, that is the 'when, how, where and why' of participation (Greene 1988b; Mark and Shortland 1985, Hartwig and Barki 1994).

In the case of agricultural technology development, the emphasis of participatory approaches has primarily focused on the farmer/producer as the stakeholder or end-user. However, given the complexity of public good issues, such as sustainable development, their resolution will require integrated approaches to natural resource management through the collective action of a much broader group of stakeholders. These stakeholders would include resource users (eg. property managers/producers), all three tiers of government (eg. policy, planning, and regulatory, extension and advisory services), producer and community groups (eg. Landcare, Integrated Catchment Management, producer advisory groups to research and government agencies), R&D providers (eg. researchers in CSIRO and government) and educationalists (eg. in Rural Agricultural Colleges, Universities).

The benefit of involving decision-makers and other information users (ie. stakeholders) with diverse perspectives in the R&D evaluation process is also widely recognised (eg. Patton 1986, Prinsley 1994).

Although collaboration with such stakeholders is increasingly being argued as an important element of successful technology transfer of research findings, there has been little analysis of the outcomes of such R&D collaboration. The role, impact and effectiveness of R&D collaboration are therefore highly uncertain. Methods for evaluating the return on investment (rather than scientific quality) of R&D on multidimensional issues with broad societal purposes (such as ESD) are poorly developed.

The CTC1 project adopted a 'facilitated' participatory approach to interorganisational R&D cooperation. This R&D cooperation involved a network of linkages with staff of the three collaborating NT Government agencies, scientific researchers from the CSIRO Landassess DSS project and other related projects, and representatives of Scott Creek property. As described in Chapter 2, the context of the collaborating groups evolved throughout the life of the project.

There are two key questions about R&D collaboration.

First, do participative approaches and/or R&D cooperations impact on partner and/or individual performance? Second, what are the benefits and costs of participation and collaboration? This report uses the CTC1 project as a case study to examine some aspects of these issues (see Chapter 5).

3.2.2 Defining stakeholders

The key stakeholders and potential end-users of the CTC1 research were identified early on in the scoping phase of the project by the CSIRO researchers as:

- NT Government agencies with a role or function in land resource management (eg. policy, regulatory, extension and advisory services),
- producer/community groups (eg. Landcare, producer advisory groups to government agencies and R&D agencies),
- educational institutions (eg. Universities and Rural Agricultural Colleges),
- researcher providers (eg. CSIRO, CRCs, government agencies), and
- research funders (eg. RIRDCs).

However, because of the evolving nature of the R&D process (see Chapter 5), and the dynamic situational or institutional contexts within which the DSS development was being undertaken (see Chapter 2), the end-users of the R&D changed over the course of the project. That is, the individuals concerned and the relative degree of involvement of target stakeholder groups did fluctuate and change over the project life.

Participation refers to the process by which stakeholders of the R&D, or end-users of the innovation system development, affect decisions about the R&D process. In this project, this was achieved through initiating and guiding activities around the DSS development. User and/or stakeholder participation was integral to the approach adopted in many CTC1 activities, including the following.

- The overall R&D process, including problem definition, system design, and R&D evaluation processes, which involved an interorganisational cooperation or collaborative alliance between key stakeholder groups. This is examined in Chapter 7.
- The knowledge acquisition process for the DSS knowledge-base on ecological structure and functioning and the impact of grazing management. This was an iterative and evolving process of interpersonal interactions. It involved elicitation, incorporation, evaluation, feedback, and refinement with key domain experts (eg. pasture ecology, animal production, soil conservation, soil science) and other data sources. This is discussed in Chapter 6.

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- Evaluation of the DSS system development. This was an iterative process of evaluation, feedback, and modification of system relevance, functionality and utility with key stakeholders from the collaborating organisations and other CSIRO researchers. This is examined in Chapter 8.
- Evaluation of R&D effectiveness. This involved semi-structured interviews, supplemented by information obtained from DSS system evaluation workshops, and informal discussions and interviews over the course of the project. This is examined in Chapters 7 and 8.

3.2.3 Stakeholder interactions

From the start in early 1990, the Landassess DSS project team recognised the need to adopt a customer-oriented focus through cooperative relationships with potential end-users and other stakeholders. This approach acknowledged the complexity of the management issues being addressed, the

diversity of data needs, and growing public demands for relevance in research outcomes. These relationships evolved as the team dealt with potential stakeholders who were mainly NT Government agencies covering pastoral land management (that is the CCNT, DL&H and DPI&F), and with other scientists and local experts. From time to time, the managing agent and the property manager of Scott Creek property near Katherine and the local land care group co-ordinator were also consulted on various aspects of the project. These interactions provided opportunities for re-evaluation for both the DSS developers and its stakeholders.

A key issue for the researchers/ system developers throughout the project was how to deal with different stakeholder priorities. A 'strategic constituency' approach was adopted by the project's Principal Investigator to:

- address predominantly those issues voiced by the designated principal collaborator, that is CCNT, that the DTCP team had the capacity and authority to handle;

Table 3.1 Types of interaction and examples of typical purposes.

TYPE OF INTERACTION	PURPOSE
<i>Informal discussions through meetings and telephone conversations</i>	<ul style="list-style-type: none"> • Scope stakeholder interest • Identify stakeholder perceived needs • Negotiate active involvement • Data acquisition • Planning project activities • Informing partners on progress of system development or other relevant information such as institutional factors • Trouble-shooting problems • Project management
<i>Semi-structured interviews</i>	<ul style="list-style-type: none"> • Eliciting expert knowledge • Evaluating stakeholder perspectives on: <ul style="list-style-type: none"> – DSS development process – satisfaction with prototype performance – future development potential of DSS
<i>Group workshops</i>	<ul style="list-style-type: none"> • Eliciting expert knowledge • Scope issues of concern and related information needs • Demonstrate progress on R&D and gain stakeholder feedback on relevance, system functionality and further needs • Hands on evaluation of system performance and future development potential
<i>Joint field trips</i>	<ul style="list-style-type: none"> • Gain field experience and coming to a common understanding of eg. resource survey data; • Field experimental work
<i>Joint presentations/discussions</i>	<ul style="list-style-type: none"> • Reporting to CSIRO Divisional Advisory committees of industry representatives; Landcare group meetings
<i>Training courses</i>	<ul style="list-style-type: none"> • Stakeholder evaluation of prototype system development and performance • Hands on experience in the use of the DSS computer system

- bring out the differences in priorities expressed amongst the stakeholder groups and, where feasible, involve strategic stakeholder in decisions.

In practice, most differences were resolved through negotiation with participants, in particular in those situations where requests were made that required resourcing which could not be provided by the various stakeholders. Most of these negotiations were conducted by the Principal Investigator with technical assistance from other team members through a process of presenting a limited set of options to the collaborators for discussion and resolution.

The interactions took a number of forms including informal discussions, semi-structured interviews, workshops, field trips, joint presentations, training courses, and general correspondence. They had various purposes and motives including on-going needs assessment, objective-setting, information exchange, knowledge acquisition, negotiating involvement, project planning, resource attainment and distribution, and project and process evaluation. Typical purposes for the various types of interactions undertaken in the course of the project are provided in Table 3.1.

The form of these stakeholder interactions varied over the life of the project as well as across the different

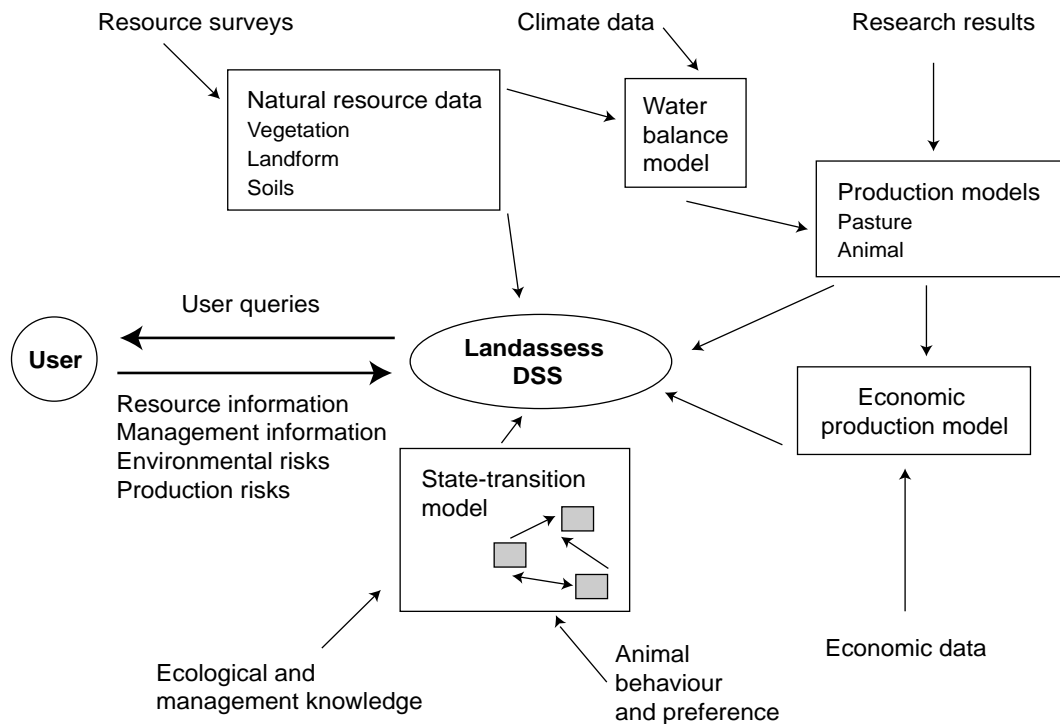
stakeholder groups. Interactions between CSIRO and the R&D stakeholders at times involved only one stakeholder group, and at other times individuals, mixed stakeholder groups within a single organisation, or cross-organisational interactions. The project process is described in Chapter 5 of this report.

3.3 Sustainable grazing management: interdisciplinary approaches

The CTC1 project adopted integrated interdisciplinary approaches to develop and implement the knowledge-base on the sustainable management of the grazing land resource. In particular, it focused on developing an integrative framework to assess pasture condition and its variability in space and time, in order to better understand the impact of grazing management options. It was assumed that trade-offs would be necessary between environmental and economic goals of beef production systems in the native pasture systems of northern Australia.

This required the integration, at a scale relevant to grazing management, of data and appropriate theoretical and

Figure 3.1 Overview of data, knowledge and models in Landassess DSS.



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analytical frameworks from a number of disciplines to: (a) define the problem context, and (b) facilitate an assessment of the spatial and temporal variability of environmental and economic risks.

The types of data, knowledge and models represented and integrated by Landassess DSS are illustrated in Figure 3.1. The theoretical and analytical frameworks are discussed further in Chapter 6 of this report.

3.4 DSS system development: an iterative and evolutionary approach

The Landassess DSS system innovation development process was iterative and evolutionary, in both its prototyping of systems and its acquisition of knowledge.

3.4.1 Iterative and evolutionary processes

An iterative approach was integral to the whole system development process, that is, within:

- prototyping cycles,
- knowledge acquisition cycles, and
- user interface development.

Opportunities were made to revisit, reaffirm or modify the technology and the knowledge-bases. This approach involved regular workshop demonstrations, refinements of system and user-interface requirements, and evaluation by users, other stakeholders and team members,

3.4.2 Prototyping

Prototyping is a system development approach in which a number of system prototypes are developed through the life of the project. These prototypes include some of the components and functionality of the final system. Their purpose is to give the users a feel for development of the system, and to provide a focus for discussion of requirements. Some of the benefits of prototyping have been identified as (Alavi 1984):

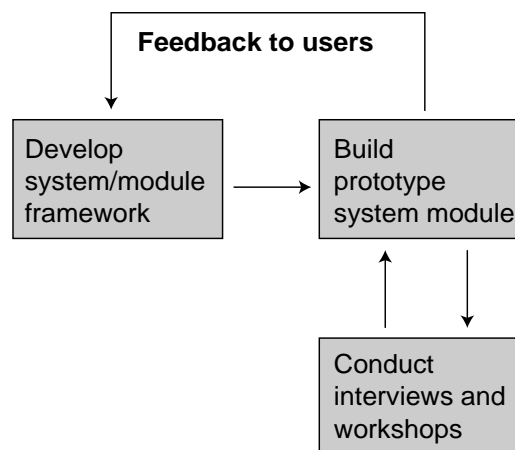
- A prototype is real and provides a tangible means for a user to comprehend and evaluate the system and to elicit more meaningful feedback in terms of their needs and requirements.
- A prototype provides a common baseline or reference point.
- Users are enthusiastic because they can see possibilities at an early stage in the project, and are able to have a significant input into the final appearance of the system.
- Prototyping establishes better relationships between developers and users.

Prototyping is particularly appropriate where exact user requirements are unclear, and where there is a need for experimentation and learning by users and developers before commitment to a full-scale system (Alavi 1984). With an evolving problem definition and an evolving problem context (eg. institutional/policy), the exact requirements for the Landassess DSS were likely to remain undefined for some time. To address this issue, and to facilitate both the integration of the new technology system into an existing work/computing environment, and the management of the users' and DSS development team's expectations, a prototyping approach was adopted.

These benefits were essentially those that the overall R&D process was intended to encourage, in that the core skills involved in developing Landassess DSS were not isolated from the overall R&D process. They were also essential to the 'learning' processes associated with both the system innovation development process, and with actual use of the DSS product.

Several system prototypes were developed during the course of the project, and demonstrated to stakeholders at workshops. The feedback from these workshops helped the continuing development of the system. The prototyping and demonstrations also provided an opportunity to pursue stakeholder-specific objectives of the project. This approach is schematically illustrated in Figure 3.2.

Figure 3.2 Prototyping approach used in Landassess DSS



3.4.3 Knowledge-based approach

Hoppe (1990) proposed an evolutionary knowledge acquisition process to handle situations where the specification of both the problem and the model are evolving. Much of the knowledge required for Landassess DSS was not embodied in any formal scientific model which could easily be incorporated into a DSS. Therefore knowledge-base, many of the modules or models in Landassess DSS

were developed through the use of knowledge-acquisition processes involving experts in diverse fields.

This approach involved workshops, individual interviews, and a review of literature to develop a theoretical framework for the knowledge-bases in Landassess DSS. Once a framework was developed, further workshops were required to develop the rules and relationships within the framework. The rule-based models so derived were then integrated into the DSS framework. The knowledge-acquisition process was an ongoing and iterative process with regular workshops with experts to ensure that the knowledge-base was maintaining its integrity and consistency. The frameworks, and the integration of information technologies to utilise these knowledge-bases, are described further in Section 6 of this report.

3.5 Summary of project approach

The CTC1 project undertook a facilitated participatory approach to an inter-organisational cooperation. It was achieved through initiating and guiding activities around the DSS development process. This approach evolved through a series of episodic, iterative and experiential interactions with potential stakeholders and end-users of the R&D. The project's stakeholders were changing over the life of the project, but they were primarily NT Government agencies and interest groups with responsibilities relating to pastoral land management. This approach led to the development of an integrative interdisciplinary approach.

The system innovation development process that developed Landassess DSS was iterative and evolutionary in both its prototyping of systems and in its acquisition of knowledge-bases.

4 Evaluation methodology: a multi-method qualitative approach

“As an innovation or program change is implemented, it frequently unfolds in a manner quite different from what was planned or conceptualised in a proposal.”

Patton, 1987, p. 19.

4.1 R&D evaluation process: multi-dimensional and dynamic

The scoping activities of the CTC1 project, as detailed in Section 1.2 of this report, identified the need for an evolutionary and participatory approach. This was mainly because there were multiple stakeholders involved with multiple objectives, and stakeholder needs were unclear. Therefore the evaluation process of the CTC1 project needed to be dynamic and multidimensional to monitor not only anticipated outcomes, but also unanticipated consequences, and changes in the developmental process and the context. This evaluation process had a number of dimensions:

(i) the *on-going assessment of needs relating to technological design and development* (eg. on-going issue/problem identification, stakeholder decision-making context, DSS system functionality, delivery platform). The objectives being:

- to ensure the relevance and utility of the DSS system innovation development to the targeted stakeholders and end-users; and
- to develop ownership of the R&D products.

This assessment is discussed in Chapter 6 of this report.

(ii) the *evaluation of the R&D process* (eg. stakeholder perceptions of issues, individual and organisational learning processes, interorganisational cooperative R&D, and the stakeholder interaction process). The objectives being:

- to improve the effectiveness of the implementation of the CTC1 R&D process.
- to provide opportunities to ‘learn’ how better to engage within multiple stakeholder R&D contexts.

This process is examined in Chapter 7 of this report.

(iii) *reflecting on potential impacts*, planned and unanticipated (eg. individual and organisational impacts, stakeholder perceptions of the R&D). The objectives being:

- to identify with key stakeholder groups an agreed set of potential uses for the Landassess DSS prototype and to

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explore its future role and developmental potential for sustainable grazing management in the NT

- to improve understanding of what can realistically be expected of science-based R&D on DSS system innovation developments relating to sustainable land management.

This is examined in Chapters 8 and 9 of this report.

4.2 A qualitative evaluation approach

Patton (1986) defines evaluation research as:

... the systematic collection of information about the activities, characteristics, and outcomes of programs for use by specific people to reduce uncertainties, improve effectiveness, and make decisions with regard to what those programs are doing and affecting.

The CTC1 project adopted a number of qualitative methods and data collection techniques for these evaluation processes. These are discussed below and the evaluation of the project process and outcomes are examined in Chapters 6, 7 and 8 of this report.

4.2.1 Documenting the process

Documents related to the project were collated over the life of the project by the Principal Investigator to provide a project evaluation resource. The documents included notes of outcomes of meetings, telephone conversations, informal discussions, and interviews, as well as CSIRO project management documents (such as project proposals and justification, annual reporting, workplans), and general correspondence. These data contributed to the analysis of the dynamics of the R&D implementation process. The focus of this analysis was to better understand:

- the project's strengths and weaknesses;
- the nature and extent of stakeholder participation; and
- the organisational or situational context of the R&D process, and its impact on the CTC1 project's implementation process and its outcomes.

4.2.2 Evaluating the system development process: a formative approach

Formative evaluation is an on-going process that can be integrated into the development and implementation of a research project. It involves on-going collation and feedback of information on the research planning and implementation process that permits changes and modifications to the R&D process as appropriate.

Workshops were held regularly. They allowed CSIRO DSS developers and key stakeholders to discuss the DSS's relevance, utility and functionality. They were also a forum for information exchange, and for furthering the collaborative relationship. At

times, these workshops also involved other CSIRO researchers, a representative of the local Landcare group, the VRCA, and the managers of Scott Creek.

Project team members and the IWRRDC/GRDC/RIRDC Program Manager gave feedback to the project leader and assistance in guiding the evaluation of the R&D process. The system innovation development process is discussed in Chapter 6 of this report, and the collaborative R&D process is examined in Chapter 7.

4.2.3 Evaluating DSS usefulness: an ex post strategic constituency approach

A strategic constituency approach (Altschuld and Zheng 1995) was adopted to identify the degree of perceived usefulness of the DSS by the different constituent or stakeholder groups, and to develop and foster stakeholder 'ownership', and eventual responsibility, for the DSS product.

A final series of four one-day workshops was held in Darwin in November 1994. It involved CSIRO Division of Tropical Crops and Pastures (DTCP) and the three NT Government agencies with responsibilities in land management: the Conservation Commission of Northern Territory (CCNT), the Department of Primary Industries and Fisheries (DPIF) and the Department of Lands and Housing (DLH). The workshops were designed by the Principal Investigator with the assistance of other team members and the Program Manager. A member of the CTC3 project team facilitated the four workshops.

The principal aims of the series of workshops were:

- To bring representatives of all parties in NT Government, who had expressed an interest in Landassess DSS, up-to-date with the development.
- To bring CSIRO DTCP up-to-date with developments in NT which had (and may in the future have had) a bearing on the use and further development of Landassess DSS.
- To identify the various expectations of key stakeholder groups about the current and potential uses for Landassess DSS in the NT
- To identify potential resourcing needs for those uses seen to be of high priority.
- To develop the basis of a plan to progress the joint development and use of Landassess DSS between the three agencies and CSIRO.

In order to take account of the different levels of prior involvement in the CTC1 project, and to provide each of the groups with enough background, three separate one-day workshops were held with representatives of each of the three NT Government agencies. Each of these workshops involved a broad mix of participants in order that the different expectations and evaluations for the DSS were encompassed. The workshops included the policy/administrator, advisor/

extension, computer systems staff, and data collectors/resource survey staff of the government agency.

These workshops involved:

- an introduction to the purpose and process of this *ex post* evaluation process by the CSIRO Principal Investigator;
- an overview of the Departments' role and responsibilities in relation to grazing management by a senior Departmental representative, and of the CSIRO's roles and responsibilities by the CTC1 Principal Investigator;
- a 'guided' hands-on session with the Landassess DSS computer package focusing on the 'contextual' use of the DSS and general familiarisation with its functionality provided by the DSS developers.
- a 'brainstorming' session involving small groups of participants (5–6) on the potential uses of the DSS in the context of their Departmental role and responsibilities, and also a consideration of its potential limitations. These were recorded in a format of: system user, for what purpose, with whom (ie. client/beneficiary), modifications to Landassess DSS required, information required.

Each group then reported back to the main workshop group.

- a summary session and indication of commitment of the agency to provide input to the subsequent combined department workshop were given.

The final one-day combined department workshop or plenary session involved participants from each of the three agencies and comprised:

- A presentation by a senior representative of each NT department and the CSIRO team to overview their roles and responsibilities on grazing management.

- Feedback on the potential uses and perceived limitations of Landassess as identified in the three previous individual departmental workshops.
- Joint discussion session to identify necessary tasks and responsible groups within NT Government and CSIRO to finalise the current prototype for the Katherine Daly region, and identify a process for consideration for further development of an agreed plan to move ownership of the system to the NT agencies, and identify a process for further applications of the DSS in other relevant regions.

A formal report on the outcomes of this workshop was prepared by the Principal Investigator and workshop facilitator. Summaries of the outcomes are reported in Section 8 of this report.

4.2.4 Stakeholder evaluation of R&D effectiveness: a strategic constituency approach

A strategic constituency approach was also adopted for the evaluation of overall R&D effectiveness which provided an opportunity to examine the collaborative R&D process as a system. A series of semi-structured interviews based on a scenario approach were conducted with 11 key stakeholders of the Landassess DSS project in June 1995. The purpose of these interviews was to get stakeholder input into the evaluation of what parts of the Landassess DSS project worked and what did not from their perspective, and what could have been done differently in hindsight. The interviewees are listed in Table 4.1.

The interviews were private and face-to-face and generally from 1.5 to 2 hours. They were conducted jointly by the CTC1 Principal Investigator and the Program Manager, then audiotaped and transcribed for analysis. To begin with, the interviews were structured using 'key events' or 'scenarios'

Table 4.1 List of stakeholder interviewees

CCNT	<ul style="list-style-type: none"> • Executive Officer, Land Conservation (at the time Executive Officer, Parks and Wildlife) • OIC Land Management Section, Land Conservation (at the time Acting Executive Officer, Land Conservation) • OIC Land Resource Survey Section, Land Conservation • Soil Scientist, Land Resource Survey Section, Land Conservation
DPI&F	<ul style="list-style-type: none"> • Director Northern Pastoral Division, Katherine • Chief Economist
DL&H	<ul style="list-style-type: none"> • Director, Pastoral Lands Branch • Chief Pastoral Inspector, Pastoral Lands Branch
CSIRO	<ul style="list-style-type: none"> • Senior Principal Research Scientist, Agricultural Systems and Land Resource Management Program • Senior Research Scientist, Agricultural Systems and Land Resource Management Program Pastoral
Industry	<ul style="list-style-type: none"> • Company Director for Scott Creek Station, Member Pastoral Land Board

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as the basic framework for questioning, and as the unit of analysis. The format of a typical scenario was:

- *When* (a date and place)
- *What* (the nature of the episode or incident and who was involved)
- *Outcomes* (a summary of the key outcomes of perceived to be of consequence)
- *Context* (the environment/organisational context within which both the CSIRO partners and the relevant interviewee's organisational group were operating).

The scenarios were developed by the CTC1 Principal Investigator based on the documented notes of interactions, recollection of events, and other information relevant to describing the project context, including annual reports of stakeholder organisations and Landassess DSS project reporting to the various funding sources. These documents effectively formed a history of the project which is summarised in Chapter 5 of this report. An appropriate set of scenarios was developed for each of the interviewees which effectively provided a snapshot view of the history of their involvement with the project from the Principal Investigator's perspective.

Each interviewee was asked to consider each scenario in terms of three separate questions:

- From your perspective were these the outcomes?
- What else was happening at that time?
- What other context factors were affecting your organisation's involvement and the outcomes?
- In hindsight, what might have been done differently at this stage?

A list of 'Changing Themes Across Critical Events' also was developed from the general themes. These were provided to the interviewees as a check list of themes to consider in their response to each scenario. This check list is provided in Table 4.2. In addition the interviewees were each provided with a list of questions that reflected some of the interests of the funding agencies (see Table 4.3).

4.3 Summary of evaluation methodology

The evaluation process was multi-dimensional and dynamic involving the assessment of needs, the evaluation of process, and stakeholder reflections on potential impacts. The implementation of this process involved:

- on-going documentation of the project process over the life of the project;
- on-going evaluation of the DSS system development;

Table 4.2 Landassess changing themes across critical events

ISSUES OF PROJECT SCOPE
Objectives—for whom? For what purposes?
DSS prototype
Education, training
Databank
Facilitating—interdepartmental collaboration
Production and environmental Issues
ISSUES OF SCIENTIFIC MODELS & TOOLS
For whom? For what purposes. By whom?
Limitations
Expertise—credibility
Data requirements—scale, methods of collection,
Integrity
Equipment requirements
Useability
STRUCTURE AND PROCESS: ISSUES OF R&D
TECHNOLOGY TRANSFER AND COLLABORATION
Project responsibilities and authorities and role
relationships
Ownership
Project failure/risk avoidance strategies
Project success strategies
Timing and resource coordination's requirements and
competing commitments
Inter department/organisational work – cultural
conflicts
Relationships with funding agencies
Relationships with other stakeholder groups
Institutional monitoring and reward mechanisms
Legal issues—future collaboration
STAFFING ISSUES
Redistribution of skills and training
Availability and allocation of staff to project
Competing commitments stability of employment and
positions
Interpersonal conflicts
Individual goals
Future employment.

- an evaluation of user satisfaction with the DSS innovation development; and
- an evaluation of the overall R&D process by key stakeholder representatives.

The evaluation approach therefore encompassed multiple qualitative evaluation methods:

- process evaluation of the dynamics of the R&D implementation process and its organisational and situational context;

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- a closely related or linked formative evaluation in order to improve the DSS system innovation development process;
- key stakeholder-group expectations of the effectiveness of the DSS system innovation as a product; and
- stakeholder perspectives on the overall effectiveness of the R&D process.

In the case of the CTC1 project, the R&D cooperative approach has been facilitated primarily through the DSS system innovation development process. The following Sections of this report evaluates the CTC1 approach to an R&D cooperation (Chapter 7), and the Landassess DSS system innovation development process (Chapters 6 and 8).

Table 4.3 What LWRRDC wants to know

LANDASSESS AS A DECISION SUPPORT SYSTEM

- Are the models parameters appropriate for your use?
- What is new? What has been learned about managing sustainability?
- Has it provided insights that were unexpected?
- Did you get what you originally thought you would get? How does it differ? And how does that matter?
- How confident are you about the reliability of the software?
- How confident are you about the reliability of the model?
- How confident are you about the reliability of the data?
- Is it user friendly enough? can you use it?

CURRENT AND IMPENDING USE

- How is Landassess being used now? By whom?
- Who will use it in the short run?, Long run? And for what purposes?
- What are some of the barriers that will prevent its use?
- Is it having any impact on how you think about:
 - issues of sustainability
 - faith in DSS in general
 - your views of others? your views of CSIRO? etc.
- Do you understand land holders any better because of your involvement/use of Landassess?
- Are you a better adviser or communicator because of your exposure to Landassess? In what ways?
- Do you understand producers, or others in other departments any better because of the interaction in the development of Landassess?
- Are you more or less in favour of developing Landassess type DSS after your experiences on this project? Why?

INVOLVEMENT IN DEVELOPMENT

- How involved have you been in the development of Landassess? In what ways?
- What influence have you had in its development?
- What would you have liked to have been done that wasn't?
- Has CSIRO been as receptive to your concerns as they might have been?
- How might the multiple stakeholders been better served by this project? What might have been managed better and by whom?

FUTURE DEVELOPMENT

- Plans for monitoring and revision: who? training? backup?
-

5 Project activities at the levels of R&D management and technology design and development

“... while some very useful thinking about natural system management is around, it is still very much an art rather than a science and certainly not expressed as firm technological recipes”

Cocks 1992, p.186.

5.1 The process: managing complexity and uncertainty

Complexity and uncertainty were an integral part of the planning, development, and implementation of the CTC1 project. The R&D was undertaken within the context of a changing policy and institutional context, as previously described in Chapter 2. This involved diverse cultures, multiple stakeholders with multiple objectives, fragmentation of responsibilities, and changing roles of agencies throughout the project's life. Against this dynamic background, the CTC1 dealt with the development of knowledge bases relating to:

- the R&D management processes; and
- the technology design and development process.

Another important characteristic of the decision-making environments associated with DSS applications in sustainable resource management is the uncertainty underlying each of these domains. Uncertainty in integrated resource management relates to both the uncertainty concerning the management problem and its context, and to the uncertainty concerning what to do about the problem with respect to both ends and means (Lang 1990).

Although these two domains are not mutually exclusive, and they have a number of interdependencies, it is convenient to consider them separately.

5.1.1 The R&D management domain

The R&D management processes were dynamic and multidimensional and required on-going management. These processes related primarily to:

- the active participation and/or involvement of stakeholders with very different 'cultural' backgrounds and information needs (see Section 2.2);
- the management of multiple, and sometimes conflicting, agendas of various funding sources and collaborating organisations (for example, see Sections 2.2.4 and 2.2.5);

- the effective management of the different and evolving stakeholder objectives and expectations over the course of a relatively long R&D process (see Section 3.2.3);
- an active on-going process of 'influencing' between stakeholders of the R&D, including experts and collaborators as well as system developers, so that at any one time the interaction process was not a neutral process for either party;
- an on-going process of 'learning' for participants, including end-users and domain 'experts', which developed through either training in system use, system evaluation processes, the knowledge acquisition or capture process, or field work exercises;
- changing staffing and resource base for the CSIRO DSS development team;
- addressing scepticism of both researchers and R&D funders of the value, or return on investment, of science-based R&D on information technology innovations.

5.1.2 The technology design and development domain

This domain involved two distinctive areas of activity: modelling grazing management systems, and the system innovation development process.

Modelling grazing management systems

The biological and physical aspects of grazing management systems are structurally complex and functionally dynamic, and at the commencement of this project there were significant gaps in the knowledge-base. In particular, there was a lack of understanding or a broad consensus of opinion on the meaning of the basic concept of sustainability in grazing management systems. Moreover there were both large degrees of uncertainty and many sources of uncertainty associated with the ecological system, animal behaviour, and human management decision-making. This compounded the uncertainty inherent in land resource management systems. Uncertainty needs to be managed and effectively communicated so it becomes a recognised input to the decision-making process (Funtowicz and Ravetz 1990; Costanza *et al.* 1992).

The modelling of grazing management systems domain involved:

- the development and integration of conceptual and analytical frameworks from a range of different disciplines;
- the development of rule-based models through an iterative and evolutionary knowledge acquisition process with a diverse range of experts; and
- the management and integration of diverse types and sources of data with varying degrees of accuracy and precision.

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Table 5.1 Relationships between process phases and project domains

Period	R&D management processes systems	Grazing management	System innovation development process
1. June 1989– June 1990	Negotiating of funding for a new project to assess grazing land degradation through a Multi-Divisional Program within CSIRO. Broad objective setting for project. Stakeholder identification and scoping of interest. Establishment of collaborative links with CCNT and initial needs assessment. Identification of regional NT case study.	Scoping of land degradation issue in extensive grazing management systems. Data availability and information needs assessment.	Initial scoping of DS components (GIS, expert system, relational database management system). Identification of an iterative developmental approach. Perceived need for a rapid rural appraisal approach to eliciting grazier knowledge.
2. July 1990– February 1991	New programmer appointed. Setting of project aims and objectives. On-going negotiations with potential NT stakeholder groups for support of R&D. Initial interviews with producers and other pasture experts. Resource survey and GIS data supplied by NT collaborators.	Initial structuring of problem/issue Scoping of methodological approach.	Initial identification of logical design of system. Adoption of prototyping and knowledge-based system development approach.
3. February 1991– February 1992	Restructuring of CSIRO research team, including staffing changes, leading to refinement of project objectives. Initial active stakeholder involvement through participative workshops and a field trip to scope the project and identify user needs. Reconfirmation of CCNT participation. Establishment of collaborative links with DL&H, property managers of Scott Creek property, and the local Landcare (VRCA) co-ordinator.	Conceptual framework for assessing pasture state developed (ie. state-and-transition model concept). Structuring of resource data and initial GIS development. Recognition of the need for risk assessment to include environmental and economic dimensions in terms of the probability of transition to another vegetation state, a time frame, and evaluation of costs/benefits.	Scoping of delivery needs and platform—PC-based system adopted. Adoption of a modular conceptual framework for DSS and a phased approach to DSS development. First prototype of DSS: computer implementation of state-and-transition model (without a spatial component) and adoption of object orientation as the integrating paradigm. Establishment of initial resource database based on land units and linking to GIS coverages using PC-ARC/INFO®
4. March 1992– December 1992	Resource economist and new part time programmer appointed to system development team. LWRRDC/GRDC/RIRDC funding commences. Concern publicly expressed by DPI&F and producers over DSS development and how it might be misused by regulatory agencies. Workshops with CCNT and DL&H to refine S&T models. CSIRO and CCNT soil scientists collaborate to develop soils database Involvement of a consultant pasture management expert to review S&T model development.	Evolutionary model development of state-and-transition models from a single 11-state model to 5 separate models for different land types. Identification of transition rules for risk of change in vegetation state. Development of soil attribute classifications and erodibility assessment methodologies.	ArcView 1® implemented as GIS module for DSS. Second prototype of DSS: simple visualisation for resource data and change in vegetation state assuming uniform grazing pressure within a paddock

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Table 5.1 Relationships between process phases and project domains (cont'd)

Period	R&D management processes systems	Grazing management	System innovation development process
5. January 1993– October 1993	Commencement of active involvement of participants from DPI&F Katherine in the knowledge acquisition process for S&T models. Commencement of active involvement of Manager of LWRRDC/GRDC/RIRDC Program. Agreement for consultative involvement of staff from DPI&F Darwin. First training workshops in system use including hands on use of system for CCNT staff.	Development of climatic risk capability based on “green days” concept. Refinement of S&T models. Identification of available economic information and scoping of needs of economic model.	Third DSS prototype: capability for selection of an individual paddock within property and identification of vegetation states through implementation of ArcView 1®. DSS prototype system installed on CCNT computers for evaluation purposes for the first time.
6. November 1993– March 1994	Workshops with CSIRO pasture scientists on pasture and animal production knowledge base. Evaluation of fourth prototype DSS with NT stakeholders including Scott Creek property managers.	Development of pasture and animal production risk methodologies, including links with climatic risk and economic risk methodologies.	Fourth DSS prototype: implementation of risk evaluation in terms of animal and pasture production, and gross margins. Climate module linked to the GIS to assess spatial variability in green days within a paddock.
7. April 1994– December 1994	Additional programmer joins CSIRO DSS development team. Workshops with CCNT to scope soil state module. Demonstration of fourth prototype DSS to Board members at a meeting of the NT Pastoral Land Board. Major evaluation workshops of the prototype DSS with representatives of key stakeholder groups in NT Government. Training workshops in system use involving CCNT staff. Demonstration of DSS to property managers at a local Landcare (VRCA) meeting.	Identification and development of soil state assessment and erosion risk methodologies.	Fifth DSS prototype: ArcView 2® incorporated and soil erosion risk module implemented to assess change in spatial variability of soil erosion risk with alternate management options.
8. January 1995– October 1995	Training workshops in system use involving CCNT, DL&H and DPI&F staff. Fifth DSS prototype installed on DPI&F computer. Scenario approach to stakeholder evaluation of R&D effectiveness. Demonstration of fifth DSS prototype to industry members of the CSIRO DTCP Advisory Committee. Preparation of final project report.		Sixth DSS prototype: user interface refinements, including implementation of a help system. Preparation of User Manual and Maintenance Guide.

The models are described further in Section 6.1 of this report.

The system innovation development process

The system innovation development involved an iterative, evolving and phased process that required the consideration of three domains:

- specific design constraints relating to: evolving customer/end-user resources and needs; researcher developmental and delivery capabilities; and the available data sets;
- the application and integration of advanced information technologies with a strong customer-focus;
- significant technical problems of synthesising data and information of very different quality and type—in particular, non-uniformity of scales and precision of data, data exchange, and numerous ‘disconnected’ and sometimes incompatible data sources and sets.

This process is described further in Chapter 6 of this report.

5.2 Project implementation: an historical overview

This section provides an integrated historical overview of the changes that occurred within each of the above three domains over the life of the project. The project encompassed eight distinct phases, from the initial project scoping in June 1989 through to the completion of the prototype DSS and project documentation in October 1995. These eight phases relate to either the achievement of specific project milestones, or specific events which significantly influenced the R&D process. They also correspond to significant DSS prototype developments. The major activities associated with each of these project phases are outlined in Table 5.1. The activities associated with each phase were not necessarily continuous, but rather were episodic over any one period; many were recurrent or iterative across a number of project phases.

6 The Landassess DSS system innovation development process

“Even well engineered designs can fail when there is poor training, when the context changes, or when the unexpected occurs; this is all part of systemic risk. The emphasis should not be on which system can be built with the available technology, but whether they are appropriate and relevant.”

Angell and Smithson, 1990, p. 36.

6.1 Assessing sustainability in grazing management systems

Natural resource systems are typically highly complex and dynamic over both space and time. Pickup and Stafford-Smith (1993) point out the complexities of the rangeland ecosystem and the difficulties in arriving at assessments of the effect of management strategies, and in managing risk, in the pastoral industry. These complexities are a function of the large scale at which management takes place and the variability that arises both in time due to the effects of climate, and in space due to the effects of both climate and the structure and function of the landscape.

The effects of management may be hidden in the short to medium term by the variability of climate and landform. Consequently, these pastoral systems are very difficult to manage for sustainable development. Limitations on their use may not necessarily be the appropriate solution and may even obscure other management issues that need to be addressed (Bartels *et al.* 1993; de Leeuw and Tothill 1993; RAC 1993).

One of the difficulties in assessing sustainability in the extensive grazing management systems of Northern Australia is that the relationship between resource use levels, management, and impact of use is neither simple nor uniform.

A key factor is that natural systems, foraging animals and human management all operate at different temporal and spatial scales (Bellamy *et al.* 1993). Human management of the extensive native pasture livestock production systems of northern Australia essentially function at a paddock or property scale, although some management practices (eg. burning, weed control, soil conservation) may be implemented at a more local scale. In these extensive grazing operations, a paddock is usually thousands of hectares in size and very variable, ie. there are often many landform/soil/vegetation types in any one paddock.

Moreover, animal grazing patterns are non-uniform both spatially and temporally. The arrangement of land resources (Senft 1989) and management practices, such as fencing, water availability, stock type, strategic burning, and supplementation, affect the utilisation patterns of animals

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across the landscape. In addition, certain parts of the paddock are more resilient to grazing than others. So cattle graze paddocks unevenly, and the response by the land resource to grazing is not uniform. Degradation may occur in some parts of the paddock and under-utilisation in others. Evaluating long-term sustainability of grazing management systems therefore requires:

- A knowledge of the key processes that govern the interaction between the cattle, the plants, and the heterogeneous landscape.
- Identification of early warning indicators of potential problems for these natural resource systems at spatial and temporal scales relevant to human management.

The integrated approach captured within decision support systems (DSS) is particularly appropriate as a platform for addressing sustainable resource management problems (Stuth and Stafford-Smith 1993; Bellamy *et al.* 1993a, 1993b; Lowes and Bellamy 1994). DSSs are designed to provide decision-makers with a problem-solving environment within which they can explore, structure and resolve complex problems by bringing all of the existing knowledge to bear on the problem (Guariso and Werthner 1989; Densham 1991). Their main goal was to improve decision-making and allow users to formulate and assess alternative outcomes more objectively and comprehensively than could have been done previously (Stuth and Stafford-Smith 1993).

As identified early in the CTC1 project (see Section 1.2), a key challenge for the CSIRO researchers was how to evaluate sustainable use and management of the extensive grazing management systems. A useful approach is that described by Barbier (1987), who envisaged sustainable development as a process of trade-offs between conflicting goals, such as economic growth and environmental conservation. Because the process of assessing trade-offs is inevitably subjective and based on prevailing value systems and ethical norms, a good DSS will provide sufficient flexibility for the assessment of trade-offs to be able to vary spatially and temporally.

An early consideration in such an assessment process is the need for protection of the natural resource base on which future economic viability depends. The CTC1 project adopted an integrative interdisciplinary approach to that. In particular, it focused on providing an assessment of the trade-offs between environmental and economic goals of beef production systems in the native pastures systems of northern Australia. This required the integration of data and appropriate theoretical and analytical frameworks from a number of disciplines to: (a) define the problem context, and (b) facilitate an assessment of the spatial and temporal variability of environmental and economic risks associated with the grazing land resource at a scale relevant to grazing management. These frameworks included:

- the adoption of the land resource assessment concept of a land unit (Stewart 1968; Aldrick and Robinson 1972)

within a GIS framework to characterise the heterogeneity of the natural resource base of a grazing management unit (ie. a paddock or property), and to model change in vegetation and soil state over time. Land units are components of the landscape with similar recurrent patterns of landforms, soils, and sometimes vegetation. Land unit maps provide a proxy for complex reality, that is a framework of generalisation about the landscape that enables common characterisation of its form and function. A landscape classification system based on land units can be used, for example, to make assessments about landscape performance or response of vegetation to utilisation by foraging animals (Bellamy and McAlpine 1995; Lowes and Bellamy 1994).

- the adaptation of the ecological concept of a system state within a state-and-transition model framework (Westoby *et al.* 1989) to model: (a) the condition or 'health' of the grazing land resource, including its dependent variables of pasture and animal production, (b) the potential for change due to management and/or climatic circumstance, and (c) early warning signs of land degradation or adverse grazing management impacts on the land resource base. This model is discussed further in Section 6.4.3.
- the adaptation of the natural resource science concept of a green day or green season (McCown and Williams 1990; McDonald 1994) to model variability in potential moisture availability for plant growth as a surrogate for climatic risk.
- an assessment of soil erosion risk based on (a) an adaptation of the Universal Soil Loss Equation (Wischmeier and Smith 1978) to assess the overall severity of the inherent risk to erosion of each land unit type, and (b) an assessment of the type of soil erosion processes to which a particular land unit type was susceptible.

These concepts were represented and integrated within the spatial decision support system, Landassess DSS. The purpose of Landassess is to help understand better the environmental and economic risks of extensive grazing management systems of northern Australia.

6.2 A decision support system for sustainable grazing management

Aids to facilitating decisions about management of complex natural resource systems need to take into account significant variations in the type, scale and depth of information and knowledge available.

Many technologies have been used in developing decision support systems (DSS) including: artificial intelligence methods such as expert systems (eg. Davis *et al.* 1990, Robinson and Frank 1987, Tuban and Watkins 1986) and knowledge-based simulation (eg. Folse *et al.* 1990, Mackay

et al., 1993, Hazelton *et al.* 1992); geographic information system methodology (eg. Burrough 1986); database systems methodology (eg. Bellamy and McAlpine 1995); and process model methods (eg. McKeon *et al.* 1982). Natural resource management applications, however, require the integration of a number of these systems to accommodate the heterogeneous data and knowledge as well as to take advantage of the spatial and temporal analysis capabilities of alternative technologies (eg. Coulson *et al.* 1987). This design requirement means that DSS components must be integrated, so that scenarios can be validly compared (Bellamy *et al.* 1993a; Lowes and Bellamy 1994).

The overall methodological approach to DSS development was iterative and evolutionary and it was based on a knowledge-based and prototyping developmental approach, as previously described in Section 3.4 of this report. This Section examines the logical design of the current prototype Landassess DSS, and the function of different system modules and their interaction. It also examines the rationale for this design, and provides an overview of the DSS system innovation development process. Finally the implications of the DSS system innovation development process are considered.

6.2.1 Logical design of Landassess DSS

The Landassess DSS was developed in modules in order to ensure that additional functions could be incorporated

easily by either adding extra new modules, or modifying the existing ones, or both. Early in the development process, it was envisaged that such changes would be largely due to new information requirements and to rapid changes in PC technology and software applications.

Landassess DSS required a framework for integrating the different system components. The framework for the DSS evolved from an initial logical structure developed in 1990. The major components of the system and the use of a DSS shell were present in the early designs. Most of the changes during the system's evolution related to the type of models required (eg. state-and-transition models), and to how the models and other modules interacted. The overall framework was also designed to minimise user confusion by providing a common user interface with simple protocols for interpreting the data across modules. The logical structure of the current DSS is shown in Figure 6.1.

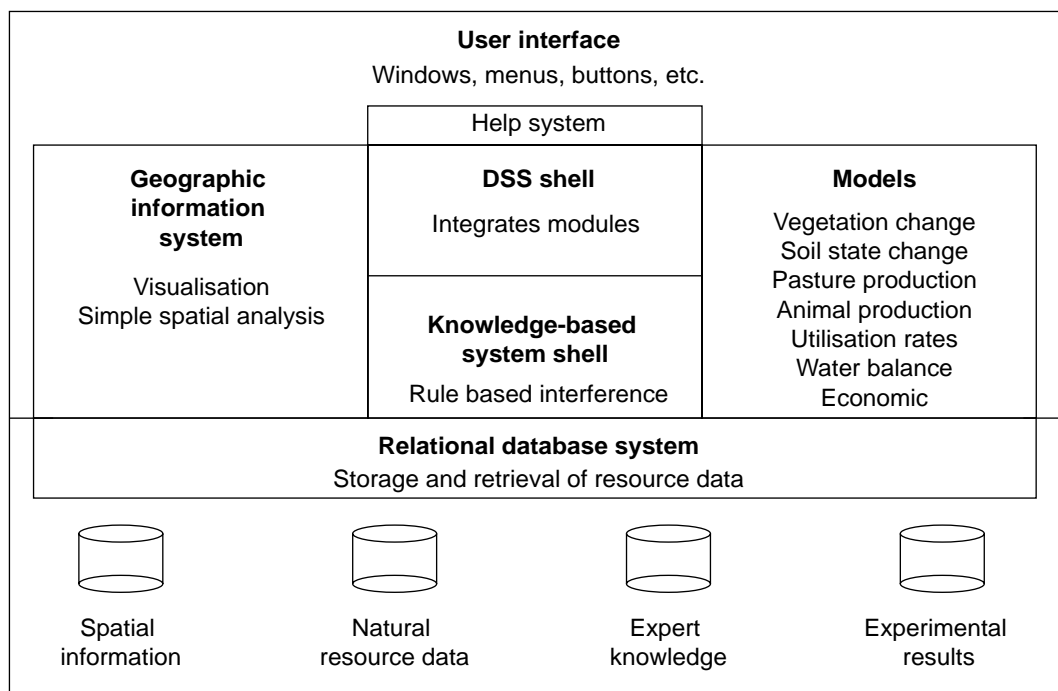
The functions of Landassess DSS in its final prototype form in 1995 are described below.

Relational database system

The relational database system has a number of functions which include:

- facilitating storage and retrieval of land resource data from land unit tables and classifications in look-up tables,

Figure 6.1 Logical structure of Landassess DSS modules



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- facilitating storage and retrieval of climate data,
- representing the knowledge-base in the form of database tables, and
- providing for storage of model parameters.

Access to these components is designed at two levels:

- at the user interface level, the user can access the resource databases and look-up tables; and
- at a system integration level, the database system is used to share information between modules.

Geographic information system

The geographic information system module links spatial units with the land resource classifications and climate databases. This module allows a user to view not only outputs such as variations in vegetation state or erosion risk across a paddock, but also land resource information in a spatial context.

This module is designed to encourage the user to examine the resource data and DSS outputs at different spatial scales (eg. paddock or property). The spatial analysis function has been programmed through the software application packages, PC ArcView® (ESRI) and Avenue® (ESRI).

Models

The models base within Landassess incorporates the following six types of model:

- Rule-based models, such as state-transition models of vegetation change, soil erosion risk, animal preference.
- Simple process models, such as, a water balance model.
- Simple numerical models, such as animal intake and utilisation rate.
- Spatial models, such as distance to water and utilisation patterns.
- Regression models, such as animal and pasture production.
- Spreadsheet models, such as economic production.

Knowledge-based system

The knowledge-based system comprises class definitions and rules, and allows inference on transitions between vegetation states. This system has the following functions:

- Permitting the user to browse the rules and relationships.
- Defining a number of models which could be used to evaluate the likely outcomes of scenarios, that is state-and-transition, soil erosion risk, and grazing preference models.
- Facilitating linkages between components of the system.

- Providing linkages between concepts and terms within the decision support system.
- Providing explanations of DSS results to the user.

Much of the knowledge-base is implemented as databases. This facilitates the update of knowledge-bases, and future re-implementation of the system in different geographical locations.

User interface

The user interface was designed to facilitate access to each of the modules in Landassess DSS by means of meaningful, simple and consistent set of screens, menus and control buttons. The design of the user interface followed standards defined in Microsoft Windows® applications within the limitations of the individual packages used for Landassess DSS development.

Help System

The Help System is closely linked to the user interface. It relates to each of the modules within Landassess DSS and is accessible from each screen. The Help System is hypertext-based and indexed using the Microsoft Windows® standard help system for the most part. There are other parts of Landassess DSS falling under the Help System which involve hyper-regions and pop-up information boxes. The Help System incorporates these functions:

- an index of commands and screens with explanations'
- a glossary of terms,
- a bibliography on grazing management systems, and
- the linking of explanations to the important terms on screens via hyper-links.

6.2.2 The DSS shell: interactions between modules in Landassess

Between the various modules of Landassess DSS there are many linkages. These are organised through the DSS Shell (see Figure 6.1 above). The following sections describe some of the significant linkages between these modules.

Geographic information system: relational database system interactions

The interface between the geographic information system and relational database modules of Landassess DSS allows the user to browse land resource databases and to view the land resource attributes at a paddock or property scale.

Knowledge-based system: relational database system-models interactions

The knowledge-based database interface is used in the management of the state-and-transition knowledge-base and

the selection of appropriate model parameters from model parameter databases. The relational database is used to hold parameters and model results in Landassess DSS. For example, the parameters for each of the pasture and animal production models are held in a relational database. The outputs from the water balance models are also held in database tables for use by the other modules in Landassess DSS.

Some of the knowledge-base rules define when appropriate regression models and other model results are required. They thus provide an interface between the knowledge rules and the model database in the DSS. For example, the DSS is programmed so that the rule base selects which pasture production model is most appropriate for different vegetation states and different land types.

6.3 The rationale for the system design

6.3.1 Facilitating and constraining technical factors

The schema outlined above represents the structure of the finished prototype. However a number of principles acted as both facilitating and constraining forces in its development. The major forces are listed below as the beginning of a checklist for other developers of DSS.

The DSS was developed within many principled and practical constraints, quite apart from the socio-political factors discussed in Chapter 2. A list of most of these constraints follows.

- *The availability of archival data:* there had been a major natural resource survey of the Douglas-Daly region near Katherine in the early 1970's and the associated map base was available in digital form. More data and knowledge were available for the Scott Creek area from past and present CSIRO research activities than from other properties in the Douglas-Daly Basin. Most importantly, the Scott Creek property was an extensive commercial property with easy access and cooperative management, and was therefore selected as the prototype study site.
- *Compatibility with user needs:* there was a need for compatibility with the systems and data formats used by the principal collaborators of the CTC1 project, CCNT. The CCNT was perceived as the main agency responsible for the longer-term use of Landassess DSS.
- *A PC platform:* The DSS was developed initially for a PC Platform to meet both the requirements of the main stakeholders and the limits of the resources of the DSS developers. In this case it was an Intel-based PC application.
- *Updatable and transferable:* The DSS needed to be readily updatable and transferable to other regions. Therefore it was developed in an open architecture, so

that new application software or new modules could be added simply. The option for porting the system to a Workstation platform was also necessary.

- *Ease of access and use of the DSS:* The DSS required a hierarchical structure with an interface which facilitated easy access and use of the system for a computer-literate individual who had at least a basic knowledge of grazing properties. The system was implemented in a Windows environment to provide a good graphical user interface capability, including menus, windows, and multi-tasking.
- *Software standards:* Wherever possible the design of the system needed to conform to industry software standards.
- *Visualisation:* Given the need to present spatial variation of natural resource distribution, the system presentations required appropriate use of graphics for visualisation purposes. This included mapping displays for natural resources and model results, graphs where required, and use of interactive graphical user interfaces.
- *Resourcing constraints:* The limited resources of the CSIRO developers particularly relating to staffing, financial and technical/computing resources were also important factors.

The DSS system needed to facilitate the integration of geographic information system data, resource databases, climatic data, expert (heuristic) knowledge, and simple scientific and economic models in a user-friendly package (Fig. 3.1). A framework for the DSS was considered which incorporated a geographic information system to give access to natural resource attributes spatially, relational database system containing natural resource data; knowledge-based system with a knowledge-base of expert knowledge; scientific models where required; and an easy-to-use user interface (see Fig. 6.1).

6.3.2 Phases of the system innovation development process

In mid 1991, the CSIRO system developers made the decision to implement the system development for Landassess DSS in three stages, as follows.

- Identification and development of a framework to assess pasture state at an individual *land unit level* (ie. effectively a uniform unit of the landscape), assuming spatial uniformity of grazing pressure across the landscape.
- Assessment of the risk of change in pasture state and the evaluation of the spatial variability in grazing pressure at a *management unit level* (ie. a paddock).
- Incorporation of pasture and animal production and economic models to evaluate *environmental and economic risks*, ie. to assess the implications of vegetation change to the sustainability of the land resource base and the profitability of production.

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In practice, these stages were in part overlapping and each phase embodied several iterations and system prototypes. There were six significant prototypes of Landassess DSS in that the prototypes included additional modules or represented a significant improvement in utility. These prototypes are set out in Section 5.2.

6.3.3 Selection of tools for development of Landassess DSS

Given the above principles and constraints, and bearing in mind that final delivery options were to be left as flexible as possible, the development tools for the DSS were selected in approximately the following order:

- i. geographic information system and database development tools;
- ii. operating system and development environment;
- iii. expert system/knowledge-based system development tools;
- iv. spatial data visualisation package (related to the choice of geographic information system); and
- v. additional software packages for specific tasks such as C++ and Microsoft® Excel® used for the water balance and economic models respectively.

Geographic information system and spatial data visualisation

ESRI's PC ARC/INFO® was selected as the tool for initial processing of spatial data in 1990 because, firstly, it was compatible with CCNT's ARC/INFO® system and, secondly, the development team already had some PC ARC/INFO® software. PC ARC/INFO® also provided the ability to integrate spatial data layers. However PC ARC/INFO had limited spatial analysis capabilities given the state of PC technology in 1990.

At this early stage of the project there was no obvious candidate for provision of the spatial data visualisation functionality. PC ARC/INFO®, while being the tool used for manipulation of spatial data sets, was far too unfriendly and cumbersome to be a good choice as a delivery tool. Other PC-based packages available at that time, such as MapInfo, had no integrative capacity, poor interfaces to external applications, and limited portability between PC and Unix platforms. The DSS development team also lacked the staffing and financial resources to implement its own mapping front-end. Fortunately the geographic information system providers started moving in the direction of providing Application Programming Languages with their geographic information system products. The trend toward development of packages in Microsoft Windows subsequently improved the utility of the packages and their integration with other application software packages.

At the end of 1991, a workstation version of a relatively user-friendly GIS package was released, namely ArcView® (ESRI). Even though the PC version was not yet available in Australia,

the DSS developers made the leap of faith that it would eventually be so, and they decided on the ArcView®. The other potential package at the time was MapInfo®, which by then had been ported to Windows®. However the issue of compatibility with CCNT spatial data formats, and some import/export problems with MapInfo®, made ArcView® the preferred option despite MapInfo® for Windows® being, at that time, the better developed and more user-friendly.

On its release at the end of 1992, ArcView® Version 1 for Windows® had limited functions (ESRI 1992). It only provided the ability to display the spatial datasets and (in a rather convoluted way) to display results from the models. It was not until 1994 that ArcView® Version 2 for Windows® (ESRI 1994) became available and provided a much improved user interface and a programming language, Avenue® (ESRI 1994). This new interface allowed for multiple views of spatial data, and the Avenue® language allowed for customisation of the interface as well as improved interfacing with other modules in Landassess DSS.

Relational database system

While recognising limitations, it was initially decided that Xbase compatible application development languages would be most appropriate. The PC-based software application package, Foxpro®, was one of the most highly developed Xbase products in 1990. At that time, it was also being used successfully in another project being undertaken by the CSIRO development team. Foxpro® allowed for the integration of SQL servers that would facilitate the porting of a system development to other platforms or its distribution across a network, if required. On this basis and given the ready availability of the software to the DSS development team, it was selected as a data management tool, even if much of the control of Landassess DSS was to be performed by the expert system shell.

Many expert system shells had Xbase compatibility as did most of the PC Based geographic information system packages (eg. MapInfo® and PC ARC/INFO®). The selection of packages through the project was made in favour of those which provided good interfaces (for users and other applications) which would ensure a degree of open architecture for future development.

Operating system/ development environment

The requirements for a graphical user interface for Landassess DSS included:

- ease of use by end-users;
- a capability for clear presentation of information and visualisation of spatial data; and
- the potential for many applications to run simultaneously.

The Macintosh and some Unix and Lisp workstations had shown the way that graphical user interface technology was

going during the mid-1980s with the emphasis on icon-driven and Windows® and menu-based user interfaces. Even though Microsoft Windows® was in its infancy in 1990, it was obvious that this was the future direction of technology, and the likelihood of the dominance of Windows® by the end of the project made Microsoft Windows® the most preferred choice of PC platform.

Expert system/knowledge-based system shell

There was a requirement for an expert system shell that would incorporate expert knowledge in the form of rules in the DSS. The shell needed to provide for an integration of the modules in the decision-support system. The knowledge-based system would be a core of the project's system development approach—that is a knowledge-based prototyping approach. Thus a user-friendly package running under Windows was required which had both rule-based and class-based representation and allowed for rapid modifications to users interfaces. Level 5 Object® (IBI 1990) was one of the few packages which fitted many of the developers' requirements, including cost and a PC platform.

Other application software

During the project there was a need to develop other pieces of software and models such as water balance models and the economic model. The programming language C++ was used to program those models which could not reasonably be implemented in Level 5 Object® (IBI 1990).

The DSS developers re-programmed a water balance model, GRIM (McDonald 1994), in C++. Microsoft Excel® was selected for the implementation of the economic model, since the project economist had existing models in a spreadsheet format. Also CCNT were already using Microsoft Excel® and it provided good linkages with other packages running in Windows.

Summary

In summary, the choice of development tools was made in order to fulfil the following criteria.

- Maintain compatibility with end-users' datasets and systems.
- Run on a PC in a Microsoft Windows environment, and be portable to a workstation.
- Ensure good linkages with other Windows applications through standard protocols and query languages to facilitate integration of modules and future developments.
- Comply with major software and data conventions.
- Fit within the development team's staff resources and budget.

6.3.4 Design and development method

The Landassess DSS design and development approach required an integrating paradigm. Object-orientation had proved a particularly valuable paradigm for design and development of software during the late 1980s (Bobrow and Stefik 1986). Central to the object orientation paradigm is the view that real world objects and system objects (ie. natural system or computer system) can be modelled by corresponding software or knowledge objects. The attributes and behaviour of the objects are thus encapsulated in the knowledge-base and software representations. There are three main parts to the paradigm:

- i. encapsulation of structure and behaviour within classes, instances and methods;
- ii. inheritance of structure and behaviour by subclasses; and
- iii. linkages between objects through methods.

It was decided that an object-oriented framework would be used during the design and development of Landassess DSS. Many of the software applications used—including Level 5 Object® (IBI 1990) and Avenue® (ESRI 1994)—incorporated object orientation themselves, and the trend in user interface development under Windows was to use object-orientation to facilitate the design of user interfaces.

Object-orientation provided a particularly powerful paradigm during many phases of the development of a decision support system. Key points from the detailed discussion of object-orientation in Landassess DSS by Lowes and Bellamy (1994) follow.

- System specification and design: when an information or decision support system is being specified and designed, the use of an object-oriented approach can make the definition of system modules and their interactions easier and clearer.
- System implementation: during development of the DSS, object-orientation allows for rapid prototyping, modifications and sharing of code modules.
- Modelling: object-orientation is particularly powerful in developing models of real world systems since the real world objects can be mapped closely onto software objects which incorporate aspects of structure and function.
- User interface development: most of the user interface development tools are based on object-oriented philosophy because of the ease with which user interface elements can be created and modified by developers.

6.4 Historical development of Landassess modules

6.4.1 Relational database and geographic information system

CCNT supplied the initial coverages for the Douglas-Daly Basin in December 1990. CCNT also supplied its 1990 draft land unit report, and this became part of the early input to the resource databases. The property infrastructure coverages were then obtained or generated from maps and Landsat images in order to subset the land unit coverage into management units and unique mapping areas. The coverages were subsetted for the Scott Creek and Manbulloo properties in 1991. The classified land unit tables were then joined with the land unit coverages. The processing of coverages was severely hampered by the restricted hardware and software resources of the development team at that time. That is, PC ARC/INFO® on a 386 PC proved inadequate for the intensive task of intersecting and subsetting coverages, so they had to be done on workstations at Applied Micro Systems and at CSIRO Division of Geomechanics. The development team obtained a Workstation and ARC/INFO® in 1994. This kind of facility at the early stage of the project would have cut more than two months from the processing of coverages.

The first version of the resource data tables was developed during 1991, and the land unit browsers were the first module of Landassess DSS developed. The resource databases were developed by resource scientists from the DTCP team with CCNT soil scientists. These databases for soil, landform and vegetation were input into a relational database structure and linked with the land unit coverages during 1991 and 1992. The process of analysing databases and verifying them for use in Landassess DSS took a significant part of 1991 and 1992.

Until the release of ArcView® 1 in 1992, there was no spatial display component for Landassess DSS, except for the PC ARC/INFO® machine which was used for analysis and preparation of maps. Following the release of ArcView 1, it was possible by February 1993 to incorporate some simple spatial display functions into Landassess DSS, included mapping of:

- resource attributes at a paddock or property scale,
- vegetation state,
- changes to vegetation state, and
- green days by soil across a paddock or property.

In 1994, the DTCP team was able to purchase a Sparc clone workstation with ARC/INFO® software which greatly enhanced the ability of the team to process coverages. Some of the spatial functions incorporated into Landassess during 1993–1994 included analysis of:

- pasture utilisation patterns, and
- spatial variability of soil erosion risk, and changes to it.

6.4.2 Knowledge-base

The knowledge-base framework was developed through a number of early meetings and workshops with scientists, pastoralists and CCNT and DPIF. Most of these were held between October 1991 and late 1993, although a few interviews with local experts in the Katherine region had been held during 1990. By June 1991, a state-and-transition model framework was selected by the CSIRO DSS developers for the encapsulation of rules relating to vegetation change, and for the interaction between management and other causes of vegetation change. The acquisition of the knowledge-base for these models was developed through an iterative process of workshops with experts and stakeholders (see Section 3.4). The structure of the knowledge-base evolved through two development stages:

- development of a single state-transition model, and
- partitioning the knowledge-base into five distinct state-transition models to suit the main land types in the prototype region (as defined by soil, landform and vegetation).

During each of these knowledge-base development stages there were three main tasks, as follows:

- i. Definition of the states for each of the models
- ii. Definition of transitions between each of the states in terms of causes, probabilities, timeframes and confidences.
- iii. Refinement of terms and definitions.

Each stage involved a number of iterations with regular review of the knowledge-base with different experts and stakeholders. In the first stage, the knowledge-base was structured within a single state-transition model framework. However, this proved too complex, both for modelling and for interaction with experts and stakeholders. The knowledge-base was therefore partitioned into separate knowledge-bases for each of the five pasture systems occurring in the Douglas Daly region. This improved the effectiveness of the knowledge acquisition process as well as the overall modelling and system development process, and had significant potential end-user benefits.

The choice of Level 5 Object® in late 1991 as the expert system shell had an important impact upon the representation of the knowledge-base within Landassess DSS. The inference mechanism in Level 5 Object® was too limited to handle the complexity of the spatial and temporal dimensions of the emerging state-transition model. For this reason, the Level 5 Object® inference engine was used for the high-level control of the DSS, with additional inference mechanisms being written in procedural code in Level 5 Object®. It was at this time it was decided that for ease of update of rule bases, the rules would be stored in databases and interpreted by the expert system shell. This proved to be a powerful way of storing the knowledge rules, and it allowed for rapid updates and modifications.

6.4.3 Models

The models within Landassess DSS fall into six main categories as outlined in Section 6.2.1. During development of Landassess DSS the models were incorporated approximately in the following order:

- i. The state-and-transition model of vegetation change was developed through a knowledge acquisition process as described in Section 3.4. Much of the advancing of model development achieved in the CTC1 project was associated with the state-and-transition model and these aspects are further discussed in Section 6.5.2.
- ii. A water balance model was run using historical climate data for a range of locations within the Douglas Daly region for a range of maximum available soil water holding capacities occurring in the region. The results from these model runs were saved in statistical tables of green day frequencies (McCown and Williams 1990) and green season patterns for different soil types. The linking of climate to land resource information in this way provided a surrogate for climate risk and allowed for the effective development of pasture and animal production models on different land types. The statistical tables of green day frequencies were used to obtain probabilities of season quality which gave confidence ranges on the production models.
- iii. Pasture and animal production models were defined for each vegetation state and incorporated into the DSS. These models took the form of regression models (J.G. McIvor and A.J. Ash *pers. comm.* 1995) relating to different vegetation states and pasture systems.
- iv. Intake, grazing preference and pasture utilisation patterns were then incorporated within a spatial framework. These models allowed for evaluation of changes across a heterogeneous paddock and for the aggregation of pasture and animal production across a paddock.
- v. The economic model was developed by the resource economist based on production and commodity/cost data through a knowledge acquisition process with key NT stakeholders in DPI&F and industry representatives. The economic model was then linked with the production models.
- vi. A rule-based soil erosion risk model was integrated with the state-and-transition model to give an indication of the changes in erosion risk with change of vegetation state on different land types. This model was developed through a knowledge acquisition process with CCNT and CSIRO experts.

Each step of this process was iterative, and there were regular refinements and adjustments to the models and their interactions.

6.4.4 Assessing trade-offs

The models within Landassess DSS can be used by the end-users for:

- browsing and mapping of spatial natural resource data, and
- assessing the tradeoffs between economic production and environmental sustainability.

The user can set alternative management scenarios on different management units, and compare the outcomes in terms of sustainability of the resource base and animal and economic production. To assess the trade-off options, the user is able to view:

- which areas of a paddock are likely to change vegetation state,
- the effect upon soil erosion risk, and
- the consequent effects upon pasture yield, animal production, pasture utilisation, and gross margins.

6.4.5 Implications for validation of models

The approach to development of Landassess DSS and the complexities of the issues and interactions involved have significant implications for the validation of models. Finlay and Wilson (1991) discuss three methods of model validation: analytical, synoptic and faith.

Analytical: Analytical validation requires checking the coherence and stability of each individual model in the DSS. The issue of analytical validation of the models within Landassess DSS is complicated by the variation in the number of types of models and the sources for those models. It has been possible to test the individual models to an extent, but given the complex interactions between models this does not necessarily imply validity of the total system. For example, the pasture and animal production models (McIvor and Ash, *pers. comm.* 1995) are known to be valid for a limited set of conditions and range of parameters. However, the way in which model results are aggregated within a spatially heterogeneous environment has not been fully validated.

Synoptic: This validation method involves checking that an acceptable output is achieved for each set of inputs which contributes to the overall validation. Synoptic validation is an ongoing iterative process involving developers and users. During the development of Landassess knowledge, the models were regularly tested through workshops and demonstrations with experts and key stakeholders. However, what is acceptable to one group of experts is not necessarily applicable to properties other than those used to develop the models. In fact, Landassess DSS was intended to simulate discussion of management options, not to set down a set of laws.

Faith: This form of model validation is for the manager or decision-maker who assumes that the modeller has done

all the validation and trusts the results. One of the dangers in development of models, and DSS in particular, is that the end-user may not be critical enough of the assumptions behind the model. Even so, user validation is a very important part of the process, and attempts often have to be made to explain the limitations to over-enthusiastic end-users.

6.4.6 User interface development: transparency of logic and useability

The development of the user interface went through several iterations, while maintaining the general structure of the first prototype. In addition, at each of the demonstrations and evaluation workshops, users were asked for their comments on each of the screens. Many small alterations to screen design and terminology were made in this way. The requirement to address the needs and understanding of multiple stakeholders made it necessary to include a degree of redundancy and multiple paths into and around the system. Development of a good Help System, glossary, and hyperlinks for explanation were important in addressing this issue.

The initial framework for the user interface remained fairly stable throughout the system development. The logical structure of Windows and hierarchies of commands remained. However, there were significant changes to:

- the layout of screens;
- the arrangement of menus and buttons;
- the interaction between screens;
- the layout of windows on the computer screen;
- terminology;
- improved explanation.

The availability of an additional programmer to the DSS development team from mid-1994 helped the User Interface development. This process involved the following steps.

- Development of initial prototype user interfaces for modules by DSS developers.
- Demonstration of user interfaces to users and other stakeholders.
- Incorporation of feedback from users where possible.
- Discussions with communication experts from CRIA and incorporation of suggestions.
- Development of a Help System.

The application development packages used for Landassess DSS development all included graphical user interface development tools which allowed rapid modifications to user interfaces. From time to time communication and user interface experts from CRIA met with the DSS developers.

6.4.7 System documentation and user manuals

The final stage of the project involved the development of user manuals and handbooks for the prototype Landassess DSS. These included:

- a description of Landassess DSS, its models, resource databases and developmental approach;
- a user guide on how to use and interpret the system, including tutorials; and
- an installation and maintenance guide to the system.

During development of these manuals the skill level of the likely end-users had to be considered. It was assumed that the users would have some level of skill in using computer systems, in particular ArcView®.

Development of effective manuals required drafting, editing and preparation of appropriate graphics and tutorial exercises; it was very time-consuming.

6.5 Implications of the system innovation development process

6.5.1 A DSS for multiple stakeholders

Because many stakeholders had to be satisfied, the system—and especially the user interface—was more complex.

- To help the updating of the system, and to allow for some modules of the system to be used independently from other modules, the system had to consist of loosely coupled modules. For example, some CCNT stakeholders needed a geographic information system linked to the resource database as a stand-alone module.
- The user interface needed to be designed to allow for multiple pathways into the system. While there was a general hierarchical structure, cross links were provided giving multiple access and cross-referencing capabilities.
- A certain amount of redundancy was incorporated into the user interface to give some choice over which part of the system to access at any one time.
- We programmed in hyper-regions, or mouse-sensitive areas in graphics or text, which allow for users to follow links relating to the region selected, for several purposes in Landassess DSS.
- Interactive browsing was required between the pasture knowledge-base and the states and transitions.
- A detailed explanation of terms was achieved by linking the key concepts on each of the screens to a Help-base containing the explanations.

6.5.2 Implications of the system development approach

Implications of the Prototyping Approach

Prototyping (as previously described in Section 3.4) is a system development approach in which numerous system prototypes are developed through the life of the project. The prototyping approach adopted in the CTC1 project proved to be very appropriate and successful for many of the reasons outlined in Section 3.4. In particular, the user requirements were initially not clearly defined, and only became clear to users and researchers as the project and Landassess DSS evolved. The development of prototypes also had the benefit of allowing the researchers to demonstrate modules before they became fully operational. This gave users a feel for the way the system development was moving, and a prototype system with which to interact. This led to enthusiasm from end-users, support for continuing system development and stakeholder participation in the R&D process.

The area of user interface development benefited particularly from prototyping. Following feedback from each of the workshops, the interface was enhanced.

Some of the potential problems with prototyping were as follows.

- Prototypes, while making users enthusiastic, can lead to overly high expectations which must be managed carefully. This is a particular issue in Landassess DSS development. However, the ongoing process of interactions between developers and users allowed for these expectations to be discussed, and in some cases to be made more realistic.
- The prototyping approach has significant overheads in overall development time, and therefore it should not be used if there is a clear design and development path for any particular module or system.
- One of the common problems with prototyping is determining when the final prototype has been reached, and therefore when an operational system should be implemented. The iterative approach gives an expectation of constant enhancements to the software even if the marginal benefits of those changes outweigh the marginal costs. In a research project, this may not be such a critical issue since in a sense all the software developments are prototypes. However, where a final operational system is required a clear end to the prototyping phase must be determined in enough time to provide for the full implementation of the final system.

Implications of the iterative approach

The iterative approach to system and knowledge-base development proved invaluable in producing a system well suited to user requirements, as well as giving a fair degree of ownership of the DSS during development. Iterations were critical to the effective development of all modules, in

particular the knowledge-base and user interface, and in defining interactions between the models and processes.

The iterative approach was found to be particularly effective for experts, stakeholders and system developers to:

- continually reassess and confirm the objectives of the DSS technology development;
- gain a better understanding of breadth and depth of the existing knowledge-base in an integrated format; and
- evaluate future knowledge-base requirements.

Also, the iterative approach (see Section 3.4.1) helped new stakeholders to check the relevance of the system.

Implications of the knowledge-based approach

Two evaluation issues (see Section 2.4) are: (i) whether the knowledge-based approach was appropriate for some of the Landassess DSS models; and (ii) whether the process by which the knowledge-bases were developed was effective.

- i. In a DSS such as Landassess DSS there is need to use diverse sources and types of data and knowledge. There are some numerical models and validated research for limited geographic areas. However much of the knowledge required in Landassess DSS was necessarily qualitative based upon expert and anecdotal knowledge and defined for limited regions with a requirement for extrapolation. A knowledge-based approach is essential for this.
- ii. Knowledge-based approaches have some problems in relation to expectations of users and experts. There is a significant phase of development of a mutual understanding of the problem, the requirements for the DSS, and understanding of terminology and processes. This is a learning process on behalf of both the experts and the knowledge engineers/DSS developers.

The knowledge-based approach proved valuable for developers, pasture experts and users. It provided opportunities for mutual understanding and learning of issues, as well as giving Landassess DSS a breadth which would not have been possible otherwise.

While the knowledge-based approach is very powerful for handling much of the knowledge base available for development of Landassess DSS, the effective handling of some process and temporal aspects is limited. Some examples within the Landassess DSS system include the effective chaining of transitions through time and modelling the processes within seasons—eg. gain of liveweight and pasture biomass. The modelling in Landassess was aimed at an annual aggregate effect.

The integration of process modelling within a knowledge-based framework can be used to solve some of these issues. However the available process models and the level of knowledge about the longer term processes would not have

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permitted development of a DSS such as Landassess DSS without the incorporation of a significant knowledge-based component.

Notwithstanding the limitations of a knowledge-based approach it still has advantages for much of the incomplete and qualitative knowledge which was available for the development of Landassess.

Implications of the state-and-transition model development

A state-and-transition model was found to provide a useful tool for increasing our understanding of the dynamics of a rangeland system, and a practical framework for (Bellamy and Brown 1994):

- Abstracting a complex and variable system through focusing on the key processes and driving mechanisms of that system;
- Capturing and integrating 'expert' or 'anecdotal' knowledge about that system;
- Identifying early warning signs of potential undesirable change(s) in that system;
- Identifying management 'windows of opportunity' or of hazard, ie critical times for management intervention;
- Highlighting gaps in the current knowledge-base to provide a basis for prioritising future research needs.

The state-and-transition model framework also proved to be a powerful means of:

- integrating the existing knowledge-base on pasture ecology and management from a number of experts;
- allowing for discussion and increased understanding of the concepts in group and individual interview sessions;

- allowing for incremental filling out of the initial schema through the iterations of knowledge-based-development. This was important in that it was not necessary to have the complete knowledge-base available initially. We were able to work from the broad state-and transition model and fill out the details (for example, change states), add and modify transitions; and
- identifying the gaps in the knowledge-base throughout the knowledge acquisition process. This included identification by experts as well as DSS developers and users.

Implications of useability

During development of Landassess DSS a compromise was needed between transparency of the logic and user-friendliness of the system. The technology used within Landassess DSS has inherent complexity (eg. the geographic information system), which means that there are limits to the extent to which the system can be made useable for a non-trained user. The user interface was developed to be as user-friendly as possible while retaining adequate functionality.

There are tradeoffs between making a system's or model's logic transparent to end-users and providing a fully precise scientific model. What is appropriate for a scientist is unlikely to be required for a decision-maker. This is an important issue in development of DSS since there is often a reluctance by scientists to accept the lower level of precision needed for some decision-making. Often a comparative or ordinal approach is acceptable for a decision process.

7 Interorganisational R&D cooperation

“... the use and consequences of information technology emerge unpredictably from complex social interaction ... [and the] dynamic interplay between actors, contexts and technology.”

Markus and Robey, 1988, p.588.

7.1 Landassess DSS R&D cooperation

The traditional way of thinking on interorganisational cooperative relationships or alliances (IORs) is that such relationships provide the context within which the technology development progresses. In the case of the CTC1 project, however, the R&D cooperation was facilitated through the system innovation development process. This section examines the nature of this relationship and evaluates its key outcomes.

7.1.1 The nature of the R&D cooperation

The Landassess DSS project was an interorganisational R&D cooperation or alliance. The ‘foundation’ partner groups in 1990 were the Land Resource Management group of the CSIRO Division of Tropical Crops and Pastures (DTCP), Brisbane, and the Land Conservation section of CCNT, Darwin. In mid 1991, they were joined by the Pastoral Land Branch of the then NT Department of Lands and Housing, Darwin, and subsequently in 1993 by some officers of the Department of Primary Industries and Fisheries.

The alliance was based on an informal and voluntary collaborative agreement to jointly undertake research on decision support for sustainable grazing management for what was perceived as the mutual benefit of the partner groups. The OIC of CCNT Land Conservation remarked:

I think, there always was, from my perspective, strong collaboration between CSIRO and the Commission ... We [CCNT] initiated a project with CSIRO. It was a collaborative project to start with, but there was clear recognition that CSIRO provided the intellectual grunt behind what we needed to know. That is to say, it is true technology transfer.

The cooperation effectively involved a network of interpersonal linkages between the CTC1 project researchers in CSIRO and staff of the partner organisations of the NT Government, several other CSIRO researchers working on related projects, and selected representatives of the grazing industry. These linkages were based largely on complementary inputs, joint problem solving, and prototype DSS ‘reviewing’ to collaboratively develop an innovative DSS product, ie. Landassess DSS. These joint activities were largely initiated by the CSIRO researchers on a needs basis, and are further discussed in Section 3.2 of this report.

7.1.2 Motivation for the R&D cooperation

Motivations underlying the decision to initiate and enter a cooperative agreement are important to identify as they ultimately influence the characteristics as well as the success or effectiveness of an IOR. Motivations for a broad spectrum of IORs have been widely discussed in the management science and organisational behaviour literature and they relate to technological, economic and people-related factors (eg. Oliver 1990; Gray and Wood 1991; Brockhoff and Teichert 1995; Souder 1993; Kanter 1994; Gomes-Casseres 1994; Browning *et al.* 1995; Evan and Olk 1995; Hosmer 1995; McFarlan and Nolan 1995).

Critical factors for the development of IORs relevant to the CTC1 project that have been identified in such studies include:

- an initial balance in relative bargaining power with each party bringing distinctive qualities to the relationship which build on one another rather than fill gaps (Bleeke and Ernst 1995);
- ‘reciprocity’ through interparticipant compatibility (Oliver 1990);
- similarity in partners’ values or culture (Badaracco 1991, Smith *et al.* 1995); and
- the establishment of trust (Zucker 1986, Browning *et al.* 1995, Badaracco 1991, Smith *et al.* 1995).

These factors formed the basis of the relationship developed between CSIRO and CCNT. The OIC of CCNT Land Conservation was initially motivated to collaborate with CSIRO by opportunities to:

- use CCNT’s land resource database more;
- provide development training work for CCNT staff, and
- get CSIRO back working in NT

Moreover, CCNT Land Conservation saw the CSIRO DTCP research group as its counterpart in CSIRO because “the two groups historically had similar beginnings in terms of interest in land capability”, and CSIRO utilised a “process-oriented approach in terms of landscapes”.

CCNT’s philosophical approach as a conservation agency was to “integrate biological conservation and land conservation with economic performance”. CCNT staff saw Landassess DSS as “one of those tools that would help them link these three together”.

Trust however is generally difficult to enforce and is associated with willing, not forced, cooperation. Trust was implicit to the voluntary relationship developed with CCNT and DL&H. Initially expectations of the collaborative process were high from their perspective, as discussed by a CCNT collaborator:

And at that time I had this vision that we could all work together between the departments ... we had a vision, and

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your Landassess was part of that vision, we thought it was going to come together very nicely.

However, DPI&F were reluctant collaborators initially and it took some time for some degree of trust and effective interactions in the R&D to emerge with them. For example, a DPI&F participant commented:

... and I guess the other problem was that the CSIRO people involved at the start were all new to the NT ... everybody [from CSIRO] was new, so nobody knew anybody when it started.

... when it started it was driven by the needs of ... whoever it was rather than the industry saying 'We'd really like something like this' ... I guess CCNT were acting on behalf of people saying, 'I think this will be really good for industry' without asking them.

7.1.3 Characteristics of the collaborative relationship and their evaluation

The interorganisational relationship had a number of distinctive characteristics:

- participative
- dynamic
- customer-focus
- multiple and evolving objectives
- upper management support
- staff continuity and commitment
- trust.

These characteristics are discussed below.

Participative

The CTC1 project adopted a 'facilitated' participatory approach to the R&D in the sense that the CSIRO developers actively guided, and at times orchestrated, the participatory process.

CCNT staff perceived that the participative nature of the project was an important long-term strength of the project:

I think the major strength of the Landassess program has been close collaboration with CSIRO in the development of a project, and not coming in subsequently. So right from the word go there was this expectation that we'd be developing this together ... and that it was a long term process. ... We had clarified our role pretty clearly, at least from my point of view, and I think from [that of] CSIRO.

This viewpoint was also expressed by a DL&H pastoral inspector who stated that being "involved in the project since the word 'go'" was a very positive and influential aspect of that stakeholder group's involvement.

Dynamic

Ring and Van de Ven (1994) propose that cooperations evolve over time: they are dynamic processes in which participants constantly evaluate their decisions to continue the cooperation. The CTC1 cooperative relationship was also dynamic. As noted by a CCNT participant:

There seems to have been a waxing and a waning of collaboration between the government agencies in NT ... all the way through.

Customer-focused

The project was customer-focused from the initial scoping phase. A CCNT participant, for example, described the relationship between CSIRO and CCNT:

... each time they [CSIRO] came up, they delivered something better than the previous time. And because we were in that arrangement, you as the consultant or the contractor, you delivered a product each time you came up. There always was something more there, and improved, and it was better ... with a view always that at the end of the day we were all going to get what we wanted.

Multiple and evolving objectives

The NT Government agencies had different objectives for their participation and involvement in the project, and these multiple objectives evolved. Based on the recordings and notes of the Principal Investigator during the project's iterative evaluation workshop process, these multiple and evolving objectives are discussed below.

In mid-1991, CCNT participants felt that the proposed DSS provided them with benefits such as the following:

- An extension tool for sustainable grazing management.
- Methods for effectively utilising the extensive existing CCNT resource survey information.
- A tool for integrating the existing knowledge-base.
- A basis for implementing the methods in the future in the Victoria River Downs region, where a major degradation problem was perceived to exist.
- The identification of major gaps in knowledge to better focus future R&D on grazing management.

By early 1993, although the CCNT expectations still encompassed the same broad themes, they had evolved to be more explicitly defined. By this time, they also included the evaluation of grazing management options as a potential important role of Landassess DSS, as well as:

- providing CCNT with additional methods and knowledge-bases for integrating data, and evaluating management options to support its legislative role relating to conservation of natural resources and the assessment of land capability/land use potential;

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- improving accessibility to CCNT's resource data and enhancing the knowledge-base of CCNT's policy makers/administrators and extension officers so that more enlightened advice on land resource management is given to producers/land managers/property managers;
- contributing to a project that is scientifically rigorous and useful and which provides Land Conservation with capability to be proactive rather than reactive, in its interaction with land managers; and
- Providing a possible framework for the new pastoral lands monitoring program.

At an evaluation workshop in November 1994, these major benefits and expectations were still similarly identified by CCNT participants. However, they now also recognised the value of participation in the system innovation development process as a 'learning' process for CCNT, and as providing a platform for addressing conflicts with other NT agencies. This participation involved:

- the concept of a knowledge-base providing a corporate memory through the storage and integration of ideas and data;
- recognition of the value of the DSS innovation development process as: (a) a forum for discussion and networking (eg. other government agencies and community/industry groups), (b) a basis for sharing data amongst agencies and educating each other, (c) a tool for land use planning to evaluate viable production areas and non-productive areas, and (d) a 'learning tool' for CCNT staff, ie. modifying the way they approached and implemented their work; and
- a shift in emphasis on grazing management options to evaluating environmental and economic trade-offs.

In mid-1991 the expectations of the Landassess DSS project by the DL&H staff essentially reflected that of CCNT as described previously. In early 1993, the DL&H identified from their perspective potential uses more specifically as providing:

- better access to relevant data to improve their advice to graziers on sustainable carrying capacities;
- an educational/training tool for pastoral inspectors to enhance their knowledge-base on sustainable resource management and improve their interaction with producers; and
- improved information for land valuations, and Pastoral Land administrative matters.

By November 1994 these benefits and expectations were still recognised, but they now also included the DSS's value as a mechanism for information exchange amongst NT collaborating agencies providing:

- a common data and retrieval system for the three agencies;

- an increased emphasis on its role for DL&H pastoral inspectors in facilitating the monitoring/extension processes with land managers, eg. providing feedback from the monitoring process; and

- a potential role in lessee management decision-making.

The benefits and expectations of the project recognised by participants from DPI&F from their initial active involvement in early 1993 were to provide:

- more logical ways of identifying the key factors driving pastoral management systems;
- a more rigorous basis to support advice to producers (eg. how many cattle can be run in a particular paddock in a particular season); and
- an educational tool to support their role as lead agency in the delivery of property management planning.

By November 1994, these benefits and expectations now also included the DSS's capability for evaluating management options, and also as a 'learning' tool. That is, Landassess DSS was seen to provide:

- a learning tool for DPI&F and other government officers, academics, producers (individuals and groups), and students that would provide a catalyst for initiating discussion on grazing land management;
- a tool for testing hypotheses (ie. evaluating management options);
- a tool that put the production side hand-in-hand with the environment; and
- support for land management policy development (eg. land use planning in the Douglas-Daly region).

In early 1993, the Co-ordinator of the local Landcare group, the Victoria River Conservation Association, identified his expectations of the potential value of Landassess DSS as potentially providing:

- an educational tool based on professional/scientific information that demonstrates management for change for the better; and
- a focal point for discussion for property management planning (PMP) and local consensus demonstration (LCD) groups.

Similarly in early 1993, the Scott Creek Property Managers perceived the potential value of the DSS as potentially providing:

- access to an educational tool that is based on professional and scientific information, and which improves their understanding of land management options, including the costs and benefits of those options; and
- an educational tool on land resource management for property managers who tended to turn over every 2–3 years.

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At a computer demonstration exercise in early 1994, these benefits and expectations were reconfirmed, and an additional role was perceived for the DSS in the context of PMP and Landcare as 'a property management tool for graziers'.

By mid-1995, the Company Director for Scott Creek Property also recognised a potential role for Landassess DSS as a platform or a catalyst to bringing the then three Departments—CCNT, DPI&F and DL&H—to work more effectively together at an operational level.

The perceived benefits and expectations of the R&D process by the different stakeholders evolved over the course of the project. Moreover, initial reservations over the potential outcomes of the R&D process by a DPI&F participants changed over time through the participatory process:

I think at this stage I probably went from being a sceptic to a supporter in terms of that ... I suppose I could see where I could be of some use ... I suppose I was starting to see some real use for it now.

In summary, the stakeholder objectives were:

- i. multiple for each stakeholder group;
- ii. different between the stakeholder groups, but with commonalities and overlaps; and
- iii. evolving, but in a direction of recognising Landassess as a tool for facilitating learning and coordination.

Upper management support

A key factor of the CTC1 R&D Cooperation was top management support from within both CCNT and CSIRO DTCP. The OIC of Land Conservation, CCNT, remained a key supporter of the project from the first interactions by CSIRO with CCNT in early 1990 ensuring resourcing, facilitating other NT Government department participation, and providing intellectual input. As discussed previously in Section 2.2.5., the Coordinator for the DTCP contribution to the CSIRO Land and Water Care MDP also provided on-going financial resourcing and intellectual support to the project.

Staff continuity and commitment

The continuity and level of commitment of key CSIRO researchers and NT collaborators to the CTC1 project at the operational level was another important characteristic. For example, the CTC1 Principal Investigator was involved and committed to the project from its inception in 1989. Initially he contributed to initial issue/problem identification and research focus, and advised on the project's implementation. From early 1991 she became project leader/resource integrator, albeit on a part-time basis. The CSIRO system analyst had a near full-time involvement with the project from July 1990 until its completion in mid-1995. Several senior staff members of the Resource Survey and Land Management groups of Land Conservation within CCNT had an active and on-going involvement with the

project from the beginning of 1991, providing data, reviewing progress and organising and participating in field trips. Although there were also many staff in both CSIRO and the NT agencies who had less continuous involvement, the significant point here is that there were senior staff in both CSIRO and the NT agencies who were connected with the project through most of its life.

Trust

As mentioned previously, the basis for this on-going commitment was basically trust amongst participants from both CCNT and CSIRO, especially in relation to the integrity of the research and the commitment of others to the project's objectives. This was a key factor in overcoming situational influences as discussed in Section 2 of this report, and the inevitable conflicts arising in a collaborative R&D process (which are discussed further in Section 7.2).

7.2 Outcomes of the R&D cooperation

7.2.1 Evaluating the R&D cooperation

Evaluation is "the act or result of judging the worth or value of something" (Prinsley 1994). Methodology for R&D evaluation, however, is still in a developmental stage. Several of recent studies (eg. Georghiou and Meyer-Krahmer 1992, Ormala 1994) have identified a number of difficulties in evaluating R&D outcomes. These difficulties seem to be particularly pertinent to R&D on public good issues, that is research with broad societal purposes, such as ecological sustainable development. The difficulties identified include:

- many of the important measures of success are intangible;
- the benefits of R&D may take a considerable time to be realised or become visible;
- attribution of particular effects to a specific unit of research is difficult as products and processes draw on a wide base of research and other influences; and
- impacts are highly influenced by the specific institutional, social and economic context.

Research on program evaluation (eg. Crane 1988; Pancer and Westhues 1989; Georghiou and Meyer-Krahmer 1992) has found that the critical factors affecting R&D and program implementation depend on the particular stage of development of the implementation process. The evolving perceptions and changing needs of the key stakeholders need to be assessed and monitored as an on-going process over the duration of the program to ensure relevance of the R&D. Therefore the evaluation needs to be an integral and on-going part of the science-based R&D methodology. Most significantly, Prinsley (1994) proposes that "it is the process of evaluation and focused interactions and systematic thinking of users of the evaluation techniques that is its major benefit and not the number that comes out at the end". In

other words, the process of developing and using R&D is as least as important as the R&D product itself.

Evaluating R&D effectiveness is multidimensional. For example, Ormala (1994) has argued that R&D impact is invariably complex, it cannot be measured directly, and it should be explored in terms of a combined set of quantitative and qualitative impact dimensions. These may include:

- individual and organisational learning effects (eg. new collaborations, networking) and behavioural changes (eg. increased skills)
- impacts on norms/standards;
- social effects (eg. system and network externalities, external learning effects, impact on the environment); and
- contribution to knowledge-bases, scientific progress, academic institutions, and human capital.

Other important issues of relevance to the evaluation of R&D impacts are the concepts of 'externalities' and 'additionality' (Georghiou and Meyer-Krahmer 1992, Ormala 1994, Brockhoff and Teichert 1995). Public good research is often justified in terms of externalities and spillovers, that is effects to non-participants as well as society as a whole. While an important consideration is the concept of additionality, that is the difference the R&D has been able to make to what would have happened without the implementation of the R&D.

The principal impacts of the CTC1 project's R&D process related to:

- creation of conflict,
- resolution of conflict, and
- individual and organisational learning processes.

These impacts are examined below.

7.2.2 Creation of conflict: as an opportunity for learning

The collaborative R&D process crystallised and exposed significant existing conflicts between the different stakeholder groups, and in so doing lead to the conflicts having to be dealt with in the context of the CTC1 project. These conflicts related to many issues, such as the following.

- (i) A significant conflict was apparent over perceptions of how the Landassess DSS product might be used by other agencies. For example, DPI&F were very sensitive over concerns within the pastoral industry particularly in the early stages of the project:

... so that ... was the dilemma in fact that it was something that could be very useful and was also something that people could see that other people could use it to knock you down. ... the fear was that people in government, or whoever, would run a Landassess through

and produce a map, leave red areas on it, and come out and say, 'you're knocking the country; this is not acceptable; if you don't change, we'll take you to court'.

These concerns were also expressed by CCNT participants:

We were conscious that the Department of Lands and Housing may of been wishing to use Landassess a little differently than what we saw it would be used for. And, of course, there was tension with DPI&F. They were trying to work out a role ...

- (ii) Conflicts arising through the collaborative and participative processes also related to different organisational cultures, in particular different attitudes and ways of doing things. For example DPI&F participants remarked:

The organisations have been the trouble and I guess there's been a lot of energy wasted along the way ... [if we were] to start again now, we'd involve a lot more people at the start and make sure we had more [inter-organisational] ownership of it, some interest in it, before we sort of started talking about it. ... I certainly think a lot of the trouble with it has been the communication problem in the NT as much as anything else.

Likewise from a CCNT participant reflecting on a meeting in 1992 involving a range of pastoral representatives who expressed considerable concern over the project and its involvement with CCNT:

... We talked about 'land degradation' and it always has been a problem for an agency that deals with producers.

- (iii) The R&D process also exposed the realities and difficulties of developing interorganisational R&D collaboration and participation. For example, CCNT participants remarked:

This was tied up with our vision of PMP that these are the three agencies who are delivering services to landholders, in particularly pastoralists, and so ... we needed to involve these other agencies ... these people had data and knowledge that we knew could be useful to be fed into Landassess. So it was our role to bring these other players together and, unfortunately, I don't think we tackled that at the right level of the market, so to speak, ... we still had these rose-coloured glasses on at that stage.

... in hindsight at this stage is where somehow we should have got much higher level support from the other two departments. I guess it would have been the right time ... so that the players that were going to make decisions about it later on were in there from the start ... in hindsight we should have done things a bit differently ...

- (iv) The most recent conflicts related to CCNT concerns expressed by the OIC for Land Conservation over the future of the R&D cooperation after the initial objectives had been reached in mid-1995:

Barriers that will prevent its use are really staff dedication and ... a continuing lack of agreement with CSIRO. I believe that if CSIRO walked away from it now and we

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signed the contract and [CSIRO] said now the software is your responsibility ... I don't believe that it will realise its full potential ... I don't think we will capitalise on the investment in Landassess unless there is a continuing agreement.

- (v) Conflicts also arose through the multiple agendas associated with the project's multiple funding sources. For example, the CSIRO developers were strongly committed to meeting the agreed objectives established with the project's NT collaborators to undertake a participatory system innovation development process for Landassess DSS. The involvement of the project in the LWRRDC/GRDC/RIRDC Adoption of Sustainable Technologies Program involved an increased commitment to new agendas which had not been envisaged in the original application for funds from LWRRDC. The project's CCNT collaborators were willing to cooperate in an evaluation process on the basis that they recognised their CSIRO partner's need for 'external' funding sources. However a conflict did arise between the CTC1 Principal Investigator and the LWRRDC/GRDC/RIRDC Program Coordinator in 1993 over the extent of the on-going evaluation process and the level of involvement of 'external' evaluators. The CTC1's Principal Investigator's concerns related largely to a perceived:

- escalation in commitment of scarce CSIRO staff time and project resources to an evaluation process that could not be fully met by the CSIRO resources and which was an unknown quantity; and
- high potential for undesirable interference in the relationship established between the CSIRO system developers and their NT collaborators, especially since the proposed evaluation process had not been part of the basis of the original agreement to collaborate.

The evaluation process was also perceived by other CSIRO CTC1 staff as an unwanted escalation of their commitment for much the same reasons.

7.2.3 A mechanism for resolution of conflict

The collaborative R&D process and the participative system development processes provided mechanisms and opportunities for facilitating more constructive cross-organisational interactions amongst the NT collaborators, and the potential for even conflict resolution. For example from CCNT participant perspectives:

This became a concrete and physical something that the three agencies could sit behind and say 'What if?' and feed on each others disciplinary experiences in an environment of disciplinary respect, rather than in an environment Where 'you know I'm right, [so] you're wrong'.

It [Landassess] is like a game. And I think it suddenly focused everyone's opinion not on who does what in

government, but rather who can contribute to what. ... So suddenly instead of us sitting around a table, we are focused on something, and you find a lot of barriers get broken down.

The main outcomes I saw from the last meeting [ie. Combined Departmental Evaluation Workshop, November 1994] was cementing those government departments. ... there was a cementing, not so much a higher level policy type of area ... but the actual people down on the ground who may not have been aware of the interaction that went on between CSIRO and CCNT earlier or whatever. So it was more the operational people who were in the same room at the end ... getting the departments at an operation level to be more aware of what the Landassess modules and thought processes were in terms of industry value.

Similarly from the DL&H perspective, the CTC1 R&D process was perceived to have helped inter-departmental integration. Having Landassess DSS meant that:

... now we had a specific purpose for the exchange of information.

7.2.4 Learning processes as outcomes

The process of 'learning' is a key to resolving complex problems. According to Kanter (1994) interorganisational relationships involve "a dense web of interpersonal connections and internal infrastructure that enhance learning". Badaracco (1991) perceives organisations as repositories of embedded knowledge and that alliances should be ways of supplementing and improving these repositories. Conceptually the concept of learning processes as being integral to interorganisational cooperations for R&D on information technology can be extended from individual to organisational learning.

'Learning' processes were an important outcome of the CTC1 project's R&D process as identified by key stakeholder groups in the on-going evaluation workshops and during the stakeholder interview process. Three principal domains of 'learning' were evident. The first relates to the development of knowledge-bases relating to the management of collaborative R&D processes. The second deals with the learning associated with the development and refinement of technical approaches and knowledge-bases relating to sustainable grazing management. The third domain concerns the contribution to knowledge-bases on the role and effectiveness of DSS system innovation development processes. This section addresses the first domain. The learning processes associated with the latter two domains are examined in Section 8.6 of this report.

The 'learning' processes associated with the cooperative R&D highlighted various benefits, such as the following.

- (i) The collaborative 'forum' and networking provided opportunities for exchange of information and alternative viewpoints.

For example, from the CCNT perspective, the learning was associated with the integration of diverse information from a range of disciplines into an accessible format, and the questioning of previous technical approaches and ways of thinking about issues:

I think one of the major spin-offs of this whole exercise has been the network it has established. The fact that it has provided a crucible for a bringing together of related disciplines many of which are only too happy to work within little boxes ... this has come up with a product that demonstrates the power of being all together.

It maybe more useful to be looking at the process rather than the DSS itself ... what we were really about was encapsulating knowledge and experience on sustainable land use and packaging it up so that it could be used.

DSS development is a process of modifying what we are doing and in that sense is research. Research in that sense is an amalgamation of ideas and its purpose is to modify the current model.

... the other dynamic has been ... that so many people had very narrow definitions of degradation. Then all of a sudden we re-defined it in a more comprehensive way. I thought we had a lot of converts to that attitude along the way.

It has provided I believe an in-house training tool, and not just for new staff ... we started to reassess a lot of our land capability data collection ... so one outcome of going through these [Landassess] workshops was that ... it started to put some more philosophical debate into what we were collecting, and why we were collecting it ... something happened—the 'Big Debate'. ... It was the best philosophical debate that Land Resource Survey had ever had. It was driven up from the ground. It was really good; and what was different about this one was that it was professionally based.

From a property manager's perspective, the learning was something that came from working as part of the project team:

... educational as far as I'm concerned, and I would think that the people that the team has been involved with would all have to say the same thing. We all worked as a team to develop it. We've all learnt right from the start.

From a DPI&F participant's perspective, the learning was through the exchange of viewpoints:

... the process of actually going through and doing it [building S&T models], putting it all together was very useful in terms of making you know in your own mind about how the systems actually work ... I thought it was a really structured way of dragging that out and I thought having someone [ie. a CSIRO scientist] ... who thinks somewhat differently to me and has got different experiences in a similar field, disagreeing with you, makes you think about it.

(ii) There was better recognition and awareness by participants of the different 'cultures' of other

stakeholders and the importance of the diversity of situational environments of other stakeholder groups, including those of the DSS developers.

For example, CCNT participants remarked in June 1995 that:

... the Landassess DSS concept highlighted the political realities of the different approaches to management of change.

Any unexpected benefits for me are the greater understanding of the role of culture in organisations ... in a period of change ... people are now a bit less defensive about their professional positions at an operational level.

... I guess I have learnt a little bit of how I believe we should be dealing with a research agency that is shifting its ground into being more user-responsive, which I might add has been great.

Moreover, a CCNT participant concluded that the Landassess "concept really did highlight the conflicts and tensions between Departments with philosophically different approaches", however, "Landassess has also given us the tools to philosophically accept differences".

Similarly from a DPI&F participant's perspective, in the process of interactively reviewing Landassess DSS with a group of producers, the learning was partly through bringing about a better understanding of other stakeholder interests and responses to new technologies:

I thought that was good, and again it was one of those times that it was very interesting for me see how much the producers enjoyed seeing something that they recognised up on a screen, and being able to manipulate it and see and play with those sorts of things.

(iii) One of the unanticipated benefits of the R&D process was that participant groups critically reviewed their traditional modes of operation, and then subsequently revised their methods of collecting and analysing or viewing their own data.

For example, CCNT participants noted that important learning impacts were that the R&D process "challenged the current concept of land capability", and allowed for the testing of hypotheses relating to management options. Other CCNT participant observations were:

I think you know to see people critically reviewing why we collect data, and how we collect data, and how it can be used in a professional context was the biggest benefit in terms of the land assessment area. The unexpected benefit was that the resource assessment people have realised that there are other agencies using our data to make economic decisions and its making us think about what the characteristics are in respect to economic performance.

... we can use Landassess to direct what are our data requirements ... Landassess has now highlighted which are the relevant bits of information to run the system. We are now using that to influence the data we're actually collecting in the field.

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... so [through] this evolutionary process of using Landassess to say, 'what information do we need?', we then reviewed our program to say that we are not delivering that information professionally. We then had to look at staff and we had to look at culture.

- (iv) The significance of 'learning' processes as a key outcome of DSS innovation development processes was perceived by a CCNT participant to create a dilemma for funding bodies and others with a product focus in assessing R&D outcomes:

I believe the process of development of Landassess is probably more important than the product at the end of the day ... we have had ... these sorts of things delivered to us in a little package, and we have put them on and thought, 'Oh yeah' and put them away. So its the product there ... This is different, I think, because we have been part of the process. The product [itself] is only 30 or 40% [of the value of the project].

... I think that developing Landassess type decision support systems is more important than having the decision support system itself ... which presents great difficulty with funding bodies. They want to know what you produced and it's very difficult to say we have produced smiles, a greater understanding, and a greater business respect.

Overall there were significant benefits associated with the 'facilitated' participatory approach adopted by this interorganisational R&D cooperation for both the DSS developers, the NT collaborating agencies, and the CSIRO researchers from other related projects. However there were costs along the way as well. These included the escalation in commitment of time and financial resources to substantial interactive processes with multiple stakeholders, the need to resolve ensuing conflicts, and the need to address the scepticism of some key stakeholders within the NT Government and the NT pastoral industry.

7.3 Summary and implications

The impacts of the collaborative and participative approach to R&D undertaken by the CTC1 project are multidimensional.

- The benefits and objectives of participation and involvement in the R&D process, recognised by many of the participants, were not just related to the development of a useful end product, that is Landassess DSS; the participants saw the overall R&D process as an active 'learning' experience.
- The project's R&D process undoubtedly has had externalities or spillovers relating to both individual and organisational learning effects and contributions to knowledge-bases as well as human capital (eg. professional development of participants).
- R&D on sustainable management has many diverse stakeholders who in turn have multiple and evolving objectives. These objectives are different for each stakeholder group, although there are some commonalities. These objectives can also be significantly influenced through participative R&D approaches to the development of DSS technology innovations.
- The efficiency of these R&D processes is very difficult to assess. Notably what cannot be objectively assessed is 'additionality' (Ormala 1994),—the difference which the DSS system development process has made.

8 Evaluating DSS effectiveness: product success or process tool effectiveness?

... Information Systems failure is a multi-faceted phenomenon of immense complexity which defies any simple solution. It is therefore very unlikely that any Information System is simply a success or a failure.

Lyytinen and Hirschheim, 1987, p.294

As outlined in Section 1.4 of this report, the project has achieved its original stated objectives, in that it has produced and delivered a DSS product that is perceived by its key stakeholders to be potentially useful and to have a potential role within the NT Government agency pastoral land management programs.

The importance of: (a) the DSS system innovation development process, and (b) the adoption of a suitable implementation strategy or approach to the ultimate effectiveness of R&D on information technology is well documented in previous studies (eg. Ives and Olson 1984, Hirschheim 1985; Lyytinen and Hirschheim 1987; Robey and Rodriguez-Diaz 1989; Guimaraes *et al.* 1992; Willcocks and Margetts 1994; Eierman *et al.* 1995). Key factors identified include: top management commitment, organisational culture, user participation in system design, system evolution strategy, and the social context of implementation, such as technological readiness of the target stakeholder organisations, and wider cultural and national setting within which the organisation operates.

Consistent with the recognition of the role that these factors have had in previous studies, a stakeholder evaluation or strategic constituency approach was undertaken. The stakeholder evaluation process focused on:

- an assessment of the future use of the Landassess DSS, including perceived principal users and purposes, the key limitations and constraints to its use, its future resourcing needs, and the future process for progressing its development. This process has been discussed in Section 4.2.3.
- stakeholder perceptions of the DSS development process, including the value of the participatory process and multi-faceted learning. This process has been discussed in Section 4.2.4.

8.1 Perceived users of Landassess DSS

There was general broad stakeholder agreement reached in the course of the evaluation workshops held in November 1994 that, in its current stage of development, the principal end-users of Landassess DSS would be:

- government agencies (eg. CCNT, DLH, DPIF),
- Landcare groups,
- producer discussion groups (facilitated),
- researchers, and
- educationalists.

The first four are consistent with the perceived view of stakeholders in 1991. Landassess DSS was generally not perceived as a key tool for individual property managers to use in day-to-day tactical decision-making on grazing management. The additional potential user group in 1994/95 was educationalists.

8.2 Potential uses for Landassess DSS

With the introduction of the new Pastoral Land Act and the development of government strategic plans, there is an increased focus in the NT Government on the integrated delivery of advice and policies. There is a recognised need for a common framework to address the trade-off between environmental/ecological sustainability and economic viability. This initiative involves all three government agencies represented at the workshop working more closely together. In this context, the main potential areas of use for Landassess DSS identified by the three NT agencies in November 1994 were: strategic grazing land management, education and extension, accessibility to information and data, R&D needs, and potential new applications. These areas will now be discussed.

- (a) *Strategic management*: Landassess DSS was seen to provide: (a) a framework for formalising the rules governing the impact of grazing management on the land resource for the Katherine-Daly region, and for providing a template for other regions; and (b) a 'what if?' problem-solving capability for testing the impacts of grazing management options on land condition, and for the identification of areas sensitive to degradation within spatially variable paddocks. It provides a tool that challenges current concepts of land capability, yet captures conventional wisdom relating to rangeland management. It is also a tool for exploring the long-term trends and implications of management options by highlighting the trade-offs between environmental effects and economic gain. It is not a tool for tactical decision-making on grazing management.

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It was seen that Landassess DSS would be used by the three agencies as one of the tools for land management policy development and implementation, and that this would involve: (i) property managers/producers in conjunction with government advisers, for example, to explore management options and how the rangeland system might respond to them; and (ii) management agencies in their legislative/advisory roles. Examples of the latter are: the feedback process to producers for pastoral land monitoring; the land use planning process relating to new land development for identifying viability and suitability for production; and Pastoral Lands Board administrative matters which require that the condition of land is considered (eg. conversion to perpetual lease, sub-division assessment, and remedial plan preparation).

- (b) *Education/learning/extension tool:* Landassess DSS was perceived as a useful tool for enhancing the knowledge of both agency staff and land managers, particularly through co-learning by providing a catalyst for initiating discussion, rather than an end-point in itself. Some examples are: support for resolving differences regarding producer recommendations; advice to new producers coming into an area as the industry intensifies; support in the feedback process to producers on monitoring of pasture condition, in particular to translate monitoring data into plans for better pasture management; and a tool for self-education and exploring ideas.
- (c) *Integrated knowledge-base:* Landassess would provide for: (a) a repository of accumulated knowledge, that is the maintenance, integration and development of information/ideas and data which effectively provides a corporate memory; (b) a 'living encyclopedia' that is upgraded as new information becomes available; (c) ultimately improved accessibility to data and information for a wider range of users in agencies, the community, and pastoralists, (d) a common data storage and retrieval system for the three agencies to share data and 'educate' each other; (e) a powerful tool for collecting and storing data relating to grazing management in a logical manner through the state-and-transition model framework and displaying it visually—in particular the GIS 'front end' was highly valued; and (f) a forum for networking, and in this sense the process of integrating and sharing information/data/ideas itself is as, or more, important than the outcome/end product of that process.
- (d) *R&D tool:* The Landassess DSS development process provided: (a) a mechanism for identifying important knowledge gaps, and hence for setting R&D priorities; and (b) a mechanism for both researcher and stakeholder ideas to be modified, and for both groups to change their approach.
- (e) *Potential new applications:* Landassess was seen to have potential for new applications (or further development of the current state-and-transition models)

in wildlife and conservation management, and also intensive agricultural systems. However the current priority was seen to be decision support for extensive beef production on native pastures.

8.3 Key limitations/constraints on the use of Landassess DSS

Although the government agency participants at the evaluation workshops in November 1994 recognised significant value in the Landassess DSS prototype implementation, they identified some potential limitations and constraints to its use:

- Landassess DSS was not suitable in its current developmental stage as a tactical management tool for property managers. Significantly, it cannot handle risk associated with seasonal variation in pasture growth.
- Landassess DSS development was restricted geographically to the Katherine-Daly region and functionally to beef production on native pastures. There was a perceived need to consider future wider application of Landassess DSS to other regions, with the possibility of its being extended to encompass evaluation for wildlife and conservation resource utilisation.
- Although producers were not seen to be the major users, there was a need for producers to now be consulted more widely on the potential uses of the DSS to gain acceptance for its use in interactions with them. Some participants felt that so far producers had not been involved enough (ie. restricted to Scott Creek property managers) in the consultation process undertaken in the development of the DSS.
- Maintenance of security and integrity of data in the longer term needed to be addressed.
- The concern was expressed that the DSS needed to be able to also evaluate at the scale at which graziers perceive land (ie. usually aggregations of land units), as a lot of local management knowledge relates to these aggregated units.

However, even if it was not developed any further, Landassess DSS was perceived to have value as a pedagogical tool, eg. in educational institutions, as a training tool for pastoral inspectors, and as a support for decision-making relating to future land use planning in the Katherine-Daly region.

8.4 Resourcing issues for progressing Landassess DSS development

The key issues relating to resourcing of Landassess DSS were identified in November 1994 as being related to:

- There was a need for a 'core working group' to drive the process of implementation and on-going use of Landassess DSS and to seek out information from other stakeholders/agencies.
- The knowledge-base and models will always need updating as information becomes available.
- There will be a continuing need for on-going technical support from CSIRO.
- Future resourcing needs could not be precisely identified until each agency has explored the technology more closely in the next six months.
- NT government agency funding will need to be identified to support its use in the long term.

There was general consensus amongst the NT Government stakeholder groups that the Landassess DSS package provided a framework which could be usefully developed to meet the needs of those agencies responsible for management of rangelands in NT. Development was almost complete for the Katherine-Daly region, and there was a potential for its future application in other regions (eg. Victoria River Downs). It was also seen to have a potential role in the proposed CRC for Tropical Savannas as one of several tools or models for looking at rangeland management.

The NT agencies agreed in principle to maintain the Katherine-Daly prototype system. This required training in system use and maintenance, and co-operation between the three agencies. It was recognised that CSIRO would no longer be able to take the lead role after July 1995. Beyond this date, CSIRO agreed to continue to provide support to the NT agencies, although it would require support for operational costs to cover interactions with NT agencies.

Once the NT agencies were more familiar with the use of the system, they would indicate their training requirements on system use to CSIRO. Those responsible for system maintenance in the NT however would require more intensive training. It was suggested that CSIRO would train a few key people in depth in both system use and maintenance, and that those people could then provide assistance and training to other agency staff. In this regard, beyond July 1995 CSIRO operating costs would need to be met by NT agencies.

The feasibility of applying Landassess DSS to the VRD region was explored. The general consensus was that there were sufficient resources and data available within NT to do this, and that most of the 'costs' were already sunk. Once the agencies had a good idea of the completed prototype and had tested it, a decision on how to proceed in future could then be made. To facilitate this process, including training of NT staff by the CSIRO DSS developers, an interagency Landassess DSS Steering Committee was established involving a senior representative of CCNT, who would act as coordinator, as well as from DLH, and DPI&F, and the CTC1 Principal Investigator from CSIRO.

Due to the transfer of the OIC of Land Conservation to another Section in early 1995, and the subsequent structural changes within the NT Government in June 1995 (see Section 2.2), this Steering Committee never formally met. Further development of Landassess in relation for the three NT agencies awaited the outcome of the restructuring. Some funds to support CSIRO operational costs had been identified as budget items.

8.5 The value of the participatory development approach

Many studies have emphasised the importance of stakeholder participation in system innovation development processes as discussed in Section 3.2.1. They have generally focused on the effects of participation on various individual, group and organisational level criteria, such as attitudes, behaviours and performance. Expected benefits of participatory system development and participatory R&D or evaluation processes cited in these studies include: (a) providing a more accurate and complete assessment of user information requirements; (b) prevention of costly system features that are unacceptable or unimportant to users; (c) greater user acceptance, support and ownership of the technology innovation; (d) improved user understanding of the technology development; (e) heightened perceptions of the technology as valid, credible and persuasive; (f) providing an arena for bargaining and conflict resolution about design issues; and (g) contributing to the political climate or conditions conducive to meaningful utilisation.

During the stakeholder interviews undertaken in June 1995 (see Section 3.2.4), it was confirmed that participation in activities associated with the DSS system development process encouraged ownership of the system innovation development process. For example, a CCNT participant commented:

The first area was basically CSIRO intellect, then us [CCNT] providing data and sort of tests all the way through. And I think that was a major strength because right from the word go there was fairly clear understanding. We were starting in a way from scratch there ... in terms of understanding grazing land use ... It's something that you have an input in, I have an input, she has an input, and we all recognise that our inputs are valid.

In particular, the opportunity for individual collaborators, whether a NT Government officer or another CSIRO researcher, to contribute their own data or information as an input to the DSS development strengthened ownership and acceptance of the DSS as outlined, for example, by a CCNT participant:

One of the things we did was reassess and, re-evaluate all our data for the Douglas Daly basin ... I was pleased that we were able to use our data and even though we knew that it was data collected in the 60's & 70's ... from what

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I've seen now we're really confident ... being able to use our data and apply it to something like this.

Likewise, a CSIRO researcher involved in the DSS system development reflected on a workshop held in December 1993 that:

I can recall that being a fairly big step forward, getting some of the production data that we'd been collecting in the field into another form for Landassess ... From our point of view, I thought that it was more personally satisfying than the outcome it had for the project ... really having contributed that information, I was feeling much more part of the Landassess project ...

8.6 Multi-faceted learning processes

Current trends in research on decision support systems (DSS) suggest that the role for decision support technology lies not in supporting tactical decision-making, but in providing a flexible learning environment through which learning about the decision situation or context takes place (Angehrn and Jelassi 1994; Wood and Wood-Harper 1993).

'Learning' processes were an important outcome of the CTC1 project's system innovation development process as identified by key stakeholder groups in the evaluation workshops and during the stakeholder interview process. The outcomes included the following.

- (i) Improved understanding of participant's own data and information and its utility to others. For example, from a CCNT participant's viewpoint:

I think what we increased is the understanding and the difficulties in migrating data, in transferring data sets, and the difficulties in actually us saying that we have a data set and others saying, 'you haven't got these figures, and you haven't got this sort of information that we can get these surrogates from. You have nothing we can use quickly'. So we understood better about the data we were collecting in those early phases.

Similarly from a collaborating CSIRO researcher's perspective, it provided the opportunity to identify the real knowledge gaps:

I guess one of the outcomes for me was how little we could codify some of these states and transitions, and that a lot of the transition states that people raised were probably related to personal observations or experiences—that they had mostly anecdotal information rather than experimental—and that the end result was probably some areas where we had far too many detailed experiences ... and other areas where nobody had any knowledge about anything.

- (ii) The DSS system development process led to: (a) participant groups critically reviewing traditional modes of operation, and (b) the subsequent revision of methods of collecting and analysing or viewing their

own data. For example: a DPI&F participant commented that the knowledge acquisition process led to a review of the way they assessed and analysed their data:

... the main benefit I've had out of being with it is just that discipline and that process of going through and developing those [S&T] models and that I think has been very useful for me ... I think that was something that may have slipped by largely if we hadn't been forced into it ... after that meeting ... we actually got out all our old records again, all the old photographic records we had, and we actually re-did all of our state-transition models for the VRD, which we then put into our MRC submission for NAP2 funding ... so I think at that stage I was really sold on it this whole concept of S&T model – just testing how the system works at any one time.

After reassessing the needs of pastoral land management, CCNT participants commented on the changes in routine data collection during resource survey work:

When we focussed on land management, we found that soils were not the only characteristic of interest in our pastoral systems. Suddenly we realised that we were not supplying good information. So we now had a reassessment of the Land Resource Survey Section which resulted in some staff difficulties. So through this evolutionary process of using Landassess to say what information do we need, we then reviewed our program to say we're not delivering that information professionally. We then had to look at staff, and we had to look at our culture.

And, again:

... one of the things we did was to reassess and reevaluate all the data for the Douglas Daly basin.

From the DL&H perspective, participation in the development process meant a new way of thinking about sustainable land use and the assessment of pasture condition, as outlined by a participant in June 1995:

We'd been introduced to the concept of state-and-transition. We started to apply that sort of concept as we were driving around, rather than just saying this patch of country has had it, or no, it's in good condition.

- (iii) The value of the learning associated with interactive use of an integrative DSS product was also an important outcome. For example, from the CCNT participant perspectives, Landassess can be used in refining understanding and providing feedback to test 'models'. This meant that using Landassess DSS was a learning process in itself, as suggested in interviews with several CCNT participants:

... it was a fact that state and transition [approach] gave us a better understanding of the system. ... we understood then that there's a range of steps that it goes through and each one has a different potential ... we were starting to understand, just through the interaction with this new development, a much better understanding of how landscapes respond and, if nothing else, I think it has

been fairly valuable for the people who have been exposed to it.

... We can use the product ... but Landassess is also a process. So we can use it in property management planning by getting the agencies sitting around the table talking about how you plan a property, what are the management tools? what are the economic implications of that? So ... we can start using this as a facility ...

Initially we saw it as an aid to make better decisions and to help officers that are new to the area come to grips with the issues and problems and responses in the landscape in a more integrative way in the CCNT office.

... this was a tool to be used in-house to help extension agencies of whatever department to understand processes in the landscape better, and understand why things are as they were ... and maybe give them a better idea in terms of providing extension to a land holder ...

The main targets of the DSS are government officers and agencies who can use it to go through a whole range of land management issues and then use their judgement to select the key elements, and then to interface one-to-one with landholders in the Territory ... I think the main application is with scientific and land management officers who would use it as a sieve to pick out relevant issues.

Similarly, DPI&F participants in evaluation workshops saw potential value in the use of Landassess as a strategic tool in "training and challenging people to look at long term trends and implications rather than tactical planning decision support":

I think the major strengths have been being able to put the various knowledge-bases together in ways you can manipulate it. Just the thinking behind it and putting that together in a system that worked, and accessing a lot of data ... coming out with some answers that you can think about. So I think that it is a way of getting on top of a lot of resource data that is otherwise meaningless and unfriendly.

Likewise, CSIRO researchers remarked on the strengths of the learning processes through the interactive use of the DSS:

... the outcome that you get out of it ... it's probably the understanding of the system that you're getting by using the model rather than the numbers produced at the other end.

(iv) The participative DSS innovation development process created and exposed some conflicts for the participants. Conflicts were created by the participative process of the CTC1 project related to time constraints, for example, as a CCNT participants remarked:

... when a project such as this comes along, you have your own work load and then you've got another work load over and above that, and you have also got constant demands from the hierarchy.

... we'd given a commitment we would cooperate, but in my annual work program it's not officially sanctioned.

Likewise a DPI&F participant commented:

I think one of the things you have to realise in a place like this is the incredible complexity of work that individuals seem to deal with on a daily basis ... this is why it's really important that the product needs to be really attractive, it needs to be extremely user-friendly ... there's a real cost benefit to all these sort of activities and when people have other priorities those cost benefits ratio have to be really good.

However, it was perceived also by the Scott Creek managing agent as providing:

... a dilemma in that it is a tool which on the one hand is potentially useful at both policy and enterprise levels, but on the other hand it is what graziers most fear in the hands of regulatory authorities.

8.7 Summary of the effectiveness of the DSS development process

The project has produced and delivered a DSS product that is perceived by its key stakeholders to be potentially useful and to have a role within the NT Government agency programs. The perceived usefulness of the DSS system innovation development was based in part on:

- the DSS functionality that addressed a range of needs;
- active user/stakeholder involvement in the system innovation development process;
- stakeholder 'learning' experiences in developing the DSS system; and
- the iterative and evolutionary development methodologies.

The effectiveness of the CTC1 project was seen therefore to be as much an outcome of the development process as much as the potential usefulness of the DSS product.

The influence of the dynamic and varied cultural and situational contexts of the key stakeholder groups may well be significant to the future success of the DSS product in the N.T, as has been alluded to previously in Chapters 2, 5 and 7. Moreover, the effectiveness of the use of the DSS can only be realised beyond the timeframe of this evaluation. However for R&D on complex resource use issues with broad societal impacts, issues of causality are virtually impossible to assess over an extended timeframe.

Appendix 3 gives the views of a biological scientist involved in CTC1 on the development and potential of Landassess and its implications for research.

8.8 Major benefits: product success or process tool effectiveness?

Notwithstanding the limitations on establishing the long-term effectiveness of the CTC1 project, the major benefits achieved during the participatory stakeholder R&D process were learning about:

- the complex concept of sustainable resource use in extensive grazing management systems,
- design principles and methodologies for effective DSS development processes (see Chapter 6), and
- collaborative approaches to interorganisational R&D cooperations (see Chapter 7).

Significantly an unintended benefit of the project was the synergy and the appreciation of the value of, and necessity for, working together. In particular, it has highlighted the interdependence of people and groups as well as knowledge-bases. This applies to both the NT stakeholder groups and the CSIRO researchers. The benefits that might be achieved in the future that were recognised by the NT stakeholders also relate to educational and stakeholder interaction processes. In effect therefore the major benefits of the DSS system innovation development process relate to Landassess DSS as a process tool, both in terms of its development and its future use.

9 Recommendations on R&D on DSS

“... technologies are a product of their time and organisational context, and will reflect the knowledge, materials and conditions at a given locus in history.”

Orlikowski, 1992, p. 421

9.1 A paradigm shift for the role of science-based decision support technology

This research project has affirmed that resource management issues with broad societal purposes are multidimensional and complex. The achievement of sustainable use and development of our rural resources requires the collective action of a broad and diverse group of stakeholders. These stakeholders include not only individual resource users (eg. property managers/producers), but also ‘on-going’, evolving groups such as:

- policy, planning, regulatory, extension and advisory agencies within all three tiers of government;
- producer and community groups (eg. Landcare, Integrated/Total Catchment Management, producer organisations, conservation agencies);
- R&D providers (eg. researchers in CSIRO and government);
- educationalists (eg. in Rural Agricultural Colleges, universities, schools).

The fragmentation of responsibilities and the diversity of approaches relating to resource management and environmental stewardship across these groups present barriers to integrated action on sustainability issues.

The CTC1 project has demonstrated that DSS technology innovations can create opportunities to foster communication and integrated action across a range of diverse stakeholder groups through focusing on support for learning processes. This invokes a new paradigm for the role of science-based decision support technology innovations in sustainable resource management. The new paradigm requires a shift from seeking ‘the correct solution’—or a limited choice of management options—in tactical decision-making (ie. problem-solving), to using tactical decision-making as a tool for:

- learning about the decision environment and the problem context; and
- understanding the organisational environments within which stakeholder groups operate.

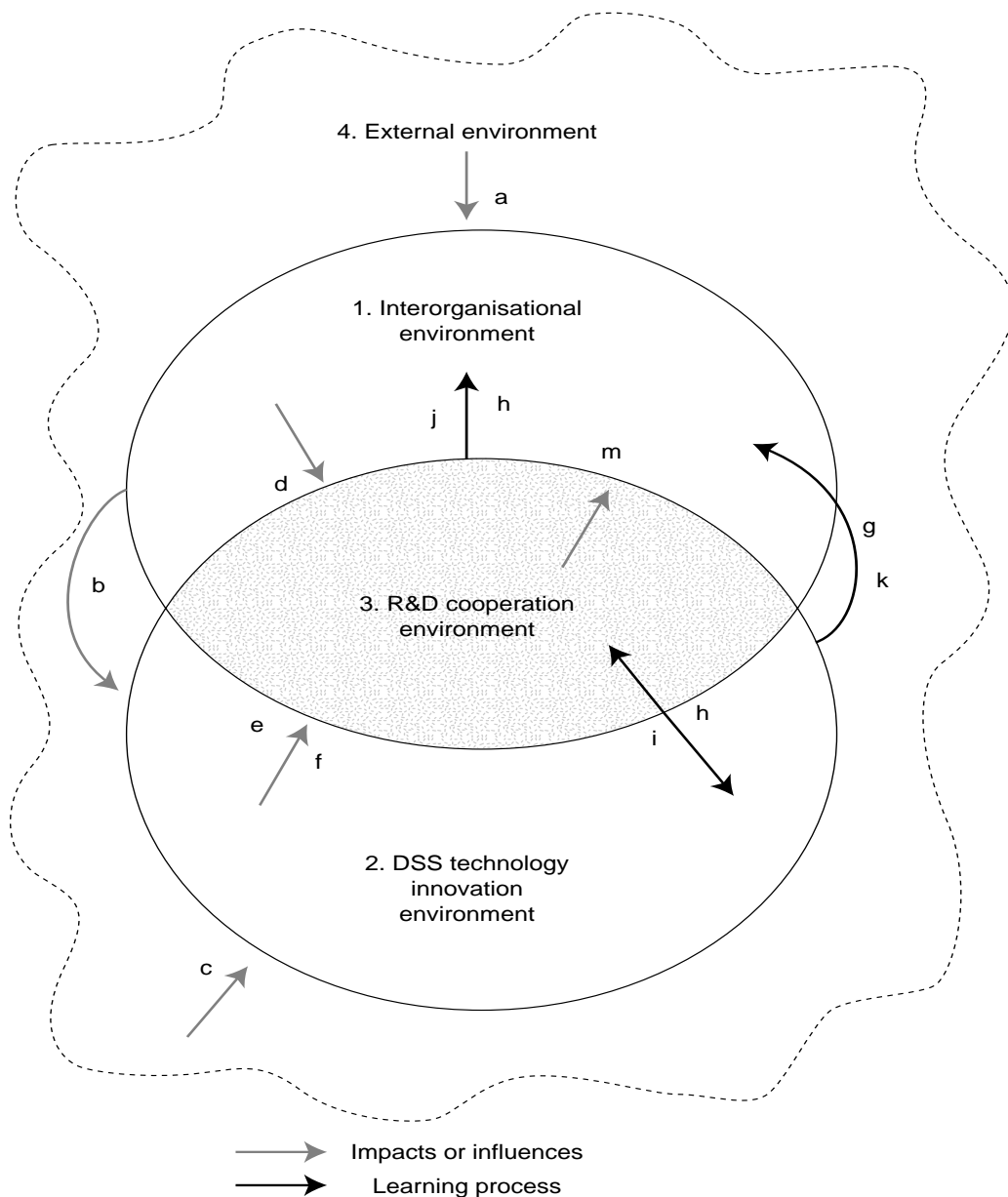
This process emerges in the collaborative development of a DSS technology innovation. Through this guided

interaction, interorganisational R&D cooperation is initially helped in part because: (a) the R&D itself requires such cooperation; and (b) the implications of being seen to not collaborate become transparent. The collaboration is maintained in part because the iterative development cycles are short enough to provide concrete evidence of progress made. Through participation in which stakeholder comments are addressed in subsequent cycles of development, a learning mini-ecology is created that encourages further input and reflection. The collaboration is also developed and maintained in part because of the determination and product championing of key individuals.

In it, the inter-organisational environment [1] relates to the diverse situational contexts of each of the various stakeholder groups with some responsibility for, or interest in, the broader resource use or policy context of the issue of concern. In particular, it encompasses the diversity of responsibilities, needs, relationships, decision making processes, and cultures of the stakeholder groups (including that of the DSS developers) comprising this interorganisational environment. The inter-organisational environment is influenced by forces and/or factors [a] operating in the external environment [4] over which the stakeholder groups may or may not have effective control.

This paradigm is schematically represented in Figure 9.1.

Figure 9.1 A new R&D paradigm for the role of science-based decision support technology innovations



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The interorganisational environment of the CTC1 project has been examined in Sections 2.2 and 2.3 of this report.

The external environment [4] is the context in which stakeholders operate. This could include: obligations to state, national and international policy initiatives, strategies, or conventions; the expectations of the roles and performance of the stakeholder organisations or constituency groups by, for example, external R&D funders and/or the broader community; and the current status of the available technology to support the research, such as computer software and hardware. The external environment of the CTC1 project has been discussed in Sections 1, 2.1 and 7.3 of this report.

The inter-organisational environment [1] influences and imposes constraints [b] on the decision support technology innovation environment [2]. This latter environment encompasses, for example, the DSS objectives, the system design and development methods, integrating frameworks/paradigms, and constraints relating to a number of factors. These constraining factors include the existing knowledge-base, the need for effective validation methods, the DSS developers' computing resources, and stakeholder requirements. The inter-organisational environment is characterised by purposeful, flexible, iterative, prototyping, and knowledge-based approaches. Within the context of the technical constraints [c] (such as the current status of computing technology) imposed by the external environment [4] and those constraints imposed by the interorganisational environment [b], the DSS developers can have relatively effective control over the decision support technology innovation environment [2]. This environment within the CTC1 project was examined in Sections 3.2, 3.3 and 7 of this report.

The interaction of the inter-organisational environment and the decision support technology environment shapes the R&D Cooperation environment [3]. This latter environment relates, for example, to the overall R&D objectives, stakeholder interactions, project resourcing (human and financial), and evaluation needs. It is dynamic, participatory and evolutionary, being responsive to both the inter-organisational environment [d] and decision support technology innovation environment [e] over the life of the project. Most importantly, it is initiated and facilitated through the iterative and evolutionary decision support technology innovation development process [f]. The R&D Cooperation environment of the CTC1 project is examined in Sections 3.2, 5, 6 and 8 of this report.

The traditional view of DSS development processes is that an initial needs assessment process leads to the development of a technology innovation for the assessment of a solution to a problem, which may or may not incorporate a choice about that solution. Learning in this traditional paradigm occurs through the identification of a tactical solution through the use or application of the technology innovation product. Learning therefore occurs directly through the

impact of the DSS technology innovation environment on the interorganisational environment [g]. This traditional view is a linear process-output model of DSS development and implementation. In practice, this approach has been found to benefit the agricultural and natural system scientists rather than other stakeholders, such as the resource managers (ie. farmers/producers).

In the new paradigm proposed above, the R&D Cooperation environment [3] is created through the interaction of the interorganisational environment [1] and the DSS technology innovation environment [2] through episodic, iterative and evolutionary cycles of stakeholder interactions. These interactions are guided by the DSS developers, and concentrate on the development of a technology innovation product [f]. In this paradigm, learning emerges incrementally through:

- an interactive and iterative process of incremental improvements to an integrated knowledge-base [h]; and
- an on-going iterative process of evaluation of stakeholder requirements that creates feedback cycles to the DSS technology innovation development process, which then in turn influence the R&D Cooperation environment [i].

Learnings may also occur through the interactive use of the various prototypes developed progressively over the life of the R&D process [j]; this is apart from the subsequent use of the final DSS innovation product beyond the life of the initial R&D cooperation agreement [k]. Significant impacts on the behaviour of individuals or organisations/stakeholder groups may also emerge through active participatory involvement in the R&D process [m]. These include changes in individual or organisational modes of operation. In this approach, learnings will accrue to and benefit the on-going groups defined above.

Improved understanding of the decision environment and the broader context of the problem can be confidently expected. Particular learnings at individual and organisational levels relate to:

- the needs, values, belief systems, and constraints of other organisational cultures [h,i]. This requires an enduring interorganisational R&D cooperation that involves the co-operation and active on-going participation of a broad range of stakeholder groups.
- the breadth, depth, complexity, and limitations of the existing knowledge-base relating to the resource management issue, the driving or critical factors influencing the issue, and its spatial and temporal dimensions [h,i]. This requires iterative and evolutionary prototyping technology development methodologies that foster co-ordination of activities across stakeholder groups and system developers.
- the decision dilemma relating to the resource management issue, such as the nature of the

environmental and economic trade-offs [j,k]. This requires the interactive use of an integrative DSS innovation product with good visualisation capabilities.

Other potential outcomes relate to individual or organisational behavioural changes, for example in the types of data they collect, how they analyse or interpret their data, and the way they interact with other stakeholder groups. This requires active on-going stakeholder participation through an enduring R&D cooperation.

Even this paradigm on the role of science-based decision support for sustainable resource management may not have gone far enough, that is it may not be holistic. As Adelman (1992) recognised, the decision to develop a DSS is nothing more than an hypothesis that this particular option will be an effective response to the problem environment. This may or may not be true. A further step may be to address the question of whether we should be trying to solve this problem through a DSS technology innovation development process at all, ie.—are we asking the right question? Other options, either singularly or in combination with a DSS technology innovation development process, may be more effective and efficient.

9.2 Implications of the new paradigm for science-based decision support technology

The new paradigm presents a major shift in developing and evaluating science-based decision support technology. Under this paradigm, DSS are to be developed and evaluated not only as tools for bringing about changes in the ways key stakeholder groups examine possible alternatives for improving sustainability, but also in how they collaborate upon such issues.

9.2.1 Issues of evaluation of DSS: process tool versus technology success

Traditionally, evaluation of the effectiveness of computer technology innovations—such as DSS, expert systems and organisational information systems in general—have mainly been approached from the viewpoint of an applied problem. This means using criteria such as user acceptance and level of usage of the innovation product, task efficiency and user/organisational relevance, or system functionality and ease of use.

However, science-based decision support technology innovation for sustainable resource use and management is characterised by a multiplicity of stakeholders with multiple and evolving objectives and a focus on broad societal purposes. Such innovation also has a broad range of potential outcomes and impacts, including learning processes and stakeholder behaviour modifications outlined in the previous section. Therefore, technical and institutional criteria should

not necessarily be the dominant criteria for evaluating effectiveness.

Consequently, the new R&D paradigm requires a range of different evaluation criteria and methods that place a greater emphasis on the effectiveness of the technology innovation development in terms of a process tool rather than technology success. That is, a more holistic evaluation approach is required that encompasses intangible outcomes (eg. stakeholder learning processes and behavioural change, improved stakeholder relationships and interaction processes, and broader societal benefits), as well as tangible outputs (eg. technical and institutional impacts) at a range of operational levels and time frames.

The CTC1 R&D process has identified the importance of generating an effective cooperative R&D process to capture the full benefits of a technology innovation development process. It has also highlighted the importance of using effective learning processes. Specific outcome criteria of the R&D process are not necessarily identifiable in advance, and there are no universal standards for the assessment of R&D on sustainable technology innovations. Hence an effective evaluation approach is to recognise the unique features and context of each situation, and be flexible in the choice of criteria and operational evaluation strategies. These criteria themselves will need to be negotiated and affirmed with the major strategic constituents as part of the iterative development of the DSS.

9.2.2 Implications for stakeholders of science-based decision support technology

The implications of this new paradigm for different types of stakeholders of a science-based technology innovation development process are now considered.

All major stakeholders

(i) The design and management of the R&D process has implications for all major stakeholders, including the following.

- An iterative and evolutionary R&D process can emerge through a guided participatory process of stakeholder interactions focused on joint activities to develop a technology innovation.
- An effective R&D process requires active participation of stakeholder groups through an enduring R&D cooperation; this may or may not be open-ended, but is based on a long-term purposeful relationship that facilitates the emergence of trust. Such relationships are most effective where the partners have similar values, beliefs, and cultures.
- The multiple and evolving stakeholder objectives can be significantly influenced through participative R&D approaches.

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- On-going management of such a relationship requires sustained work and commitment of all parties throughout the R&D process. Participation alone is not sufficient: stakeholders need to be able to affect decisions relating to the innovation development process so that they feel some 'ownership' of the R&D process.
 - A collaborative R&D process may crystallise and expose existing conflicts between the different stakeholder groups. In turn it can also provide mechanisms and opportunities for facilitating more constructive cross-organisational interactions amongst the collaborators, and even create the potential for conflict resolution.
 - Many of the most important outcomes of R&D processes are intangible and play out over a long period of time; so there is a need to adopt an R&D process that creates a continuous learning environment.
 - Innovation in technology development occurs through a host of small incremental improvements which provides a basis for accumulated learning processes.
 - A technology innovation development process needs to be iterative and evolutionary, rather than an aggregation of predetermined sequential phases. This will improve the influence of stakeholders interactions on the process by providing effective feedback cycles to enhance mutual learning.
 - If the emphasis shifts from support for tactical decision-making to that for on-going learning processes, there is a change in the level of precision of information required to support such decision support technology. This encompasses a shift to more qualitative and 'best bet' information which can be managed through knowledge-based approaches, as well as hypertext and hypermedia tools.
- (ii) Evaluation of the effectiveness of the R&D process has implications for all major stakeholders, including the following.
- Approaches to evaluation of the effectiveness of the R&D process should be multi-faceted, encompassing not only technical and institutional impacts but also less tangible outcomes (such as stakeholder learning processes and behavioural change, how the technology innovation development process impacts on the R&D Cooperation and interorganisational environments, and broader societal benefits).
 - The R&D assessment process needs to be considered in the context of the broader evolving situational factors relating to the social and political context of the R&D process.
 - It is important to generate an effective technology innovation development process, and there are no universal assessment standards. Therefore value trade-offs will be inherent in the negotiation of evaluation processes.
- On-going monitoring of the useability of the DSS prototypes and development processes by constituent/stakeholder groups through strategic constituency evaluation approaches may be an important indicator of overall effectiveness.
 - Given that the criteria for effectiveness will evolve as the multi-method evaluation approach changes over time in response to both the situational context and the evolving stakeholder objectives, an evolving on-going evaluation strategy is in turn required.

Technology developers

(i) Additional implications for the technology developers relating to the design and management of a facilitated participatory technology innovation development process include the following.

- The technology innovation developers need not only to clearly define their target audience early in the R&D process, but also to focus on 'on-going' evolving groups.
- Designation of the actual end-users will change over the course of the project as the issues being addressed become more clearly defined, and as the roles of stakeholders in relation to the issue evolve. The technology innovation development approach needs to be able to manage the changes in primary stakeholders and in their multiple objectives, as they evolve over the course of the project.
- The situational contexts in which each of the stakeholder groups/end-users as well as the system developers are operating will change independently of both: (a) the R&D problem being addressed; and (b) stakeholder and system developer control. A technology innovation developmental approach is required that provides a capability for constant adaptation to changes in targeted stakeholder needs and technological advancements that occur over the life of the project. For example, a system evolution strategy, such as the use of iterative prototyping, can accommodate a constantly changing interorganisational environment and evolving system objectives. Because of changing stakeholder needs and technological advances:
 - (a) A system design strategy is required that accommodates varying quality and depth of information, such as provided by a modular, object oriented, and knowledge-based design approach.
 - (b) Object oriented techniques and the use of hypertext and hyper-media have the potential to enhance the use of prototyping, and allow for increased participation in the iterative and evolving system innovation development process.
 - (c) Visualisation and graphical user interfaces aid the comprehension of concepts and information. The use of graphical tools to display results from models as well as

to provide easy interface with the system makes it more useful.

(d) An hierarchical design allows the user to understand the structure of the system and it also can provide linkages between related modules. This increases the useability of the system by avoiding unnecessary backtracking through the system.

(e) Explicit representation of uncertainty and confidence in knowledge-bases gives users greater confidence in the models and greater understanding of the limitations of the system.

- An iterative and prototyping approach can be particularly effective for experts, stakeholders, and system developers to reassess and confirm the objectives of the DSS technology development in an on-going way.
 - Although there are significant benefits to be realised from a participatory approach to an interorganisational cooperation, there are also potential costs. These include the escalation in commitment of time and financial resources to substantial interactive processes with multiple stakeholders by the DSS developers, the need to resolve ensuing conflicts, and the need to address conflicts amongst some key stakeholders.
- (ii) Additional implications for the evaluation of the effectiveness of the technology innovation development process for the technology developers include the following.
- The perceived usefulness of the DSS by key stakeholders is influenced by: (a) the degree of active user/stakeholder involvement in the system innovation development process; (b) the use of iterative and evolutionary development methodologies; (c) the DSS functionality; and (d) stakeholder learning experiences during the R&D process.
 - The dynamic and varied cultural and situational contexts of the multiple key stakeholder groups may significantly influence the effectiveness of the technology innovation development process.

Agricultural/natural systems scientists

Additional implications for agricultural and natural systems scientists include the following.

- An iterative and prototyping approach to a technology innovation development process is particularly effective for gaining a better understanding of the breadth and depth of the existing knowledge-base in an integrated format. Such an approach also helps to assess future knowledge-base requirements, integrate a scientist's data and understanding with that of other scientists, and recognise what is known about sustainability issues.

- From the researcher point of view, it is one thing to work within a cooperative inter-organisational R&D relationship, but undertaking research on the role and effectiveness of such an interactive process itself creates significant conflicts of time, financial resources, and personal relationships with collaborators.

R&D funders and providers

- (i) Additional implications of the design and management of the R&D process for R&D Funders (eg. R&D Corporations) and R&D Providers (eg. Research Organisations, CRCs) include the following.
- For R&D on complex and multidimensional sustainability issues through an inter-organisational cooperation, there is a need for an effective scoping phase to: (a) negotiate participatory relationships with the key collaborators; (b) scope the key management issues; and (c) define agreed objectives. But it should be recognised that these relationships and the agreed objectives are likely to change as part of the collaborative process.
 - Multiple, and sometimes conflicting, agendas of multiple funders can mean an escalation of commitment to specific aspects of a project well beyond that which was originally planned. This may result in episodic conflicts of interest emerging amongst stakeholder groups, system developers, and agendas of some funding groups. These changing agendas will need to be managed in a different way from that currently practised when using milestones.
- (ii) Additional implications of R&D evaluation for R&D funders and providers include the following.
- Assessment of R&D effectiveness needs to encompass both the process and the product: (a) the effects related to the innovative process of system development, both as an on-going activity of the R&D process and subsequently; and (b) the utilisation of the innovation product, both at the end of the R&D process and in the longer-term.
 - Research outcomes may relate to individual and organisational learning processes, improved relationships, and enhanced stakeholder interaction processes rather than more tangible outcomes.
 - Given the long time frame over which many of the outcomes will manifest themselves, the efficiency of such science-based technology innovation development processes is very difficult to assess. In particular, it is hard to assess the difference which the process has been able to make, in comparison to what could have happened without it.

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Appendix 2

Critique

Landassess DSS—a biological scientist's perspective

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CSIRO Tropical Agriculture

Development of Landassess

I was first exposed to Landassess in early 1991 and my initial reaction was not overly enthusiastic, largely because the work was in the developmental stage and I didn't have a good appreciation of the goals and objectives of the project. The conceptual approach to the project was not clear at that time and appeared distant from any potential benefits to resource managers/users. I realise in hindsight that this probably occurred because the users themselves, at that stage, did not have clearly defined requirements and that these emerged more definitively only after substantial interaction and increased trust developed among the user groups.

From my scientific perspective I was also unsure how the melding of knowledge-based systems and more quantitative biological models could be achieved and implemented. However, as an active participant in the development of state-and-transition models of vegetation dynamics for Landassess I became very positive about the "knowledge-based" systems approach, for two reasons. First, the iterative, workshop approach to developing state-and-transition models was far more efficient at arriving at seemingly sensible answers than relying purely on research data (most of which were unavailable in any case). Second, the workshop process in itself was quite rewarding and helped develop relationships between researchers from different agencies working in northern Australia.

The potential of Landassess became more evident to me when the GIS and state-and-transition modelling prototype became operational and I could witness visually how land resource condition changed in response to different grazing management strategies at the paddock scale. I could see how the spatial expression of the effects of grazing management would be visually impacting on resource users, particularly if they could relate that spatial representation to their knowledge of individual paddocks. From my research perspective I saw great potential for linking Landassess to our understanding of vegetation dynamics and foraging behaviour at small spatial scales to the more spatially relevant scale of the paddock.

Recognising this potential of Landassess, not just for resource users but also for our own research, I was more

than happy to contribute further to the project through assisting in the development of relationships between resource condition and pasture and animal production.

Overall, my involvement with Landassess during its development was rewarding and this involvement is continuing today as we attempt to make Landassess applicable to other regions. In the end, the value of any DSS is determined largely by how well the developers define and respond to user needs, which is a not inconsequential task.

Implications for Research

The processes used in the development of Landassess have some important implications for biological research. My comments below relate mainly to my role as a scientist who is interested in understanding how grassland systems respond to grazing management and from this understanding developing recommendations for sustainable pastoral production.

The approach taken in Landassess has the potential to be more widely applied to our understanding of how natural systems respond to management or disturbance. Biological scientists should be more willing to use the participatory and iterative knowledge-based approach employed in Landassess to generate "best bet" relationships where data are non-existent or where the system is too complex to quantitatively model with any confidence.

As scientists we generally spend too much time ensuring that our understanding is precise before we are willing to commit opinions without qualification. In many areas we would be better served by deriving important relationships through interaction with other scientists. Such a process would allow better prioritisation of declining research dollars to the most important areas where hard data are considered essential. I believe Landassess provides a framework that allows good use of both quantitative data and knowledge-based systems and challenges us to think about the prioritisation of data requirements.

Having just downplayed the need for a precise quantitative understanding of individual components of natural systems, I feel that Landassess could benefit from being more dynamic, particularly in running its management scenarios. At present, stocking rate and climate are static variables. In rangelands, the interaction between a highly variable climate and stocking management is the key determinant of vegetation dynamics. An approach that embraces this variability rather than excludes it would be extremely beneficial to resource managers/users to gain a more realistic representation of how the interaction between climate and management affects both production and the resource. From a research perspective, a more dynamic approach would allow us to better assess the sustainability of various management strategies at the paddock scale.

Case Study 2. Decision Support for Sustainable Management of Grazing Lands

My final comments relate to the worth of modelling and decision-support systems. In general these have been increasingly questioned by R&D funding agencies and research organisations which in the last decade or so have seen little end-user impact of these approaches. Through its participatory approach whereby a wide range of people was able to contribute to the development of the final

product, Landassess has to some extent been able to overcome the problem of foisting a piece of technological software on a group of unreceptive end-users. It is to be hoped that this has a positive side-benefit in R&D agencies having a more favourable disposition towards decision support systems in the future.

Case Study 3

Market Research for Decision Support for Dryland Crop Production

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Market Research for Decision Support for Dryland Crop Production

Abstract

Scientists build and use models. Scientists learn through the processes and communication that surround the construction of their models. The continual refinement and adjustment of scientific models is evidence of the learning taking place amongst scientists. Scientists are engrossed with matching model performance with reality. But scientists' needs for learning are quite different to those of farmers.

Farmers build and use models too, as a guide to practical action and new opportunities. Like scientists, they continually upgrade their models in response to new information (obtained through the mass media, and field days) and through their individual and shared interpretation of events on their farm and in their district. Farmers want to identify and manipulate the important variables – ones that they can control – that lead to demonstrably better outcomes. Learning, through building and upgrading models, is evident through changed behaviour.

The purposes of scientists and farmers differ. Our research strongly suggests that the continual embellishment of scientific models to serve the needs of scientists (to meet the purpose of more precise description of natural systems for an audience of fellow scientists) has no more than marginal relevance to the needs of farmers managing their business in an environment characterised by uncertainty about markets and seasons, and its impact on productivity. Yet this has been the justification hitherto for considerable investment in the development of agricultural decision support systems which are not used in practice. These products are residual artifacts of an emerging scientific understanding of the biophysical processes that underpin agricultural production. They are largely disposable.

In this study, we attempted to capture farmers' models through interviews with farmers and advisers in Central Queensland and on the Darling Downs (southern Queensland), and to describe scientists' models through participation in the Agricultural Production Systems Research Unit (a joint project of QDPI and CSIRO, devoted to the development of crop and soil simulation models). In addition, we participated in the APSRU on-farm program (in which scientists' models were demonstrated to farmers); we conducted two workshops in which farmers and advisers were asked to evaluate four different approaches to decision support (including the use of rules of thumb); and one of us (PC) re-interpreted his experiences in the closing stages of the SIRATACOTTON pest management project.

Our focus in this project was on how scientific models could be used to open up possibilities, with much improved outcomes, for farmers. We thought that they should generate insights, with potential to improve outcomes, which to date had been overlooked by farmers relying solely on their models. To do this, we actively questioned the purposes of the scientists, and their assumptions about the purposes of farmers.

Our observations suggest that use of decision support systems often contributes to the premature closure of discussions, closing off debate between scientists

and farmers, and creating dependence when we believe our aim should be to open up possibilities for doing things differently. This is particularly the case when model-based products are promoted without due recognition of the understandings that farmers already have and which find expression in their own models and rules of thumb. The decision support system, as currently implemented, is an old-fashioned technology; by itself, it is taking us nowhere. The underlying professional skills in systems analysis are not being used to greatest advantage by regarding communication between such different audiences as a packaged product. Failure to recognise, to question, and to build upon, the different perspectives, values and purposes of these different audiences only serves to reinforce existing power relationships and restricts the development of novel patterns of innovation.

The issue becomes that of articulating different categories of model, used by different groups of people to do different things: of using models to help bring two different perspectives to bear on an issue of common concern in order to effect change and development in both. Realisation of this objective will require considerable re-engineering of institutional R,D&E processes aimed at achieving outcomes with clients. The development, use, and abandonment of model-based tools will be part of this.

So here I am, in the middle way, having had twenty years –
Twenty years largely wasted, the years of l'entre deux guerres
Trying to learn to use words, and every attempt
Is a wholly new start, and a different kind of failure
Because one has only learnt to get the better of words
For things one no longer has to say, or the way in which
One is no longer disposed to say it. And so each venture
Is a new beginning, a raid on the inarticulate
With shabby equipment always deteriorating
In the general mess of imprecision of feeling,
Undisciplined squads of emotion. And what there is to
conquer
By strength and submission, has already been discovered
Once or twice, or several times, by men whom one cannot
hope
To emulate—but there is no competition –
There is only the fight to recover what has been lost
And found and lost again and again: and now under
conditions
That seem unpropitious. But perhaps neither gain nor loss.
For us, there is only the trying. The rest is not our business.

T.S. Eliot, *Four Quartets*

Throw the lumber over, man! Let your boat of life be light, packed with only what you need—a homely home and simple pleasures, one or two friends, worth the name, someone to love and someone to love you, a cat, a dog, and a pipe or two, enough to eat and enough to wear, and a little more than enough to drink; for thirst is a dangerous thing.

You will find the boat easier to pull then, and it will not be so liable to upset, and it will not matter so much if it does upset; good, plain merchandise will stand water. You will have time to think as well as work...

Jerome K. Jerome, *Three Men in a Boat*

Market Research for Decision Support for Dryland Crop Production

Peter Ridge and Peter Cox

Contents

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7 Summary and recommendations

Acknowledgments

References and Further Reading

Appendix I

Commentary on the Final Report of Project 3, by R.L. McCown (CSIRO Leader, APSRU; designer of this project and the sister on-farm project studied by this project) and Peter Carberry and Mike Foale (leading APSRU scientists in the on-farm project)

I History

I.1 The original objectives

The original project objectives (as stated in the Project Proposal to LWRRDC) were:

1. Describe existing cropland management strategies and outcomes in four sub-regions to provide a baseline.
2. Identify ecological needs and economic opportunities for improved strategies.
3. Understand decision-making processes, identify opportunities for decision support and the features of information products likely to be adopted.
4. Identify farms and farmers for inclusion in networks for R,D&E in a companion project.

A second thrust of the proposed research was an examination of existing decision support products.

These will be examined in detail with their authors, with farmers who use the product, with non-user farmers and with farm advisers. We shall develop a working group with other researchers and extension specialists to advise on appropriate research procedures. We will ask: Does the product represent the decision adequately? Is risk adequately considered? Are economic considerations adequately incorporated? Is the use of a computer contributing to the quality of the decision, or is it a distraction? Can we specify the design characteristics of successful products on the basis of our current experience? To what extent does success reflect the nature of the problem, the users of the product, or the product itself? Can we design research that more consistently generates successful products that farmers will use in making their decisions?

(Quoted from the Project Proposal)

At the time the original proposal was made, APSRU had only recently been set up as a joint project between the CSIRO Division of Tropical Crops and Pastures (CSIRO) and the Queensland Department of Primary Industries (QDPI). APSRU was established to exploit the skills in both organisations in the simulation modelling of crops and soils. Those who set up APSRU argued that these skills could improve decision-making in resource use by farmers. The perceived success of the SIRATAC (cotton) and *Wheatman* (wheat) projects was taken as evidence of this, and of the value of computer-based decision support systems (DSS). There was some apprehension in the group that this might not be entirely straightforward and the view was expressed that APSRU did not want to be known five years later as 'the modelling group', with the implication that it was isolated from the real world of decision-making. That would be taken as evidence that APSRU had failed.

In preparing its strategic plan for 1991–1995, APSRU saw its task as client-oriented R&D of agricultural systems

to improve production efficiency, risk management, and sustainability in subtropical Australia. The plan aimed to gain a better understanding of clients' decision-making behaviour so as to find opportunities for providing them with useful information products.

This project was to show that APSRU was determined to be relevant to the needs of farmers, farm advisers and policy makers. It represented a commitment to 'do' market research, and to respond accordingly, rather than to generate products solely on the basis of simulation technology. There was one problem: no one in the group had any background or skills in marketing.

I.2 Background to the project

Each of us brings a unique perspective to the interpretation of data. It matters little whether the data are scaled quantitatively or qualitatively (nominal data): what we can see in data depends partly on our training, and partly on the interaction of our experiences with this training. The authors of this report brought quite different (multiple) perspectives to the conduct and interpretation of the research on which it is based. A strength of this work is that, by becoming more aware of the multiple biases that we as authors and readers bring to our interpretation of events, the best aspects of using 'triangulation' of multiple approaches can be reinforced as a way of bringing about methodological rigour. Thus, we believe that it is important for the reader to be aware of the background of each of the authors. Our personal accounts form the background to the project from our perspective.

I.2.1 Peter Cox's story

My original training was in biochemistry—probably one of the most reductionist of the biological sciences. I took my MSc degree in plant pathology, partly out of an interest in the properties of systems at higher levels of organisation (parasitism, pathogenesis) and partly because the UK Ministry of Overseas Development was willing to pay—on condition that I worked for three years in a developing country afterwards. I did that, became disillusioned with agricultural research, and returned to the UK to the Department of Industrial Science at Stirling University to do my PhD in technological economics, an inter-disciplinary field dealing primarily with the management of innovation. My thesis was about the use of models to support decision-making for pest control. The models included both mathematical programming and simulation. I spent the next ten years working on contract in various developing countries in Africa, south Asia and the Pacific. I got caught up in the Farming Systems Research movement when I worked for the Department of Agriculture and Livestock in Papua New Guinea in the 1980s.

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Several experiences influenced my thinking (and my approach to agricultural R&D) over this period.

I had spent over two years trying to figure out how to live with the rice stem nematode, a serious disease of deep-water rice in Bangladesh. I was showing a colleague round some of the rice areas as part of my handing over at the end of my contract. We spoke with a farmer who was harvesting his crop a bit early, and we talked about the disease. He thought it was not really a problem if you used an early variety—I had taken two years to reach a similar conclusion, two years I might have saved if I had spoken with him first (although I would probably not have appreciated the significance of his observation if I had not tried to figure it out myself).

In Papua New Guinea, I was side-tracked into doing research on the chemical control of taro leaf blight—because experiments on a research station are easy to do, because nobody else was working on chemical control, because I could rationalise the use of this technology, and because it provided me with ‘bread and butter’ research while we developed a program of farming systems research. I did not follow up clues that control of the disease is possible through agronomic practice even though this would have provided an excellent opportunity to work with farmers to tackle their problem on their own terms.

I moved to Australia in 1988 to join the SIRATAC program with the CSIRO Cotton Research Unit at Narrabri. SIRATAC (an early computer-based DSS for cotton pest management) was collapsing and the scientists were intent on developing technological fixes (‘decision support systems’) to maintain the SIRATAC program. It seemed to me that the problems lay elsewhere: they were social, not computational; and that the early apparent success of SIRATAC was based on a very special combination of circumstances unlikely to be replicated elsewhere (Cox 1996). I joined APSRU in 1991. The justification for my appointment was in part because of my experience of SIRATAC (I had witnessed at first hand what can go wrong); in part, because I appeared to assert a point of view more closely aligned with that of farmers rather than scientists; in part, because of my insistence on seeing things differently. It was thought that my skills would help APSRU focus on practical issues, and help design practical solutions. Some expressed concern that I would not support the development of DSS technology: that I had already made up my mind about it. At this time, talk within the group resembled that of farming systems research with which I had developed a certain sympathy.

The formal proposal for the project was written largely by Dr Bob McCown. Dr Peter Carberry also had a hand in it. Both have international reputations as scientists: McCown in cropping systems, and Carberry in crop physiology and modelling. I had some input, but I was still recovering from my experience of Narrabri to be too critical of the APSRU style of doing business (and, in any case, I was on leave!).

After all, McCown had endorsed the value of my contribution even though I had been thrown out of the CSIRO Division of Plant Industry at the end of my contract in Narrabri. In those days, APSRU was open to different ways of seeing the world. Market research appeared to be an acceptable framework for looking at client needs, even though none of us had any direct experience of ‘doing’ market research. It also appeared to be based on a naive assumption that if you ask people what they want then they can and will tell you, and that this should determine your product development strategy (regardless of product development costs, feasibility, possible synergy with other activities etc.). We proposed to examine central Queensland, Darling Downs, southern Queensland and northern NSW progressively in successive years of the project. The project was also linked in a loose way (although I don’t recall that the links between these two projects were ever thought through) with the GRDC on-farm pilot study. The decision by GRDC to fund this in central Queensland but not on the Darling Downs meant that much of the technical on-farm work and staff would be concentrated on central Queensland. In the first instance, it seemed logical to plan the market research project in parallel with the on-farm project in central Queensland.

In order to secure funding for the IWRDRC program, we agreed, at the instigation of Peter van Beek, Systems Special Projects Officer with QDPI, to link the project to the recruitment of a QDPI extension officer to work as project officer, and establish links with Professor Jim Taylor of the Distance Education Centre at the University of Southern Queensland (USQ). It was envisaged that the project officer would register for a PhD under the supervision of Taylor. This fitted with our interests in establishing links with the local university, and gaining access to the skills in programmed instruction/distance education at USQ. In the event, QDPI was unable to release one of its officers for the project. Taylor proposed Noel Thomas, a member of his staff. To ensure that Thomas’s PhD program was balanced, I also managed to involve Dr Paul Ledington, of the University of Queensland. We had a workshop at the Distance Education Centre to outline Thomas’s PhD proposal. There appeared to be substantial agreement about the significance of using models to capture different perspectives (of farmers and scientists particularly). The articulation of these different models, and the use of discrepancies between them as potential entry points for learning, appeared consistent with both Taylor’s approach (educational psychology) and Ledington’s (soft systems methodology). The language of models, and the notion of discrepancies between them (in both structure and function) was also endorsed by McCown. Shortly after, Thomas withdrew from the project because of changed personal circumstances. Peter Ridge joined the project as project officer in February 1994. Ridge has a considerable reputation in the south as a consultant and systems thinker. His appointment as project officer was welcomed by McCown.

In the meantime, I had tried to keep the project alive by beginning farmer interviews in central Queensland with Dr Alan Garside who had been appointed project officer for the central Queensland on-farm project. McCown, Garside, some others and I held a planning meeting for the on-farm project in Emerald. It debated the number of people/groups to include in the on-farm project. McCown was arguing for a single farm/farmer, which would be enough to test the crop simulation models. I (and Garside) argued for a larger number of farmers and at least two groups if we were to say anything sensible about the role of groups (networks of farmers) as a way of doing research and interpreting/validating/extending model output. It was far from clear at this stage what the role of the models would be. Garside was sceptical that they had any role at all, but the monitoring required for model calibration would be useful in its own right. The argument was then about the intensity of monitoring required to track system performance (low) or to calibrate the models (high). The compromise was to set up two groups of farmers, one near Emerald, one near Moura. A third site (a producer demonstration site) at Springsure was also included as a gift to QDPI Extension in Emerald (improved monitoring; use of models to help interpret). Two groups with about five farmers in each was the minimum configuration we felt confident with. McCown agreed to this.

Garside set up the groups using his contacts in the QDPI: one in Capella through Graeme Spackman (ex-QDPI, now a private consultant), and one in Banana through Stuart Cannon (QDPI soil conservationist). Garside and I organised a meeting with these two groups. We emphasised that we wanted to work with them on experiments they were already doing which had something in common with the interests of researchers. This meant water and nitrogen which scientists saw as both driving and limiting the system. Thus fertiliser experiments were included. Experiments on herbicides and neomin were not. To some extent, Garside and I had taken over the research agenda by changing the way it is set: we emphasised farmers' involvement in setting priorities, the experiments farmers were already doing, and the constraints under which farmers conduct their own experiments. The challenge to the professional researchers was to demonstrate that they (with or without their modelling tools, as they chose) could usefully contribute to these activities within the constraints imposed by their accepted methodology (Cox *et al.*, 1993a). That paper pointed out that this was an activity of a modelling group, and that if APSRU had any comparative advantage it would be through the use of models, in some way as yet unknown. Thus by early 1993 the on-farm research had to do with the value of researchers' models within the context of farmers' experiments. The on-farm project and the market research project had converged.

In August 1992, I began the field work in central Queensland, working with the farmers who formed part of the on-farm project. We asked them how they used the four

different technological components of a farming system which McCown had suggested as most likely to lead to more sustainable farming practices: fertiliser, purposeful crop sequences, surface management, opportunity cropping. We summarised their responses as rules, and checked these with them individually. We aggregated the rules and checked again at two group meetings. We felt that we could not unpack any more. We also tried to elicit some decision trees and some personal estimates of the likely distributions of yield. People found these exercises more or less easy. We compared elicited distributions of sorghum yield with model output obtained from John Dimes who used one of the crop models now included in APSIM. There were clearly discrepancies: the model over-estimated the yield in the middle part of the distribution. This might be explained as evidence of a yield gap; if so, it provides one example of the way to use crop models in the context of an on-farm program. This was not pursued.

I had previously introduced Christina Gladwin's work on ethnographic decision-tree modelling as a way of capturing farmers' decision-making behaviour and presenting it to the other scientists. We tried to pattern the rules the farmers had agreed to into a decision tree. This did not work: some decision twigs were evident, but it was clear that the tree-like structure was a superimposed construct which significantly altered what farmers had told us. Art Shulman, who took part in some of the interviews for his documentation of communication within the technology transfer process, pointed out that all the models are different and that we needed to capture that. The rule sets are a convenient way of capturing farmers' models. There are many models (ways of doing things; ways of describing/making explicit what we do), because people are trying to do different things, because they face different resource constraints and opportunities, and because they see the world differently. The models which we had elicited/constructed captured these differences well: between farming systems (crops; crops with cattle; cattle with crops); and by location (Banana; Capella). There was some evidence of stability in the rule sets despite a severe disturbance (the long drought), as Art pointed out, and adaptation to changing circumstances (the differences in the historical exploitation of soil fertility in Banana and Capella). The rule sets also clearly differed from the scientists' model in breadth (the scientists' model has a rather narrow scope, but is rich in hierarchical complexity), stability (the scientists' model was brittle) and adaptability (the scientists' model has been slow to adapt to changing circumstances and remains focused on water and N regardless of the mice and locusts).

We felt that we could now say something about farmers' models in a way that captured some of the richness of their behaviour, and which contrasted this with the scientists' models (Cox *et al.*, 1993b, 1995). Complexity of models was clearly an issue. I have discussed this (Cox, 1993) and made the point that complexity is a matter of design, not a

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given. It is something that we choose to incorporate or not (to a specific extent), not something that is thrust upon us. Complexity arises out of the interaction of an observer and a natural system, and is not something inherent in the natural system that can be captured in an objective way. This paper valued the elegance of the farmers' models and placed them in stark contrast with the scientists' models, which exhibit a particular level of complexity (because that is the way scientists perceive the world) for no apparent reason from a management perspective. Models that describe underlying natural processes may have little relevance to a practical situation where the issue is more about how to respond to ever-changing patterns of circumstances. Farmers' models are adept at coping with open systems; scientists' models are one way of describing a quasi-closed system. Our design vocabulary was starting to expand.

Some of this I began writing up by Christmas 1993. I used my previous experience with SIRATAC as a case study—partly because I now saw this as politically safe since the SIRATAC User Group (SUG—previously SLUG, the SIRATAC Loyal Users Group!) had folded and SIRATAC was no longer operational. I had hoped to include as co-author Ken Brook, who had been manager of the SIRATAC project before moving to QDPI. I was starting to point out the apparent absurdity in the notion that scientists' models provide any immediate basis for decision support for practical decision-making at farm level. This argument was consistent with my experience both at Narrabri and now at APSRU. I believe that the scientists were upset because of their previous commitment to developing simulation models and using them in decision support products, and because I was not expressing sufficiently strongly possible alternative 'places' for crop simulation models. Any criticism of APSIM (as the APSRU cropping simulation environment had now become) was now clearly off limits. McCown said that he would block publication of the paper. I tried to get Dr Greg McKeon to contribute to the paper in order to insert the 'balance' which he, Brook and McCown claimed it lacked. (I thought it was pretty balanced already, and that my criticism of modelling activities directed at decision support at farm level was relatively muted, and intended to achieve a better balance). After some time, McKeon and I reached a kind of agreement about the case I was trying to present, that the arguments were both valid and substantial ... but they still hurt. McKeon would not agree to be co-author unless Brook did. Brook refused because he saw this as disloyalty to SIRATAC and the SIRATAC staff with whom he had worked for so long. I elicited Shulman's help in structuring the paper better so that the argument was clearer and talk of failure would not close down all communication. Shulman pointed out the relevance of escalation theory to this situation. That fitted and was incorporated in the paper. It was eventually submitted for publication in early 1995 (Cox 1996), well over a year after it was first written, and it has since been accepted by *Agricultural Systems*.

About three months after Ridge joined us, the modellers began their kitchen table sessions with farmer groups, first with the groups set up by Mike Foale, a CSIRO soil monitoring expert, on the Darling Downs, and then more widely. I objected that these had little to do with the joint experimentation that Garside and I had promoted in central Queensland two years before. McCown and Carberry maintained that the approach was entirely consistent with what we had proposed; indeed, that what they were doing was what I had said they should do. The models were initialised on the basis of monitoring data obtained from the on-farm trials (or at least from commercial paddocks) but the issues were dictated not by the demands of unpacking an issue that all parties had agreed was important (and using tools appropriate to it) but by what the models could do. To a large extent (but not entirely—the appropriate treatment of the variable costs of cotton production is an example), scientists did not appear to listen to or value the contributions of farmers to the discussion either during the kitchen table sessions or at other times: the scientists' model was right since from their point of view it provided an objective standard by which practical reality could, and should, be judged.

I attended a number of these sessions. In some, I was impressed by the way the farmers proposed explanations for obvious errors in the model output (e.g. overland flow of water, temperature discrepancies, radiation differences between seasons). In others, the farmers' models were clearly able to cope very well with the issue faced. The value of information about the deep nitrogen bulge found in the on-farm monitoring is an important case. During an interlude when the crop models fell over, we asked the farmers what they would do if they knew they had deep N; some said they would pull back on their N rate a bit (but still use a starter rate); some said they would not do anything differently because in some years the roots would not get down far enough to reach the N source. The scientists' model could not handle that issue till six months later; and still the interpretation of the model output was confused. The possibility that information about deep N might have zero value was not accepted by scientists. By the end of 1995, this was still not widely accepted. Indeed, the distinction between the value of the N and the value of information about the N was never clearly expressed by scientists. I tried to open this discussion over e-mail. I pointed out that there is a range of answers to this sort of question, that it can be approached by using a range of models of varied complexity, and that farmers' models can do a good job in handling issues of this kind. Such comments were not seen as helpful and further discussion was discouraged. My attempt to open debate about the appropriate use of the particular category of model represented by APSIM thus did not meet with immediate success in mid-1994.

An external review of APSRU towards the end of 1994, intended to evaluate the performance of the group against

the original objectives and plot a direction for future development, only reinforced these concerns. It appeared to endorse a previous conception of the value of a particular category of model (computer simulation) regardless of the issue at hand, as against an issues-based analysis with or without the use of particular models. For me, the history of APSRU over the last five years has effectively been a re-run of the SIRATAC story at Narrabri, despite the early attempts to avoid such a fate. Some people (Ridge, Freebairn) see this; others appear not to. This is disappointing because four years ago APSRU staff did not wish to be known as the 'modelling group' and were intent on being relevant to farmers, although perhaps unclear about what that meant. What we have seen is a reversion to previous modes of behaviour, whether under the pressure to obtain external funding for projects, or to satisfy the review, or to satisfy an inappropriate reward system that values scientific papers of a certain kind. This cloak of objectivity fails to recognise, let alone to value, the insights of other stakeholders, and the changes required in the way we do business if we are to influence others to behave differently.

To a large extent then, we have shown up some of the limitations of a particular class of crop model to support routine decision-making in the management of agricultural production systems (Cox, 1996). We have been partly successful in getting model constructs of other stakeholder groups on the agenda (Cox *et al.*, 1995). We have suggested other ways of doing business, working with stakeholders to examine matters of mutual concern, which have been taken on to a greater or lesser extent (Cox *et al.*, 1993a, 1994, 1995, 1996). And evaluation of models is on the agenda (Cox *et al.*, 1995). But the preoccupation with a unitary model persists albeit with some exceptions, most notably Freebairn's support of other model categories.

There is scope for using simple models to help explore the different courses of action available to practical managers (either in the context of group discussions, or one-to-one). These models will largely be a refinement of existing rules/models. Models of the APSIM type are poorly justified in this context because of their lack of transparency and their need for considerable technical support. That technology has been oversold, and we need to step back from it to evaluate it properly. People, for whatever reason, tend to undervalue their own models/constructs compared with the 'objectively-derived' constructs of professional science. My critique of simulation modelling is two-pronged: it points both to the inadequate exploitation of these models as research tools (because people just believe them and do not interrogate them in the context of a specific issue); and to the excessive claims made by scientists about the ability of these tools to guide the practical management of production systems—i.e. about their value as DSS. It is still about horses for courses, but only just.

1.2.2 Peter Ridge's story

I came to APSRU early in 1994 after ten years as a cropping consultant in Victoria's Wimmera region. My move into consulting was in part prompted by my realisation, from research on reduced tillage systems, that routine monitoring of soil water and nitrogen could offer the possibility of more intensive cropping than was then normal. This realisation was prompted by the 1982 drought when crop failure caused soil water to be left untapped. This water, originally accumulated through the wet 1981 season, was carried forward into 1983. For this reason, I promoted the re-cropping of paddocks in 1983 which had failed in 1982. The normal practice was to return them to fallow. This proved rather more successful than expected and it took us some time to appreciate that the main cause was the accumulation of large quantities of mineralised nitrogen under failed crops through the drought.

I started consulting early in 1984. It was a good time to start as there was plenty of money about after a very good 1983 harvest. 1984 was a very average season but good reserves of soil water, accumulated under fallows prepared in the wet 1983 winter, promoted some very good yields. The cropping system began to change very quickly. By 1983, field peas were quite well established as an alternative to cereals and were promoted for their value as a disease break (cereal cyst nematode and take-all). The area of field peas peaked in the late 1980s and other crops were progressively introduced. These included chickpeas (highly profitable at \$300 plus per tonne), faba beans (sometimes profitable, but often diseased), canola and safflower. Growers were starting to ask a lot of questions and were challenging the old insistence on a fallow to accumulate soil water from one winter to sustain crops through the spring of the following year. Routine monitoring provided some of the answers to these questions. Some crops (e.g. faba beans and canola) regularly left substantial reserves of soil water which could be exploited by growing a crop in the next season. Soil nitrate nitrogen was generally higher after faba beans than after chickpeas. New highly-productive sequences of crops which virtually eliminated the threat of cereal root diseases emerged from these discoveries.

In addition to the routine monitoring of soil water with a neutron probe, I started to measure soil nitrate N (0–60 cm) in 1985. My interpretations were based on Reg French's work on fallowing in South Australia and research (simple models) published by Bob Myers (Myers 1984). I monitored my first canola crop (called rape in those days) in 1985. It was grown on country that had been sown to medic and fallowed. Soil testing in the autumn revealed 170 kg/ha nitrate N (0–60 cm) which was the highest level recorded in any paddock that year. I thought that this should be more than ample for a good canola crop. The crop suffered an early set-back from red-legged earthmite, but once these were brought under control the crop took on the appearance of a cabbage patch gone wild. It grew so high that we were

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not sure that it could be windrowed. It proved to be a bonanza of 3 t/ha at \$370/t on a rising market.

Chickpeas were the next exciting prospect. The Department of Agriculture was keeping the technology close to its chest, but by 1986 farmers were clamouring for a slice of the action. Weed control was a major issue and, after five seasons of replicated trial work, the department recommended Bladex (4l/ha and \$40/ha) for broadleaf weed control. The growers quickly became frustrated with a product that was so thick that it could not be coaxed through the filters of their boomsprays. Bladex also failed to control weeds when used according to the label. I was aware that Allan Mayfield, then with the South Australian Department of Agriculture, had done some unreplicated observation trials with simazine and atrazine on chickpeas. I could think of a dozen other mixtures that might prove successful. With a grant of \$5,000 per year from the Victorian Wheat Research Committee, I undertook a program of trials that spanned three years (1987–89). By the third year, almost all Victoria's expanding area of chickpeas (100,000 hectares in 1989) was treated with simazine and atrazine which proved highly effective and cheap at \$7/ha.

To validate my approach to soil nitrate testing, I undertook a few simple nitrogen fertiliser trials on paddocks with low and high soil nitrate N. By 1989, I was keen to expand these trials and to introduce simple tissue tests (sap nitrate) to allow growers to monitor the nitrogen status of their crops. They could then consider top-dressing with urea according to the opportunities presented by each season. I won financial support from GRDC for this purpose. I found that tissue tests were an especially useful adjunct to soil testing in identifying opportunities for top-dressing urea in seasons of above average rainfall. The growers did their own trials to validate the approach—usually with missed strips in paddocks and occasionally with strips in missed paddocks. Changed behaviour flowed quickly from the learning so acquired.

Throughout this time, new crops were continually being introduced: vetch, lentils and linola. Markets were emerging and disappearing. For a short time, vetch was being sold at a premium as ersatz lentils; but this market disappeared overnight as the result of a health scare about its use as human food. Growers (and their advisers) were continually attempting to make sense of this kaleidoscope of experiences. They had to make their next move without ever being clear about the meaning of their last experience. No longer could the growers afford the luxury of waiting for the definitive answer to emerge from long-term research. There was an urgent need for immediate interpretation as a guide to action.

The formation and early work of APSRU had attracted my attention. I had read in the *Queensland Grain-Grower* of Mike Foale's exploits with simple hand-driven soil sampling equipment. I met Bob McCown at the Agronomy Conference in Adelaide in September 1993. I was left with

the impression that the APSRU group was focused on cropping systems issues and that its modelling capability could provide some useful leads. I thought that the modelling approach should be able to provide opportune answers to the urgent questions of the day. I was looking for a change of direction after ten years in consulting, and relocating to Toowoomba offered more opportunities for my children as they approached their upper secondary years. I also believed that my background could be useful to APSRU which was attempting to apply its expertise to managing crops in sustainable cropping systems.

I was not entirely comfortable with the 'Market Research' project proposal but thought that it was sufficiently vague for me to develop a project to suit my interests. I mistakenly believed that I had three years to bring the project to fruition, but within three months of my arrival I learnt otherwise. I embarked on some initial open-ended interviews with producers on the Darling and Western Downs to gain a better understanding of their cropping systems and the rules and models that they use as guides. I wanted to do this because I foresaw follow-up interviews in which questions about the scope for doing things differently would be asked, but I got side-tracked on to other matters, including an involvement in the sister on-farm project. I accumulated data in the form of transcripts. The preparation and checking of transcripts occupied much of my time. It was clear that data of this type are open to a variety of interpretations. I was not uncomfortable with this because my interpretation of scientific data often differed from that of my peers: I could often see possibilities and opportunities for farmers that had been overlooked by the scientists who originally collected the data. I accept that we bring our own unique perspective to the interpretation of data, and that these are shaped by the learning which we accumulate through formal education and experience.

1.3 Background to our methodology

In developing our approach to this project, we drew heavily on the ideas of Checkland (see Checkland, 1981; and Scholes, 1990). We recognised that issues to do with the management of biological production systems are, in Checkland's terms, Human Activity Systems (HAS). The way to successful intervention in an HAS is different from that used by scientists to describe natural systems because it cannot be studied as a system independent of, and external to, the actors who form the system. Researchers are part of the system in which they are intervening; and if they are not part of the system, their intervention will be ineffective. While there can be many different perceptions of an HAS, depending on the position of the actors and the arena in which they are operating, the value of an HAS model resides in whether it helps to create opportunities to negotiate an improved (less problematic) situation for particular actors.

Since the nineteenth century, science has accumulated an impressive record of achievement through the application of methods which are characterised by reductionism, repeatability and refutation. Breaking down the whole into its component parts has been an effective way to develop understanding at the process level about the behaviour of biophysical systems. But the application of such understanding to the business of managing complex systems may require a different approach. One approach used by scientists is to re-create the whole by re-combining in models their disunited pieces of understanding. This is the approach used by crop physiologists in their development of crop simulation models. In other cases, the system cannot be re-created from its parts because the whole has properties that are quite different to the sum of its parts. This is the concept of emergence. The relative importance of emergent properties is the basis of the category mistake which has led researchers to apply the same approach to managing production systems as they have traditionally used to describe biophysical processes. This mistake has persisted only because of the extent of the cultural gap between scientists and farmers; but this is jumping ahead in our story.

Our approach in the market research study loosely followed that of stages 1 and 2 of Checkland's Soft Systems Methodology (SSM). We took the view that because we were not even sure what the problem was, we needed to immerse ourselves in the problematic situation over an extended period: to dance, to affect and be affected, in order to discover a pattern in it. We were hoping to effect change, and possibly new learning, with other actors. We joined the dance; we suggested new steps; we tripped over; we recovered. And the dance moves on.

The HAS included APSRU and its scientists, crop producers in north-eastern Australia, and their advisers (agribusiness, public sector and independent). We wanted to understand what our colleagues in APSRU hoped to achieve through their construction of crop simulation models; how this could be made more relevant to the goals and needs of crop producers; and the extent to which advisers reflected the needs of farmers, and therefore could be relied upon to facilitate interactions between APSRU scientists and farmers. But, more importantly, we took Vickers's view (Checkland and Casar, 1986) that social systems are not so much goal-seeking, but rather about maintaining relationships which create possibilities for the actors. Communication was central to the project.

Over a three-year period, various qualitative and quantitative approaches were used depending on the nature of the inquiry (the episode in which we were involved). The justification for the choice of a particular method will be evident in the body of the report, where we also discuss the limitations of each approach. Each episode suggested further possibilities which we tried to build on. The approach we adopted (our route through the project) was rather different

from that initially envisaged. Our relationships with other actors also changed during, and as a result of, our involvement in the project. And our ideas about methods of engaging, and how to talk about different episodes, also changed.

In initial interviews with farmers in central Queensland, we tried to capture what farmers were telling us about the way they managed various technological components which were believed by researchers to contribute to the development of a more sustainable production system (use of fertiliser, opportunity cropping, purposeful crop sequences and surface management). It became clear that different farmers managed these in different ways; that what farmers told us could be represented by rule sets; that the rule sets constituted the farmers' own models of the systems they were managing; that these models constituted effective management tools for the problems they faced; and that these models differed in several important ways from the models of scientists (Cox *et al.*, 1996). Later work by Peter Ridge on the Darling Downs confirmed in our minds the value of this interpretation for improving communication between farmers and scientists. These 'systems of action' are described in Chapter 2. But the low use of DSS products by farmers for routine decision-making, which was confirmed by our initial interviews with them, led us to question the assumptions underlying the design of DSS technology and its provision within a traditional framework of extension practice. Thus early on we were led to switch directions and to focus more of our effort on the way in which models are developed and used by scientists.

We easily formed relationships and established communication with farmers and advisers. Communication between ourselves and our colleagues in APSRU was rather more strained. Our approach was viewed with suspicion because it was not seen to be objective, reductionist science. We failed to communicate successfully that the study of human activity system can never be 'objective', and that our interpretations (models) can never be other than a small sample of the many possible interpretations (models) that might be advanced. We consider that those we did advance are of value both to farmers and scientists because: they avoided the trap of endorsing a linear, one-way communication channel—a trap experienced at first hand by both Ridge and Cox (Cox, 1996); they opened options for novel configurations of interaction; and they valued pluralism in interpretation as an effective strategy to cope with complexity, uncertainty, conflict, and differences in the perception of these. This would not have been achieved through the imposition of a reductionist, scientific approach. These 'systems of thought' are described in Chapter 3.

Our scientist colleagues quite clearly had different expectations from us about the results of our study. They wanted us to define the specifications of decision support products which would meet the needs of the market (in

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terms of content, provision of options, input requirements, mode of analysis, and choice of output representations), so that these could be used to re-jig their crop simulation models and enable them to 'do good things'. But, as we progressed through several episodes, we increasingly questioned whether scientific models (complex simulation models intended to describe the behaviour of the natural world for a scientific audience) could provide, for instance, a decision support product which would bring about improved management. We were prompted to raise these issues by the fact that farming communities showed little interest in computerised decision support products (Stapper, 1993; LWRRDC, 1993) as well as by the patterns of innovation we witnessed as they unfolded at APSRU. From our point of view, APSRU had become preoccupied with the development of APSIM to the virtual exclusion of any other category of model. APSIM was increasingly portrayed, both internally and externally, as the vehicle for APSRU's main contribution to the development of improved management of broadacre agricultural production systems. From our point of view, this development was looking increasingly bizarre. Nevertheless, the progressive acknowledgment of process was an emergent theme (Chapter 4).

At one stage in our research, we attempted to bridge the communication gap between ourselves and the scientists by retreating to a paradigm of enquiry with which our scientist colleagues would be more comfortable, even though we were not. We recognised that their way of construing the world is based on the assumption that it could (and should) be mapped as if humans had little agency and would respond in law-like ways. We decided to encourage dialogue by setting up the story line with the use of constructs that were familiar to them—when in Roma (or Dalby, or Toowoomba), do as the Romans do. This research strategy can be regarded as consistent with our principles (1) of market relevance (here scientists are the market); and (2) of bringing about possibilities by recognising the possibilities of others. Within this framework, we conducted two evaluation workshops for decision support approaches, one with a sample of farmers at Dalby and the other with advisers in Toowoomba. At the planning stage, we spoke with some of the people involved in the development of these products in order to establish their vision for them. We used the findings from these discussions to draw up specification sheets for each product or approach. These were referred back to the developers for comment before they were used in the workshops as a basis for comparison. In these workshops, we used a questionnaire to capture some reactions of potential users to four different approaches to decision support, and quantified these reactions as ratings. This questionnaire provided quantitative data on the background of participants (e.g. areas of crops sown in the case of farmers, and contacts with farmers in the case of advisers). The questionnaires allowed us to present data, within the scientists' ways of construing, on the degree to which the

workshop process and exposure to decision support products changed the views of participants (e.g. of advisers to crop simulation models or business planning). The sessions were taped, and transcripts of these provided additional (qualitative) data about the nature of the communication between participants in the presence of the decision aid. The results of the two workshops are presented in Chapter 5.

In a general way, our approach was consistent with recent thinking in qualitative data analysis. Thus (after Miles and Huberman 1994, pp. 6–7):

- qualitative research is conducted through an intense and/or prolonged contact with a life situation
- the researcher's role is to gain a 'holistic' (systemic, encompassing, integrated) overview of the context under study
- the researcher attempts to capture data on the perception of local actors 'from the inside', through a process of deep attentiveness
- the researcher may isolate certain themes that can be reviewed with informants
- a main task is to explicate the ways people in particular settings manage their day-to-day situations
- many interpretations are possible, but some are more compelling for theoretical reasons or on grounds of internal consistency
- the researcher is essentially the main 'measurement device' in the study
- most analysis is done with words.

In addition, and importantly, we tried to incorporate a non-neutral constructivist position which recognised ourselves as actors (effecting actions, actively seeking to bring about change) in the problematic situation.

Rigour resides in the use of multiple methods, and in the scope for individual methods to provide additional evidence, to confirm or deny a particular interpretation. Rigour in data collection and analysis was sought in several ways:

- triangulation, with progressive verification of patterns, through our involvement in multiple incidents, with various groups of people (scientists, farmers), at various locations (farmers in central Queensland, and on the Darling Downs), at various times (over the three years of the project);
- direct participation in critical incidents (e.g. the on-farm project in central Queensland, the development of an interpretation of the deep nitrogen bulge) and subsequent follow-up of the interpretation with other participants;
- verification through proposing alternative explanations of critical incidents, opening up possibilities for novel

interpretations of a shared experience, and through confirmatory feedback on the substance of conclusions from some of the actors involved (but importantly not all);

- generalisation through recounting, and reinterpreting in the light of current experiences, other situations in which we had been involved e.g. Cox's experience of SIRATAC; and
- through deliberately engineering particular kinds of interaction with other actors (e.g. the two DSS workshops), in ways sympathetic to their perspective.

Rigour needs to be distinguished from efficacy and evaluation. Outcomes emerge within relationships with each party's outputs being evaluated (and re-evaluated) by the other. Whereas the capturing of the process requires rigour (recognising a consistent pattern from multiple perspectives), the value of the approach resides in its ability to generate new ways of looking at the world, and to negotiate novel meanings with other actors, leading eventually to better outcomes. The notion of rigour is itself socially constructed, and part of our project was to stimulate re-negotiation of this construct with our colleagues; this is still going on.

The conduct of these relationships is essentially episodic and discontinuous; the nature of these relationships changes as a result of continual engagement (including different kinds of engagement with different groups); and people willingly enter into relationships of this kind to seek ways of doing things differently. We are learning to live in a more complex world inhabited by multiple stakeholders with multiple agendas.

We learned that there are as many perceptions and models of natural systems as there are of human systems. The distinction between natural and human systems, proposed by the scientists as a way of conserving their particular point of view, cannot be maintained, because the management of natural systems is very much a human activity, and it is only through the human system that we come to know the natural system¹ (Shulman *et al.*, 1990). Progress in the way agricultural production systems are managed is more likely to be realised if all actors actively seek out and evaluate alternative ways of viewing the world than by rigidly adhering to a single point of view. The best farmers are masters of this. They actively pursue opportunities to challenge their own perceptions and models. They do this

by active observation, through formal and informal discussion, and through their reading. There is, to our way of thinking, clearly a need to embrace multiple models to meet the different needs of, and to communicate with, the many individuals who constitute the HAS associated with farming.

In summary, as part of this project we sought:

- to capture farmers' models of what they are doing;
- to develop and use an effective representation of their models so as to discuss them with our scientific colleagues;
- to argue for the effectiveness of farmers' models for what farmers are trying to do;
- to demonstrate the power of these models compared with the simulation models of the scientists for what farmers were trying to do;
- to get the notion of multiple models (whether for different purposes, or for the same purpose but used by different actors) accepted as axiomatic;
- to raise the issue of the way in which different models (models with a different purpose, models used by different people) may be articulated;
- to propose preferred modes of articulation if purposeful change in the way agricultural production systems are managed is to be achieved; and
- to suggest a framework (re-engineering) within which such a transition could be managed.

At the outset, we did not realise the size of this task: the shift from an output-oriented culture to an outcome-oriented culture is substantial, particularly for a science-based organisation such as CSIRO. By our continual questioning of the actions of our colleagues we were in real danger of subverting the kind of relationships we were trying to build (ones we believe to be necessary for attempting the transition). Yet, if we did not question those actions, we would have been seen as endorsing a particular point of view which we did not see as helpful to progress (at least not to the exclusion of all others). This would lead, we believed, to ever-deeper organisational commitment to the provision of DSS products which no one would use, and which therefore had no value. This put us in a difficult position.

2 Systems of action

2.1 Introduction

By 'systems of action', we refer primarily to the world of farmers, the practical managers of agricultural production systems. But those aspects of their world in which we were interested were initially defined by the interests of the scientists. Thus, in our interviews in central Queensland, we restricted our questions (interrogation) mainly to the use of the four technological components regarded by scientists as potentially contributing to more-sustainable farming systems (see Miles and Huberman, 1994). In addition, we attempted at first to use a tight approach to data display based on Gladwin's ethnographic decision tree modelling (Gladwin, 1989). We encountered problems with this which we describe in our paper (Cox *et al.* 1995). A dance metaphor provided an alternative framework, more dynamic than a tree, and one that emphasised the nature of the communication processes in which we were involved.

2.2 Farmers in central Queensland and on the Darling Downs

2.2.1 Personal characteristics and market responses to DSS

I'm not prepared to make a change. Maybe if I was 10 or 20 years younger I'd be happy to...I'm not prepared to lay out big money at this stage in our farming life to change our farming methods. ...Yes it could be done, but we're hoping to give up farming in about five years.

Producer, Dalby September 1994

In 1994, the average age of farmers in Australia was 53, and their number continues to decline. These statistics mask a huge adjustment problem, namely that a large number of farmers are anxious to leave farming in the next few years, and are therefore not prepared to jeopardise their financial security in retirement by adopting new methods: their priority is to maintain their generally strong equity position. This is especially the case when most new methods involve an investment in learning, as well, perhaps, as borrowing to invest in new equipment. It is therefore not surprising that the management of much of Australia's farming land remains conservative.

Those who are charged with developing new technology and decision support products must recognise the limitations imposed by the high average age of farmers and adjust their approach accordingly. This includes working alongside farmers with technology appropriate to their stage in life and their aspirations as farm families. This will usually mean working with simple low-risk technologies; but most importantly it will mean very clear and concise

communication of the benefits in terms that will have wide appeal. There are plenty of these technologies, but their very simplicity means that they no longer excite the imagination of scientists. In these cases, the communication of the technology is far more challenging and exciting than the underlying science which is often twenty or more years old. However, there is real danger in re-packaging old science as computerised decision support: while it revitalises the interest of scientists in the old and mundane, it does nothing to widen its appeal for those who might benefit most from its application.

Alternatively, decision support developers can choose to work with a more receptive group of farmers who are usually younger, have bigger debts, and are more ready to embrace risk and debt in the interests of greater ultimate reward. This group, which may represent 20–30% of the farming community, generally accounts for most of its production. They are usually better educated and are young enough to take a longer-term view. However, decision support packages and crop simulation models do not always appeal to this group because at least some of them know that what they contain is already out of date:

As the computers get more powerful and are able to take into account more factors, well you see we're already doing that...I suppose they're good for putting down on paper what we already know.

Producer, Dalby, September 1994

2.2.2 On-farm research

If our experiment works we're going to cultivate up the rows, grow them on 30 inch rows, and cut down on the use of chemicals.

Producer experimenting with chickpeas, Chinchilla, July 1994

All the producers interviewed as part of this project provided their interpretation of one or more experiments that they had conducted over the last five years. In all cases, these experiments had been done in isolation and there was no *formal* means of sharing insights between neighbouring farms. What insights were shared through informal means is unknown.

Even within quite short distances around Dalby, the topics of on-farm research were quite diverse. Some were examining the establishment, survival and productivity of a range of pasture grasses and legumes, while others were assessing the green manure value of lablab (*lablab purpureus*) for its effects on ensuing crops.

In other areas (including the farmers in central Queensland interviewed by Cox), experiments related to the use of grain legumes to reduce outlays on nitrogen fertiliser, and there were many instances where farmers were checking responses to nitrogen and phosphorus fertiliser. Here, there was some evidence that farmers formed self-selected groups and shared their experience.

The interpretation and exchange of information between growers urgently needs to be facilitated. This can best be achieved if they work in small groups, under the umbrella of a larger organisation which can expedite exchanges between groups and across regions. In addition, if communities are to get the most out of these uncoordinated experiments, there needs to be an attempt to collect some additional data, such as from chemical analyses of soil and tissue, and through the use of weather stations. In this way, it should be possible to interpret these experiments better and accelerate the learning by linking the results from farmers' experiments with those of professional science. The TOPCROP and MEY Check programs were introduced to standardise the approach to data collection within a region, but most importantly they aimed to maximise the learning from farmers conducting their own monitoring. The models of professional science can also contribute to this learning so long as they are transparent and flexible enough to allow participants to focus on, and highlight, the most promising issues.

We asked farmers specifically about their use of four technological components which scientists believe contribute to the development of more-sustainable farming systems: crop sequences, fertiliser, opportunity cropping and surface management. Other issues emerged during the interviews such as marketing, and storage facilities for grain and fertiliser (Cox *et al.*, 1995). The five aspects discussed below provide an indication only of what farmers already know, and the way in which they articulate their knowledge.

2.2.3 Rotation principles

If you keep planting the same crop year after year you start getting a build up of weeds.

Producer, Dalby, September 1994

According to some blokes that you talk to they've had no trouble growing prime hard wheat in the next year following chickpeas.

Producer, Chinchilla, July 1994

Most farmers interviewed recognised the value of rotating both winter and summer crops to control weeds. Many rotations consisted of three winter crops (with an intervening summer fallow), followed by two or three summer crops (with an intervening winter fallow). No diseases, such as nematode or fungal infections of crowns and roots seem to have influenced the development of crop rotations.

Generally, there was little use of detailed soil monitoring, in developing and modifying cropping programs (opportunity cropping). The only exceptions to this were found among those farmers who had been intimately involved with APSRU and its soil monitoring techniques as part of the on-farm project. At least one on-farm cooperator had been using deep testing for soil nitrate for some years. The push probe was used widely for assessing the status of soil water

but the link between its use and changed decisions was tenuous.

Dryland cotton is not yet widely grown on the Darling Downs, although it earned important income for most of the participants in the APSRU on-farm project on the Downs. Whether or not they grew the crop, most farmers were keen to debate whether cotton could be grown sustainably in rotations in the longer term. Lack of soil cover after cotton was seen to be a serious drawback.

For the \$10 an acre it costs to plant that's cheap insurance to keep your topsoil.

Producer referring to lack of soil cover after cotton, Dalby, September 1995

There is a widespread recognition that cotton thoroughly dries soil profiles and leaves the soil prone to soil loss. Most dryland cotton growers are therefore prepared to re-crop cotton stubbles directly to a cereal (generally barley), well aware of the possibility of crop failure, in order to restore soil cover and maximise the opportunities for recharge of soil water in the following summer—they plan to manage the consequences of their actions.

2.2.4 Nitrogen fertility

Dad tells me the other day he used to get 15–16% protein, no troubles at all, but now we're struggling to get 13; 12 just about pulls it up without fertiliser. ...But once again I don't think that actual fertiliser is the answer. It will certainly help but I wonder if it's going to be detrimental in the long run.

Producer, Chinchilla, July 1994

All the farmers interviewed expressed sentiments similar to the above. There was a general recognition that fertility had declined markedly over the last twenty years so that wheat of prime hard quality was no longer assured.

Those farmers who were actively involved with APSRU were happy to apply nitrogen fertiliser to solve their fertility problem, but the others were less enthusiastic about bag nitrogen, and were often actively experimenting with grain legumes, green manure crops and pasture legumes. The results of these experiments were often quoted in terms of the increased yield and protein content of wheat and sorghum crops that followed.

There was no general appreciation of the quantities of nitrogen removed at harvest of the various crops, or that the higher yields, achieved through improved timeliness of operations over the last 15 years, were hastening the decline in fertility. The rule of thumb about the crop's requirement for around twice as much nitrogen as is removed at harvest was not widely appreciated by farmers. However, this issue has recently been the subject of some workshop activity on the Darling Downs (Lawrence, personal communication).

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Moreover, growers had not been exposed to the rules of thumb that determine how much extra nitrogen fertiliser is needed to reliably guarantee prime hard wheat at various yield expectations.

The concept of applying nitrogen to achieve a target yield was familiar to a few cotton growers participating in the APSRU on-farm program. In one case, a cotton grower described a relationship between the target yield for cotton and its nitrogen requirement, which was subsequently found to correspond with published information (Ridge *et al.*, 1996).

None of the growers interviewed knew that sampling surface soils for total nitrogen or organic carbon content could provide an index of a soil's nitrogen mineralisation capacity. Sampling for this purpose has been done routinely by APSRU for participants in the on-farm project, but its value to growers, in terms of savings on nitrogen fertiliser, has not been explained. Farmers responded with interest when it was revealed at a workshop session on rules of thumb at Dalby (see Chapter 5), that each 0.5% of organic carbon equated to about 30–40 kg of mineralised N per year, worth about \$25–30 per hectare per annum in fertiliser savings. This revelation has obvious implications for producers negotiating share-farming and lease arrangements, and in screening properties for purchase.

2.2.5 Crop choice

Like your chickpeas, they come in for harvest at the same time as you want to start planting cotton...it's a lot easier to have only one winter crop planted.

Producer, Dalby, September 1994

If it is early, you put cotton in. If it is late, you put sorghum in. It is as simple as that.

Producer, on-farm session, Brookstead, June 1994

When describing their rules for selecting crops, farmers consistently listed profitability, yield and marketing risk as important factors in their decision, although they rarely referred to them in these terms. In addition, their choice of crop had to be compatible with other elements of the cropping program, especially where there was a clash between crops in their respective demands on a limited pool of labour.

Crop choice was often dictated by the timing of a planting rain. Detailed soil coring for available soil water and nitrogen was rarely used to choose between crops: while soil water is often crudely estimated from growers' use of the push probe, and reference to their rainfall records, they use this merely to provide a guide to crop prospects. This information might then be used to adjust the balance between crops—for example, grow more barley and less wheat if soil water reserves are low. This arises from a perception that barley needs less water than wheat for an economic crop.

The decision to choose a crop is therefore usually made in the context of many interacting factors which appear over time. The most important of these are: the timing of planting rains, market outlook, rotational benefits (including stubble cover), and the ability to control weeds in the crop. In some cases, crop choice is restricted by the likely carry-over of herbicide residues from previous crops. The more detailed specification of available soil water and nitrogen, so as to use crop simulation models for developing tightly specified yield distributions, may help but its value depends on the relative importance of other factors which affect the decision.

2.2.6 Planting date

We don't adjust sowing date...when it rains you plant...and according to the time of year you adjust your crop type.

Producer, Dalby, September 1994

In the northern grain belt, crop options and opportunities are often restricted by a lack of planting opportunities. Even when soil profiles are full, there are sometimes no opportunities for growers to take advantage of the good reserves of sub-soil moisture. A few growers have overcome this by deep planting into moisture at wider than normal row spacings. In 1994, after heavy rains (200 mm) in March, an on-farm cooperator near Capella achieved a 0.8 tonne per hectare chickpea crop by adopting this approach. This provided excellent returns with chickpea prices at \$600/tonne, but would have been marginal at normal prices of \$250–300/tonne. In this case, the insight did not come from the output of a chickpea simulation model but from kicking the soil with the farmer and talking through his options. Planting was precipitated by a shared realisation that chickpea prices were likely to remain high, that chickpeas could emerge from depth, and that wide row spacings would not adversely affect their yield. Yield distributions were not explicitly considered.

Like the frost probabilities of Wheatman, we take that into account, but I would still plant if it rained and the frost probability was fairly high.

Producer, Dalby, September 1994

Given the lack of planting opportunities in Queensland, the emphasis on frost damage (and its avoidance) in the computerised decision support package, *Wheatman*, appears to be misplaced. Most growers would be loath to miss a planting opportunity: even though frost is a risk with very early plantings, they would still elect to plant at least part of their cropping program, possibly with longer-season crops and cultivars. In practice, growers attempt to manage this risk through a portfolio of different crops, and varieties of different maturity. Growers recognise the risk of frost damage, acknowledge differences between crops in their susceptibility to frost, and appreciate that frosts are more frequent in drier seasons. *Wheatman* may have contributed to this knowledge but much of it would have been drawn

from experience, shared and accumulated over a long period.

2.2.7 Marketing

Even though we sold a heap this year at \$500 per bale, the price is now \$600 per bale, and considering it was \$400 per bale three months ago.

Producer, Dalby, September 1994

Many farmers who had over the years become accustomed to a regulated market, with a guaranteed minimum price, are now feeling very vulnerable in a deregulated market, particularly the smaller producers who feel less able to manage market risk. They do not produce enough to make an investment in on-farm storage economic. They are unable to put together sufficiently large parcels of grain of consistent quality to attract buyers. They feel disempowered.

On the other hand, larger producers, with a turnover in grain of at least \$200,000, are in a far better position to exploit price volatility. They see deregulation of markets as an opportunity rather than a threat. Nowhere is this more apparent than among cotton growers who thrive on managing the large production and marketing risks that are an integral part of their business. Larger producers have sufficient volume to justify the installation of crop storage facilities, and they can put together large amounts of produce to attract buyers. They are also able to enlist the support of marketing consultants.

Given the differences between these groups of farmers, there seems little point in better specifying production risks, with a view to managing them better, unless marketing risk is tackled at the same time. What matters to growers is the product of price and yield (less costs), and there appears to be little justification for focusing on one factor to the exclusion of the other.

2.3 Advisers

During this project we formally interviewed public and private sector advisers in order to understand better how they have contributed to the development of, and currently use, computerised decision-support packages such as *Wheatman*¹. In some cases, we also asked about their expectations of APSRU, and their views on the relevance of its modelling capability (APSIM) to their needs as advisers.

2.3.1 Wheatman

We would be more concerned that it correlates with what we expect in yields and proteins...at least for the good growers that we are working with.

Public sector adviser, 20 January 1995

The users of *Wheatman* were largely confined to advisers in QDPI. They, like their colleagues in APSRU, were concerned with the 'credibility' of their models: that yields predicted by *Wheatman* should closely match the experience of growers. They felt obliged to establish this credibility before they could advance it as a source of new insights and possibilities.

The general opinion is that [*Wheatman*] will be used more among agribusiness and consultants because it is a reasonably complex program.

Public sector adviser, 20 January 1995

[*Wheatman*] is good...for consultants and agronomists to run through it all to get their rules of thumb in line.

Public sector adviser, 30 November 1994

QDPI personnel involved in the development of *Wheatman* thought private sector advisers would be important users of the program. There was little evidence to suggest that this was the case as yet (see Chapter 5), but there was at least one agribusiness adviser who indicated that he used it on behalf of farmer clients. At least one other public sector adviser said he used *Wheatman* at the start of each season to update his understandings in preparation for presentations to farmer meetings.

People that have used *Wheatman* may use it once or twice then learn from it to the extent that they don't need to go back to it. ...I believe that I've got *Wheatman* in my head.

Private sector adviser, 30 November 1994

Most of the advisers interviewed believed that once *Wheatman* had been thoroughly interrogated then much of the information it contained could be compressed to some working rules—i.e. that it was not very re-usable. At least one respondent valued the look-up table for days-to-flowering for varieties of different maturities. However, if that is to be referred to regularly during the sowing period it would be more convenient to have a printed version on hand instead of regularly running *Wheatman*.

...frost is a very difficult thing to quantify. ...Look back at those bad years...have all been late frosts and the earlier plantings have got through it.

Private sector adviser, 30 November 1994

The original focus of *Wheatman* was frost risk and its management through the manipulation of planting date and variety. One adviser was not confident that *Wheatman* could adequately predict the yield loss from any given frost event because there appeared to be a whole host of factors, apparently not included in the underlying model, that could

¹ Neither APSIM nor Howwet (see Chapter 5) was commercially available at the time of the study, but advisers were familiar with what kinds of output models could generate. Some of them clearly had expectations for APSRU.

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alter the effects of a frost on a crop. Further enquiry revealed that the basis for calculating yield loss from frost damage was not widely appreciated by those responsible for the development and promotion of *Wheatman*.

...the positives are the farm paddock records...and the graphical output. ...it's a pretty comprehensive package with the paddock recording, spreadsheets, costs and prices.

Public sector adviser, 20 January 1995

The focus of *Wheatman* has changed over the years. Originally, managing frost risk in wheat was the priority, but it now covers a range of technical issues including fertiliser use, control of wild oats, disease risk, management of herbicide resistance, and the calculation of gross margins for the options of interest. In recent months, the potential of its paddock-recording facility to support individual learning has been highlighted. This is a very ambitious goal for any computerised decision-support product. It has been difficult to establish how *Wheatman* will support learning by individuals who work on their own records in isolation. Our interviews with farmers suggest that they normally prefer to learn within groups, and that this learning is more likely to emerge from the joint construction of models and interpretations based on paddock records and other local data.

2.3.2 APSRU and APSIM

Many of the advisers interviewed had been part of the APSRU on-farm activities. In our discussions with them, and in a subsequent evaluation of the Dalby pilot on-farm project by Dr Jeff Coutts (Rural Extension Centre, Gatton), it was clear that they became involved with APSRU because it offered scope for learning.

You don't necessarily need the modelling. I think that you can just go out and do the monitoring...I just think the models just add a bit extra dimension.

Public sector adviser, 30 November 1994

Much of the learning stemmed from APSRU's monitoring of soil water and available nitrogen, which was needed as an input for running crop-simulation models. Several advisers spoke highly of the learning that accompanied the soil sampling but were more circumspect about their experiences with the models.

If a model can verify a rule of thumb and maybe question some others...I think that it can serve a fairly useful purpose.

Public sector adviser, 30 November 1994

It has got to be better than what I'm doing at the moment for me to want to use it.

Private sector adviser referring to APSIM, 30 November 1994

Although many advisers were critical of APSIM output (eg. yields), they were generally keen to remain involved with APSRU. The advisers remain positive about APSRU and APSIM because they envisage that further development of APSIM will eventually allow it to account realistically for rotation effects, will identify the most likely frequency of cropping within rotations, and will be sufficiently fine-tuned to cope with the nuances that they observe in crop productivity in their district (100 km radius). Their expectations for APSIM are high and it remains to be seen whether APSRU can satisfy them.

2.3.3 APSIM in the hands of advisers

Several private sector advisers, who admit to an earlier scepticism about the value of crop-simulation models in their work, are now embarking on an ambitious program of training in the use of APSIM in order to become accredited providers of it. Their commitment to this is substantial. To date they have, in aggregate, invested over \$30,000 in computers, soil sampling equipment and weather stations in addition to their commitment of time to training which is expected to exceed 12 days over the next 18 months.

These advisers say that their enthusiasm stems from a realisation that they can no longer satisfy the demands of their best performing clients for information that will guide them to even greater crop productivity. Their hope is that APSIM will meet these demands and allow their clients to break through the productivity barrier. This of course assumes that the barrier relates to an issue (e.g. nitrogen or water) that APSIM handles, and that the model will highlight the best way of relieving constraints. If the problem lies somewhere else (for example with VAM or root disease), then it is unlikely that APSIM will be helpful.

Moreover if APSIM can be used to re-create the specifics of a paddock, then the simulated yield can be used as a benchmark against which to judge the management of the crop. This is particularly relevant to cotton, where insect monitoring and well-timed insecticide applications are crucial to crop success. There is also the possibility of using simulated yields to establish objectively the extent of losses arising from events subject to insurance claims, such as hail. The use of crop-simulation models in this way (when, even in an ideal situation, they provide a yield prediction with a considerable margin of error) would require substantial negotiation between the affected parties.

Finally, the yield expectations derived from the crop-simulation models in APSIM are being considered as a basis for risk management by agribusiness firms which supply inputs and extend credit to the farming community. In this case, there is a real danger that the models will be viewed as a substitute for, rather than informing, professional judgment in managing the risks inherent in an agribusiness supply firm, and the legal implications of this for model developers should be viewed with concern.

2.4 Reflections on our approach to 'systems of action'

We began our project using the ethnographic, decision-tree, modelling framework proposed by Gladwin. This provided an alternative modelling approach to that of the scientists. It got us thinking about rules and sets of rules. We recognised that the rule sets may have been rationalisations, after the event, of the way farmers approached their decisions. But they were *their* rationalisations. As models, they appear to us to have equal status (although a different purpose) with the scientists' models. Yet the notion that farmers have models too was a strange one for the scientists. Thus, the assertion of farmers' models allowed us to question the idiosyncratic features of those of the scientists: why are they daily time step?; why are partial models valuable?; how do we know that the models are right?; what is right anyway?; why do they need all those inputs?; why aren't errors recognised?; what is the importance of different sources of error?; why are they so concerned with precision?; and why is the credibility of these models among farmers so important for them?

This was a deliberate strategy for effecting change in the scientists' models. It also helped to move the agenda towards greater recognition of multiple models (representations), the use of different models for different purposes, and greater acceptance of scientific models as 'just another point of view' in the context of management. After very few interviews with farmers and advisers we gained sufficient understanding to enable us to distinguish between the models used by different farmers, and between farmers' models and scientists' models. Since this was our purpose, it made no sense to catalogue a much wider range of farmers' models even though that appeared to be the aim of the original project and the way in which the scientists had originally envisaged it—as 'how farmers make decisions'. This route (equivalent to stamp collecting) would not have enabled us to bring a searchlight to focus on the scientists' models and contrast them, as we wished to do, with the way in which farmers make decisions (or at least how they talk about making them). The discrepancies were so large that a small sample was sufficient to do this. This highlighted the nature of the problem we face in designing decision-support products by scientists for farmers.

The more we learned about 'how farmers make decisions', the more we realised that decision-support products, developed by scientists for farmers, did not succeed in changing farmers' ways. Success is more likely to flow from a focus on process rather than products. This was the real basis of our project.

3 Systems of thought

3.1 Introduction

Since 1991, APSRU has refined and developed an 'operational research' capability in the form of a software package called APSIM (Agricultural Production Systems Simulator). This was a response to an emerging recognition 'that a "systems approach" was needed to meet the challenges presented by the complexities, uncertainties and conflicts in modern agricultural production systems' (McCown *et al.*, 1995). This view apparently emanated from the scientific community, partly thanks to some successful use of models with tactical decision-making in crop production (Hamilton *et al.*, 1991).

A major advantage of the module configuration of APSIM is its ability to simulate the performance of cropping systems, and the impact of one crop on succeeding crops, through simulated effects on soil water and available nitrogen. This is claimed to represent a major breakthrough in which the power of individual crop-simulation models is, for the first time, brought to bear on cropping systems. APSIM is expected to respond to 'extremes of environmental inputs' in predicting yield variation for the purpose of analysing economic risk. At the same time, it will simulate trends in soil erosion as influenced by management factors such as crop sequences, intercropping, and crop residue management.

Tools like APSIM are expected to aid the search for better farming practices. But the connection between the predictive performance of models and their ability to deliver better farming practices is far from clear. Reliably mimicking past crop performance, and producing tightly specified yield distributions, are not sufficient conditions for learning and gaining new insights. Rather, we would maintain that it is the interpretation of past experience, and skill in spotting patterns of events as they unfold (and responding to these in an appropriate way), that are the key to increased productivity on farms.

The strategic plan recognised that rainfall was the 'main determinant of both the nature of the production system and variation in financial returns'. Hence, improvements in production efficiency and risk management were expected to come from more effective and efficient use of rainfall. To date, the concept of water-use efficiency has been rejected because it fails to account for the timing of rainfall events (Hammer *et al.*, 1993). Rather, simulations are used for yield predictions, either to recreate the specifics of a past event, or as yield distributions that reflect known seasonal variation in the environment. However, there is very little insight in yield predictions alone, unless the sources of variation can be identified and apportioned between controllable (e.g. stored water) and uncontrollable factors (e.g. timing of rainfall), and unless the proposed

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apportionment differs significantly from the way it is already being done. Description of the past is not enough.

Clearly, progress in managing crops better will only come from highlighting the controllable factors, and identifying the technologies which will produce more effective and efficient use of water—i.e. through improved storage of rainfall, and more efficient conversion of water to economic product. The focus must change from recreating the past to identifying what can be done differently to improve the prospects for clients. In establishing the case for change (and thus helping to bring it about), the emphasis shifts from providing answers to negotiation and interpretation of possibilities. The current preoccupation of scientists with model output, rather than how it affects others' decisions (i.e. its outcome), is evidence that we still have a long way to go to achieve this transformation.

In order to do this successfully, the emphasis will also need to shift away from the provision of information products (with its connotation of containment in the interests of efficient transport) to the processes of knowledge-creation in the wider community. This means that relationships will need to be nurtured on an on-going basis, rather than dismantled on completion and delivery of information products. If APSRU's outputs are to be relevant to managers, then the organisation must recognise that management is mostly about networks, long-term relationships and commitment. Credibility comes from performance within this context, not from the power of simulation tools owned by one party to recreate the past.

3.2 Characteristics of scientific models

Casti (Casti, 1992) describes the characteristics of good models: accuracy, simplicity and explanatory power. *Accuracy* implies good, but not necessarily perfect, agreement between predicted and actual effects. *Simplicity* implies that the model contains few *ad hoc* assumptions and leads to a less cumbersome, more straightforward, mathematical formulation. *Explanatory* power implies that there should be some interpretable connections between the formal entities comprising the model and the physical entities characterising the natural system under study.

Casti also presents a checklist of criteria for distinguishing science from pseudo-science. If any of these characteristics applies then, Casti maintains, we are dealing with pseudo-science: anachronistic thinking; seeking mysteries; appeals to myth; casual approach to evidence; irrefutable hypotheses; spurious similarities; explanation by scenario; research from literary interpretation; and refusal to revise.

A concept like water use efficiency (WUE), and its incorporation in rules of thumb, appears to satisfy very neatly Casti's requirements for what constitutes science (as well as his notion of what constitutes a good model in science).

This contrasts with the crop-simulation models. This is not just a semantic issue because the models gain their legitimacy from claims to be scientific. The apparent preoccupation with precision, rather than accuracy, is taken to support this assertion. The concern is not whether we are measuring the right thing, but that we get a precise estimate of the things we do measure. But precision is an issue because it establishes the claim to legitimacy for use of the models, not because it produces a better outcome. It should be clear that we are treading through a conceptual minefield here. The argument from authority (that the models should be used because they are scientific) should not go unquestioned. On the other hand, this may not matter if we accept the argument that our domain has shifted away from describing the behaviour of the natural world towards deliberate action in the world of practice in order to bring about change: the question then is about how to do this, not whether how we do it is scientific or not.

Models are thus being used simultaneously in several different, and sometimes contradictory, ways: as a way of describing the world; as a way of understanding the world; and as a way of acting in the world. All of these modes are legitimate ways of building and using models. But the kinds of model generated for these different purposes are likely to be rather different. Confusion arises because these problems are not faced, and to a large extent are not even recognised. Thus, it is assumed that a descriptive scientific model, based on the best available understanding of individual components of crop physiology that we have (e.g. APSIM) is necessarily of value for understanding and acting in the world. It may not be. Other models, such as use of the concept of WUE, may generate significant understanding without getting the description very precise. Models such as the rules of thumb described in Cox *et al.* (1995) may be very effective within a limited range of situations available for action, but poor at either description or understanding. Questions about the design and use of models need to recognise these different uses of models and different ways of using the same model. Argument from authority, based on the output of a single model category, is not going to take us very far if the scientific nature of the model is used solely as a basis for establishing legitimacy rather than to encourage understanding or to prompt action.

The notion of a multiplicity of models, and the deliberate use of different models for different purposes, is something towards which we are still moving. There is still a residual undercurrent that the scientific model (which *describes* the world in terms of its *components*) is the *de facto* standard against which all other models must be judged. And, in some situations, this is of course the case. In others, particularly issues to do with management and decision-making, the scientific models have a status equivalent at best with being 'just another opinion'.

3.3 Scientific models as a basis for DSS

Why do it on the back of an envelope when you can do it on the back of a pentium?

APSRU researcher

The notion of the value of information, and the cost of getting it, has been a consistent theme throughout this study. Generally, scientific models exclude the cost of information and are ambiguous about its value. More information is assumed to be better than less. The contrary idea (that there is an optimal level of ignorance, and that less is more) appears anathema to this perspective. Yet we have seen good evidence that farmers' models cope with this aspect rather well. The story of the deep nitrogen bulge provides an example (see section 4.2.6).

Soil coring to depth (1.5m), carried out as part of the GRDC on-farm project during 1993–95, revealed the frequent occurrence of nitrogen bulges deep in the soil profile (at about 1m). The questions were posed: 'what is the value of soil N that deep?'; 'what is the value of information that the bulge is there?' (i.e. what is the value of information about the occurrence of soil N); and 'what is the difference between these two answers?'. We asked a group of farmers about this. First, they said that if they knew the N was there, they would reduce their N application rate. This values the N at the cost of the fertiliser N saved. But someone else pointed out that in some years roots don't get down that far; he was not prepared to risk his crop by reducing his N rate even though he knew the deep N was present. In most years, the crop would get its roots down to the deep N, and this would provide a yield (or protein) boost; so the deep N did have value. But adjusting his practice in response to this information did not make sense, so the value of the information was zero. The farmers' models had solved this problem in an elegant manner. Yet these elementary distinctions about the value of information have barely permeated the scientists' models of this issue. Only recently have their models been able to cope with differences in the value of N at different depths. And the distinction between the value of a resource and the value of information about the status of the resource, appears to be a novel one for them.

They were impressed with its power.

APSRU researcher

We have heard this phrase very frequently over the last two years. It is held to be justification for the scientists' modelling activities. We are still unclear what it means. At best, the crop models were able to mimic past experience. Where there was a discrepancy, this was usually put down to problems with the weather data (because of the need to use data from a distant meteorological station, or because of local difficulties with data collection); sometimes with the model itself (the cotton model sometimes gave zero yields

for no apparent reason). Farmers often spotted these discrepancies and suggested an explanation. Some of the model output was strongly criticised because it merely gave the same answer as that obtained using the concept of WUE (private sector adviser's challenge at the second DSS workshop); or because it had not yet developed beyond a single crop focus which did not consider subsequent effects/opportunities (private sector adviser's main criticism, interview data); or because the model decision was irrelevant as the real decision had already been made (e.g. by the dominance of the herbicide strategy not considered by the model, or the need to plant whenever an opportunity presented itself irrespective of model output).

3.4 DSS as a basis for action

3.4.1 Problems with fundamental constructs

During the project, we came across evidence of considerable difficulty/ambiguity about fundamental constructs. We want to mention some of these briefly here because they indicate the extent of the cultural gap between scientists and farmers. We suggest that one of the issues that we face is the simultaneous negotiation of these constructs (1) so that the scientists' models can have more bearing on routine decision-making behaviour, and (2) so that farmers' constructs can have more effect on researchers' models.

What is rainfall?

Farmers frequently do measure rainfall on their properties, either in mm or points. It is less clear why they do this, and how these data are used (other than for monitoring the progress of a particular season). They distinguish different kinds of rainfall: planting rain, follow-up rain, drought-breaking rain, soaking rain, relief rain. These categories tell much about the quality of rain which is not explicit in the scientific constructs (mm of rainfall). In this sense, the farmers' constructs are more discriminating than scientific ones. In some cases, the simulation models are configured to express some of these categories through the specification of management rules, e.g. the criteria specifying a planting rain in terms of so much rain in so many days.

What is average rainfall?

Scientific models specify central tendency in various ways (mean, median and mode). Sometimes it is unclear why a particular measure of central tendency is selected, e.g. the median rather than the mean. Is this because the median is defined in relation to a fixed point on the y axis in a CDF diagram? (Surely not). Other measures are also used such as running mean. Farmers use the concept of average rainfall but this may be based on an adjustment to a local met station, or on shorter lengths of experience. This lays them open to the possibility of proximal bias (weighting more recent

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experiences more strongly than historical experience would suggest). But the argument about proximal bias is weakened when we also believe that the climate is changing over the same period as our rainfall records. This appears to apply particularly to frost risk (use of frost probabilities that give the same weighting to events 100 years ago as to more recent events is clearly inappropriate if the risk has shifted significantly, as it appears to have done—this is one of the pieces of evidence for global warming). Some professional publications use yet another measure of central tendency (the 30–70% percentiles); in this case, the average is a range rather than a point estimate. Confusion reigns about such apparently everyday concepts as average rain. We are not arguing for standardisation, rather the recognition of a variety of constructs for the purpose of negotiation. But the choice of construct does have to be negotiated, and applied consistently, if we are not just to talk past each other.

What is a full profile?

The concept of what constitutes a full profile of soil moisture is also constructed differently by farmers and scientists. Farmers investigate the moisture in the soil with a metal rod or probe. A full profile is shown by the depth to which the probe can be pushed, the effort required to push it in, the sound it makes when pulled out, and the presence of moisture on the metal surface on withdrawal. The scientific concept used by modellers is based on the idea of plant available water capacity (PAWC). This depends on the crop and the soil, which define upper and lower limits, and deep soil coring to measure the actual water content at different depths. Sometimes an alternative measure of soil moisture based on the physical properties of the soil alone is used. What constitutes a full profile depends on the tools used to define it, and the use to which the concept is put.

How are decisions made?

Our investigations suggests that farmers' decisions are captured to a large extent by rule sets. These rule sets can be quite simple. Although, no doubt, the generic rule sets we elicited are supplemented in practice by a wider set of rules relating to particular experiences, and even though there is danger in describing what is largely tacit knowledge as rules, we feel confident that this is a responsible way to represent farmers' models of their production practices. These rule sets never take the form 'I calculate the CDF of the outcomes of different strategies and, using stochastic dominance with respect to a function, I select the dominant strategy in the context of my level of risk aversion'. Indeed, such a proposition would be ludicrous in the context of the decisions they face and the resources with which they have to manage them. Scientists, of course, do construct rules of that kind.

'Wheatman predicted the yield I got'

The distinction between backwards-looking and forwards-looking applications of models is not well

understood. Thus *Wheatman* has been used (and validated) because of its prediction (presumably based on the median) of specific yield outcomes. Yet *Wheatman* cannot do this: its output is in the form of a yield probability distribution—if the actual value achieved matches the median value of the predicted distribution, that is entirely fortuitous.

Prediction

Scientists use the term 'prediction' to signify the reconstruction of the yield (or level of nitrogen or runoff or whatever) from the component processes. Thus, they are able to predict the yield obtained last season from the starting soil water, soil nitrogen, in-season daily rainfall, daily maximum and minimum temperatures etc. to which the crop was exposed during that season. The emphasis on futurity, which is an important aspect of prediction in common parlance, is missing.

What is risk?

This raises the question about what constitutes risk anyway. Are farmers expected value maximisers, or do they attach particular weight to the possibility of realising a loss (i.e. are they risk averse)? Kevin Parton's analysis (RIRDC Project no. CSC 50A) of the value of the SOI shows that the answer to this question depends on how risk is measured, and that we have very little basis for choosing between these answers unless we know a lot more about the risk farmers face and how they are managing it. In the absence of this, there is a tendency to use a risk measure which, though plausible in some ways, highlights the potential value of information. As a working rule of thumb, we suggest that for a strategy to be accepted it should look good on expected values first of all; only then would it be appropriate, in some situations, to look at explicitly incorporating higher moments of the distribution in the analysis (e.g. building a portfolio of varieties to manage the risk of frost damage which may be handled using a portfolio model based on trade offs between the mean and variance, and correlations between the performance of different cultivars); or safety-first models when faced with big decisions that put the continuation of the farm firm at stake (e.g. committing to a large area of cotton planting with high variable costs; purchase of expensive machinery) where the calculation of the cumulative density function (CDF) of a net present value (NPV) may indeed be appropriate.

Ascending and descending CDFs

Ascending and descending CDFs contain the same information but the meaning attributed to them is reputed to be different. Hence the persistent use of a non-standard representation (cumulative probability of exceedence, rather than cumulative probability). Use of arbitrary transformations is confusing. It is not at all clear that CDFs should be used at all outside the research laboratory as farmers' models do not appear to be based on them.

Stochastic dominance analysis

Similarly with stochastic dominance analysis. People are presented with CDFs (either ascending or descending), with the implication that meaning can be attached to apparent differences in them. This may be clear if one strategy exhibits first order stochastic dominance (in which case, a comparison based on the mean would give the same answer anyway), but in other situations it is far from clear what one should do. The calculus of stochastic dominance analysis is not transmitted with the model outputs. Presumably scientists expect farmers to handle this intuitively.

Bayes' theorem

Use of the SOI as a seasonal climate predictor (and indeed the use of soil water measurements) can be incorporated with subjective prior distributions using Bayesian calculus. Again, this is not transmitted with the model output. But without that calculus the key for unlocking the information held in the forecast is unavailable. One needs to know how good the forecasts are, as well as the shift in probabilities they predict, in order to incorporate the information with pre-existing priors. Scientists are transmitting a coded message but not the key that would unlock the code.

'We know what the probabilities are'

This is avoided in the use of crop models because of the way in which historical rainfall events are apportioned by the predictor (SOI phases): since all the historical rainfall events are categorised, and the revised distribution is based on the appropriate subset, the argument is made that we know what the probabilities are. But this fails to recognise the nature of the (subjective) priors held by the decision-maker, or his confidence in the forecast (which may be different to that of the professional forecaster), or the uncertainty about which state we are in fact in. Once again a vital bit of the jigsaw is missing. Scientists are transmitting coded information without the key.

Perhaps even more importantly, even if we accept that we do know what the rainfall probabilities are, the question of what the yield probabilities are (obtained through transformation of rainfall probabilities using the crop models) is still open to question. This is partly to do with the extent to which crop models explain historical experience (looking backwards): an index of determination of 70% is considered good by local standards, although that leaves 30% of the variation unexplained. But it also has to do with how confident we are in the crop models in circumstances outside those for which they were calibrated—i.e. to consider other issues, at other locations, using different coefficients. Further, there are errors associated with the inputs, particularly as we move away from a tightly specified experimental situation towards routine crop modelling for production. These sources of error are not captured in standard representations even using CDFs—error bars on CDFs are not presented as part of the analysis. In theory, the

model outputs could be treated as predictions in the same way as the SOI, but the calculus for incorporating these probabilistic predictions into the farmers' decision-making environment is, once again, not transmitted with the model. Should it be? Perhaps it should go to advisers who in turn may use it in an entirely different way with farmers.

The value of information

This gets back to the value of information. Claims are frequently heard about the value of measurement (e.g. of soil water, N), about the significance of certain kinds of input (knowledge of the SOI phase), about solving problems in a certain way (a particular way of viewing risk) without reference to the issue faced, of who the decision maker is, of the options available to the decision-maker, or her current understanding of the state of the system. All of these will affect the value of the additional information available through the DSS.

In summary, there are substantial issues to do with failure to negotiate fundamental constructs for the structure of a decision, the options available, the appropriate form of analysis, the comparison of alternative strategies, and the evaluation of outcomes.

3.4.2 Need for an analytical phase

A partial description of an open system, such as that associated with agricultural production in north-eastern Australia, does not by itself provide much of a guide for action. There appears to be a fundamental category mismatch in the way simulation models are used as a basis for decision support. This is most clearly seen by comparison with a relatively closed and well-controlled system such as an automotive manufacturing plant. In this case, the operator has considerable control over all aspects of the production process; the issue is how to manage such a complex process. Agricultural production is not like that: there are fewer handles to pull, and the results of pulling any one handle is considerably more indeterminate. It is often unclear what will happen, except in probabilistic terms, because of uncertainty about future weather. Also, the homeostatic properties of biological production systems often allow the system to recover from mistakes or extreme events: response surfaces can be rather flat, with poorly defined optima. These considerations lead directly to the need for an analytical phase between model development and use in a DSS: analysis of the problem may obviate the need to continually re-discover well-established relationships between inputs and outputs. APSIM may serve as a catalyst to re-visit the analytical, but it is not a substitute for such analysis. There should be no presupposition that use of APSIM outside this context is ever warranted.

3.4.3 Abdication of responsibility for outcomes

The developers of agricultural DSS often assert that they are not concerned with bringing about purposeful change in the way farmers manage agricultural production systems. This applies as much to *Wheatman* as APSIM. It differs from some early examples of DSS such as SIRATAC (which was self-consciously trying to reduce the number of insecticide applications used on a cotton crop), and early *Wheatman* (which was selling the idea of matching the choice of cultivar to the timing of a planting opportunity). Current discourse is more about co-learning (APSIM) or self-learning (*Wheatman*). This reflects a diffuse concern that production decisions can be improved, and that improvement will come about through improved pattern-matching between the use of inputs and the perception of emerging opportunities for effective action. Although it is undoubtedly the case that improved performance at the margin can be achieved in this way, we do need to question whether the potential gains justify attempts to match patterns at this level of resolution in a production environment characterised by high levels of uncertainty, or whether there are greater gains to be made elsewhere and in other ways. In a very real sense, the DSS product has become the target, the accepted indicator that something has been achieved. The means (or, rather, one possible means) has become the end. Without a view of the end we are trying to bring about, we lose the impetus of evaluation to choose between competing means. We see this as an abdication of our professional responsibility to achieve outcomes, not just outputs.

3.4.4 The issue of credibility

The issue of model credibility is frequently cited as a central issue by model developers. This is usually interpreted to mean adequate agreement between predicted yield and actual yield in known situations. This comparison is relatively easy in backward-looking models like APSIM (when used in this mode, see Chapter 5), but much harder in forward-looking models like *Wheatman* and APSIM when used like this. We can measure the precision with which backward-looking models recreate a past experience; but the probability distributions generated by forward-looking models cannot be checked with the same level of precision because we are unable to distinguish a shift in a probability distribution from movement along one.

This issue is treated differently in the two cases: in *Wheatman* by making ad hoc adjustments to the probability distributions to conform with local experience; in APSIM by refusing to correct model output for obvious discrepancies unless the biophysical basis of the differences is understood. The strategy of the APSIM developers is to gain greater precision when looking backwards (i.e. when reconstructing an experience or, in their language, in 'prediction') through much greater attention to initialising

the model to match the specifics of a situation. Partly, this reflects the different audiences for the two models: farmers and advisers for *Wheatman*; other crop scientists for APSIM.

Farmers clearly do learn from experiences and use this learning to adjust their plans: they move forwards by looking backwards. It is not clear that reconstruction of these experiences in a scientific model contributes in any significant way to improved switching from backward-looking to forward-looking: farmers already manage to negotiate that pivot. *Wheatman*, on the other hand, is much less concerned about the specifics of a previous situation and much more concerned to generalise about future possibilities, even to the point of nudging key relationships into line. In this, it moves beyond the way in which APSIM is currently used. *Wheatman* suffers the same problems of lack of transparency as APSIM, but (in some ways, and for some purposes) *Wheatman* may be a more advanced design than APSIM.

The assumption that credibility is such an important issue, and that it is achieved through increased precision, is curious. There are parallels between this and the development of the life insurance industry in the UK in the nineteenth century (Porter, 1995), in which the development of trust and precision also went hand in hand. As Porter puts it, 'There is a politics of precision.' Precision is valued by professional communities (actuaries, scientists) who have a vested interest in providing precision. It is far from clear that this applies to practical agricultural production where the relevance of precision is not immediately apparent. The credibility of the models is presented from a scientific culture that values precision as an end in itself. This is not the case in agriculture where the issue is more one of negotiating substantially better opportunities within the trust developed through long-term relationships between farmers and their advisers. Scientists are asking farmers to trust their models because they are precise, or at least more precise than those the farmers currently operate with. But, while this initially has some appeal to farmers, they are ultimately seeking opportunities; that is the essence of their interest in precision.

We see several dangers with the scientists' position. The single-minded pursuit of credibility through precision reinforces the dependence of clients on the model-provider: access to precision is a way of gaining power ('*They were impressed by the power of the model!*') and asserting a particular point of view. But having said that, the point of view that is asserted is rather weak since it is not linked to a political agenda to bring about purposeful change. Credibility of the model in this sense appears to reinforce the scientists' preference for researching the behaviour of virtual crops in a virtual environment, rather than tackling the pressing practical concerns of farm management. It is a legitimisation practice for the way science is currently configured.

The achievement of credibility in this way also involves a sleight of hand to the extent that apparent agreement in a

limited set of circumstances is used to justify model use under a wider range of circumstances where it has not been validated—e.g. when the concern switches from recreating past experiences (looking backwards) to exploring the future implications of a changed management practice (looking forwards), or when a model which has been calibrated to get evaporation right is unwittingly used to study drainage (a situation for which it has not been calibrated). The key is not precision, but transparency.

3.4.5 Chasing marginality

Thus, we are beginning to see a pattern emerge. Farmers' models provide an effective and efficient means for managing issues of agricultural production in broadacre dryland cropping systems. The scope for intervention lies in the extent to which these models can be influenced in specific directions to generate better outcomes. The question we face is whether the direct overlay of scientists' models provides ample (or even adequate) scope for purposeful change in management practice. We have seen little evidence for this. The presupposition that this must be the case is based on assumptions about the inadequacy of current decision-making behaviour, and the unquestioned (and largely unquestionable) effectiveness of scientific representations of partial systems (even though these are inadequate, expressed in esoteric language, using strange constructs, using an unfamiliar interface based on an unfamiliar hardware platform, and paying scant attention to improvements in decision performance at the margin).

Thus, DSS development is driven by poorly justified assumptions about human decision-making behaviour, the value of absolute 'objective' representations, and the irrelevance of cost considerations for model development and calibration. These are all part of the scientific culture. Also, they all suggest that current modelling activities are *actively chasing marginality*: in the choice of the issues they focus on (largely to do with yield); the limited range of technologies considered (fertiliser but not herbicides); the failure to identify, before developing models, just what constitutes an issue anyway (is the choice between sorghum and cotton really an issue that is decided on the basis of yield distributions?); the preoccupation with description rather than understanding or empowering others to discover worthwhile options; and the failure to adapt the model structure to the nature of the issue and the nature of the trade-offs under consideration. If we cannot see gains of \$50/ha or more, then we shouldn't be pursuing them. (To put this in perspective, one week's delay in sowing causes losses of this order.) If we can see gains of \$50/ha or more, we probably do not need a very sophisticated model to spot them in the first place.

Marginality is chased by: (1) chasing marginal issues; (2) chasing issues that require discrimination between alternatives that are close together (and therefore difficult

to choose between); (3) restricting the scope of the problem to stereotyped scenarios of little practical relevance; and (4) failing to respond quickly enough to emerging issues. The counter to this argument is that any DSS must be customisable to individual properties, and even paddocks, for it to be of any interest to farmers: this argues for greater precision in history matching of yield reconstruction, and the use of local knowledge to compensate for inadequacies in the way the system is specified. What is missing from this argument is that adequate history-matching can be achieved in other, more transparent and instructive, ways (e.g. field experiments or case studies, particularly if monitored).

In a very real sense, prior commitment to these rather complex, partial, unstable and non-adaptive models is chasing marginality in terms of the returns to investment in this activity. There are few decisions where these models are adequate, and in many of these they are overkill (because the decision is clear without them) (see Walker & Ryan, 1990); their contribution may be regressive (because of their lack of transparency, and because they distract attention from the many simple opportunities with high rewards); their use outside the context of their development is dangerous, yet those limits are not clearly articulated; and the protocols for validation are poorly negotiated. What is going on here? We argue elsewhere (Cox *et al.*, 1996) that researchers have got caught between two cultural peaks; we are in a transition phase which is neither science nor management.

Our observations support the contention of Pannell *et al.* (1995) that simpler models are not only adequate, but *better for the purposes of farm management*. (See quotation from their paper below).

3.4.6 Scope for compression

Scientists' models refer to the progressive refinement of one cell in a spreadsheet model.

Algorithmic compression (see Cox, 1996) refers to the scope for simpler model formulations (such as the rule sets used by farmers) to provide adequate guidance in a specific situation. We have seen several examples of algorithmic compression in this project e.g. the deep N story. Our experience of the SIRATAC case study also suggested that much of the benefit of the SIRATAC approach was captured by compact rule sets: (1) the thresholds for pesticide use incorporated in the *entomo*LOGIC prototype; and (2) the rules associated with the Insecticide Resistance Management Strategy (Cox, 1996; Appendix 5). Theoretical considerations also suggest that this will commonly be the case because of the uncertainty associated with future outcomes. The achievement of apparent precision has a substantial cost. In a recent paper, Pannell, Malcolm and Kingwell (*op. cit.*) put this case succinctly:

Let us stress that we are not arguing for use of simple whole-farm budgeting tools for use by farmers because they are cheaper, easier and quicker to set up and use. In our

view, the value of the information they generate for individual farmers is higher than could be generated by a sophisticated risk model in any realistic time. They [sic] key advantage is that they do not obscure or swamp the key individual circumstances of a particular farmer but rather they facilitate the farmer making decisions which account for their circumstances. That is, in comparing simple and complex models for farmer use, there is no trade off between costs and benefits: simple models are better on both counts.

3.5 Different views of models

3.5.1 As a summary of a reduced objective world

The models that originate in professional science usually seek to describe an objective world. This is a reduced world (not holistic) because that is largely the way science currently works. Indeed, this approach may be an appropriate one for APSRU to the extent that this is seen as a scientific research project intent on describing the way in which crops grow for a scientific audience. What is less obvious is what this has to do with management decision-making.

The fact that we can recreate a historical yield for a particular set of starting conditions and a particular season may be of interest but it hardly points out novel opportunities for improvement, at least not by itself. 'Computers are tools of the past' (Talbot, 1995). This is borne out by the experience of the kitchen table sessions and the DSS workshops. APSIM shines when it appears to capture previous experience. The APSIM architecture may be appropriate for summarising scientific descriptions of crop and soil processes *for scientists*. But the kind of analysis, and the degree of resolution required to use a model as a summary of a reduced objective world is not necessarily the same as that needed for improved management. We would argue that it is not the same at all.

3.5.2 As a way of understanding what is going on

This is an important and traditional use of models, particularly simple models such as the concept of WUE. By demonstrating explicitly the nature of the relationship between inputs and outputs, experiences can be explained in an efficient and effective manner. These relationships are more or less hidden in the complex cropping-systems simulation models such as APSIM—although it might be possible to reconstruct these relationships from an analysis of input and output data, these are not readily apparent. There appears to be scope for using models in this way for achieving improved performance. But this argument supports the use of simpler, more transparent, model formulations in which the relationship between inputs and outputs is clear. Rules of thumb often appear adequate for

this purpose. A spreadsheet model may be appropriate in some cases.

3.5.3 As a way of thinking through an issue

A model is often a helpful way to think through an issue. Participation in the process of model construction can contribute to more effective communication by facilitating the negotiation of goals and constraints, opportunities and pitfalls. We have seen some examples of this in the kitchen table sessions in which farmers were able to point out to scientists where they had got it wrong (e.g. the appropriate treatment of cotton variable costs; the importance of overland flow as a source of soil moisture; the importance of apparently small temperature differences between a specific paddock and a local met. station; and the value of deep N).

3.5.4 As a way of spotting an opportunity for gain

Models can provide a framework for recognising the value of opportunities as they arise. Much of our current analytical framework (the way we use models) is rendered inappropriate because of the way it treats risk. This is a controversial area because it brings into question much that we have been taught in agricultural economics and agricultural decision-analysis: decisions are not made by the detailed comparison of predefined probability distributions characterising distinct scenarios at the start of a planning period, i.e. non-embedded risk (see Cox *et al.*, 1995). Rather, in a situation of considerable uncertainty, and relatively flat response surfaces, it makes more sense to respond tactically as the season unfolds—i.e. embedded risk. The use of heuristic models by farmers is a way of doing just this. Thus opportunities for gain are defined in relation to a particular combination of circumstances, rather than detailed calculations of the probability distributions of various outcomes.

3.5.5 For fine-tuning decision-making behaviour

There may be situations where some fine-tuning of decision-making behaviour is both desirable and possible. Farmers' rule sets, effective and elegant as they are, sometimes fall down, e.g. in the face of novel technological or other options such as deregulation of commodity markets. Models can be of use here in explaining the risks associated with different price instruments in the context of the production risk defined by the particular circumstances of a specific crop. In this case, the models are probably most useful for agribusiness and service providers because of the volume of transactions in which they are involved. This may provide some justification for chasing up the marginal returns curve a bit further. But even here, we are probably

looking at relatively simple model formulations of the complexity of an average financial spreadsheet. Coefficients, including probability distributions, can be specified on the basis of the knowledge and experience of the individual farmers rather than from explicit deterministic transformations of stochastic inputs.

3.6 Reflections on our approach to 'systems of thought'

Both of us feel that we have been more successful at influencing scientists (perhaps 'getting under their skin' is a more apt description) than we would have been had we been perceived by them as outsiders: we have been accepted as colleagues within APSRU. This was due partly to our backgrounds (PR in agriculture, PC in natural science and economics); partly to particular technical competencies that we were able to display; partly to co-location with the scientists at the QDPI complex in Toowoomba; and partly because we were already familiar with their language. We were privy to many debates that we would not ordinarily have access to, had we been seen as outsiders. This alone increased the probability of bringing about change.

We consciously tried to use the scientists' communication channels: writing scientific papers; presenting papers at their conferences; submitting papers to their journals; using the CSIRO Editorial Panel to challenge particular points of view and to present alternatives; initiating challenges to

established positions, particularly through the insertion of novel metaphors into an otherwise stale debate, for instance the notion of dance, 'looking forwards, looking back'. In a political sense, this meant that we were always exposed: our concern to avoid direct confrontation limited the kinds of intervention we could attempt. As it was, Shulman had to act as a go-between (between us and APSRU scientists) on several occasions. Without this higher order intervention, we would have been stopped from pursuing the analysis of the market potential of DSS. This experience will have been worth while if our colleagues do learn with us, and move on. There are some promising signs of change in the discourse that surrounds the planning for the next round of on-farm activity (the Farmscape project).

There are two strands going through all this: (1) that the current institutional preoccupation with the development and use of complex deterministic models of biophysical processes to support managerial decision-making is poor science which can be challenged entirely from within the scientific paradigm; and (2) that the scientific paradigm can itself be challenged because it encourages behaviour which, from the outside, looks pathological (the unwarranted escalation of organisational commitment to an idiosyncratic course—hypertrophy). We can remain committed to tidying up the steps of the old dance; but the big pay-offs will come from the design of new dances. Although intertwined, these are two distinct strategies. We tried to apply both of these at the same time.

4 Acknowledging process

4.1 Introduction

This chapter, which takes its title from Cornwell *et al.* (1994) is primarily about our involvement in the kitchen table and other on-farm activities that formed part of the APSRU on-farm project. Unlike the two DSS workshops (described in the next chapter) we did not set up the framework for these communication activities. We tape-recorded the sessions and produced transcripts which were circulated to selected researchers. We also suggested an interpretation of these sessions that differed significantly from that construed by the scientists themselves. Our contribution was dismissed as unhelpful because we did not support the scientists' perception that they were obtaining substantial endorsement of their modelling activities from farmers. Nevertheless, we did witness a progressive move over the duration of the project towards the point of view we espoused, one which recognised multiple models for use by different actors for different purposes.

4.2 Kitchen table sessions and learning on-farm

4.2.1 Background

There is a bias here that models aren't really needed.

Scientist, reviewing the on-farm project 8
September 1994

Most people, in grappling with their personal and business affairs, resort to a model to think their way through the complexity and messiness of real-world issues. Models are representations of those parts of the real world that are of interest for a particular purpose. The choice of system boundaries, the complexity of the model structure, and the particular formalism used in the representation, are construed by the user according to context. Models, decision support (in its broadest sense), learning and action go hand-in-hand.

The on-farm program was initially established by APSRU to re-define the role of professional researchers within the context of farmers conducting their own research (Cox *et al.*, 1993b). APSRU's primary purpose was to negotiate research agendas with interested groups of farmers. At the same time, it recognised that its expertise in crop modelling could contribute materially to the interpretation of results from short-term experiments. These negotiations started in late 1992 with groups around Capella and Banana in central Queensland, and shortly after with another group at Dalby, on the Darling Downs. Subsequently, three more groups were formed near Brookstead.

The topics of interest to farmers often overlapped with the interests of the APSRU scientists. These topics included: fertility run-down and nitrogen fertiliser use; the potential of cotton as a summer crop; nitrogen fertiliser use on cotton; planting date effects; and planting configurations for sorghum and cotton. The experiments undertaken to examine these issues were usually on large plots (2–20 hectares), planted and harvested with farmers' machinery, and were unreplicated. The sites were carefully monitored by collecting detailed soil and weather data, so that the results from these short-term experiments could be interpreted in the light of a larger body of scientific understanding which had been captured in crop simulation models: in particular, crop simulation models were believed to be the best way to allow for the overriding effect of season when interpreting results from short-term experiments. The models were held to 'add value' to experiments and to allow meaningful experiments to be conducted without formal replication of plots (although with repeated sampling from individual plots). We remain uncertain of the statistical basis for interpretations derived in this way.

4.2.2 Credibility

We haven't got credibility, even within APSRU, for the models at the moment. ...These aren't trials to answer a question. To me, these are trials to create credibility.

Scientist reviewing the on-farm project, 8
September 1994

Over the three seasons of on-farm research to date, results from some 15–20 experiments have been accumulated. The number of insights gained from these experiments has been limited by drought. However, it has been possible to validate the sorghum and cotton crop simulation models using these data sets. The close agreement between 'predicted' and 'observed' crop yields has been used extensively to promote crop simulation models as a valid and credible way to undertake 'experimentation' on issues of concern to farmers. The initial focus on working with farmers on their experiments has shifted to the promotion of crop simulation models as an alternative tool for decision-support, learning and experimentation.

4.2.3 The credibility conundrum

Credibility is cited as a major issue by those who are trying to promote the value of scientific simulation models in the farming community. It is held that the simulation outputs must either bear a general resemblance to the experience of farmers, or match specific measured observations, before model output will be accepted as a credible source of evidence. Similar arguments are made by both the APSRU and the *Wheatman* teams. However, the demands that credibility places on models restrict the opportunities for using them to promote change: if the output must match the experience of farmers before the evidence

will be accepted by them, then there is little scope for using these tools to challenge conventional wisdom and to create an environment conducive to change. Model-based output becomes a conservative force, reinforcing current understanding, but failing to point the way towards novel opportunities to do something different. The modellers have allowed themselves to get caught in a trap.

So long as the logic of crop simulation models remains inaccessible to the producer, there appears to be no way around this conundrum. If the underlying logic can be exposed, then it seems to us that growers will be likely to consider some of the outputs that are at variance with their experience, and thus that there is a greater chance that this will affect their practice. The alternative (the situation we are in now) is an argument by authority: a bald statement that this is the way the world is, take it or leave it. Apart from being philosophically questionable, and certainly anathema to the way that we are increasingly seeing the world, it is likely to be ineffective in bringing about change: it is poor communication.

One needs to question the role of the computer in processes designed to bring about change. When the computer occupied centre stage in the on-farm sessions, it often seemed to get in the way, forcing premature closure of discussions just as these were starting to get going. The computer was being used as a standard against which farmers' knowledge was judged. Crop-simulation models, which operate on daily weather data, need a fast computer to handle the many routine calculations that reveal some of the implications of the underlying logic. However, the logic, the reasoning, the argument, and communication, are central to realising change on the farm.

Thus, from our point of view, credibility is about people not computers. The presumption that access to computers gives people credibility, rather than the fact that they are a source of different insights or can be a sounding-board for ideas, is worrying. We feel that this attitude stems from the way in which model-based output is evaluated in the scientific community where the modellers normally reside. To carry this over into the world of practical farming appears to us to be a category mistake (see Cox 1996 and Cox *et al.*, 1995, for an explanation of Gilbert Ryle's notion of a category mistake).

4.2.4 Crop simulation models on the kitchen table

Something is happening here that people value.

Scientist reviewing the on-farm project, 8
September 1994

APSRU has now conducted a large number of simulation sessions with small groups of farmers in central Queensland and on the Darling Downs. These sessions were designed to

explore the potential of crop-simulation models for decision-support and learning.

Crop simulation models have been used: (1) to explore what might have been done differently in a specific situation in the past; and (2) to explore what might happen in the future by simulating outcomes over a range of seasons (typically 10–20 years). Growers involved in these sessions said they value both approaches, although the insights gained from running simulation models across a number of seasons are not generally much different from those that the growers brought with them. For example, a comparison of cotton and sorghum using simulation models at Brookstead (22/6/94) confirmed the growers' view that cotton would outperform sorghum in six years out of eleven. At least one grower went further: 'I can tell you. Just put cotton in. ...If it is early you put cotton in, if it is late you put sorghum in. It is as simple as that'.

However, there was one instance where simulation experiments may have caused a shift in attitude, although it is still too early to know if this changed behaviour. In this session, conducted at Banana (1/8/94), simulated yields of late-planted sorghum, for a plant population of 100,000 per hectare, were very much greater (mean 3t/ha cf. 2t/ha) than those simulated for the district practice of 50,000 per hectare. This result was contrary to the views of the farmers who said: 'The trend had been to drop the plants'.

And despite the initial scepticism of some growers, as evidenced by the comment 'Well experience, I suppose, tells us something different', there was evidence of a shift in attitude by the end of the session, summed up with: 'It would be interesting to try.'

There need not be any evidence of an intention to change for the models to have value. Many growers appreciate the models when they confirm their opinion. However, they have not yet shown this appreciation by being ready to pay for confirmatory opinions. Yet even if they did, that would scarcely justify performing the same demonstration over and over again to make the same point: this can emerge from reports of the joint modelling activity. From an economics perspective, the models (considered as a publicly-funded investment in R,D&E to improve efficiency in agriculture) *do* have value only when they prompt, facilitate, or in other ways contribute to changes in behaviour. To use a weak measure of value (confirmation of a prior opinion) implies that the strong measure (change in behaviour) is not being met.

Case Study 3. Market Research for Decision Support for Dryland Crop Production

4.2.5 Monitoring on-farm

....and put these ponds on because that is the information that these models need, but it is also good information anyway.

Scientist, on farm, Bongeen, 18 October 1994

Monitoring conducted on behalf of the producer groups involved in the on-farm program has taken the following forms:

- 1 characterising soil types for moisture-holding capacity
– drained upper limit by making ponds in paddocks
– extractable lower limits after successful crops;
- 2 routine measurement of soil water to 1.8m under crops and fallows;
- 3 routine measurement of soil nitrate N to 900 mm under crops and fallows;
- 4 surface soil sampling for organic carbon content;
- 5 crop establishment, crop growth, nitrogen uptake, root penetration, economic yield, and grain nitrogen content; and
- 6 collection of weather data (rainfall, temperatures, radiation etc.), usually through the installation of automatic weather stations.

To date, this monitoring has been carried out by APSRU at no cost to farmers. Once the initial soil characterisation is complete, the commercial rate for the routine monitoring of soil water and nitrate is expected to be \$200 per paddock per sampling—for the removal of cores, drying of samples and chemical analyses. The on-going depreciation and maintenance costs of a basic weather recording station will be about \$1,500 per year. Hence, the basic monitoring required to exploit fully the power of crop-simulation models for a farm of, say, 20 paddocks, will be about \$6,000 per year. The cost of professional support, to interpret the soils data and simulation output, will be extra.

There can be little doubt that monitoring, particularly of soil nitrate reserves, is valued by farmers. In one case, near Dalby in late 1994, a grower cited a saving of \$30,000 on fertiliser outlays as a result of soil nitrate testing conducted by APSRU. In another case, near Capella, a grower spoke with relief about the nitrogen measured as still intact and available in the soil, after outlaying \$60,000 for nitrogen fertiliser in the previous season for crops that eventually failed. However, the case for scientific sampling and measurement of nitrate in the soil is sometimes not sufficiently convincing.

4.2.6 The deep nitrogen question

He should start a fertiliser company because he has so much nitrogen under his soil.

Scientist, on-farm, Bongeen, 22 June 1994

Fair way down if I read these right.

Farmer 1, on-farm Bongeen, 22 June 1994

It's a bit hard to believe that you can have 401 units of nitrogen in there.

Scientist, on-farm, Bongeen, 18 October 1994

A big bullock stood over the sampling site and urinated.

Farmer 2, on-farm, Bongeen, 18 October 1994

...by what that says you don't need any but my gut feelings...the old brain is telling me different.

Farmer 3, on-farm, Bongeen, 18 October 1994

The soil monitoring, which has been an integral part of the on-farm project, has uncovered some large pools of nitrate nitrogen deep in the soil profile. These pools arose, in part (we suspect), from the failure of a series of drought-affected crops to utilise nitrogen applied as fertiliser. However, in some cases there appears to be such an accumulation of nitrate at depth (below 60 cm) that it must also reflect the practices used, and crops grown, before the drought.

The value of this deep nitrate has been assessed in a variety of ways (see Ridge *et al.*, 1996). In some cases, it has been valued as equivalent to nitrogen fertiliser (viz. \$0.80/kg N), irrespective of its location. In other cases, it has been valued in terms of its fertiliser equivalent viz. the rate of fertiliser needed to achieve the same result as the deep bulge of nitrogen. Crop simulation models can be employed to estimate the fertiliser equivalent of a bulge of nitrogen at depth. Simulation runs with wheat suggest that its value declines markedly as the bulge moves down beyond 75 cm, and is negligible by the time it reaches 125 cm. The value of deep nitrogen needs to be discounted more when soil profiles are drier at planting.

When presented with the same problem at a simulation session at Dalby (9/9/94), the growers were quickly able to identify some of the important parameters:

If your sorghum roots are not looking for moisture, they are going to feed on the surface...I reckon that's how the bulge got there in the first place.

If the plant is starved for nitrogen at the top, he is not going to be a very healthy plant.

The consensus from this discussion was that 50 kg N at depth (in the 60–90 cm layer) is equivalent to 20–30 kg N applied near the surface as fertiliser. This very simple ad hoc analysis produced a result that is remarkably similar to

that obtained several months later by running the wheat crop simulation model.

The measurement of soil nitrate to depth, the associated modelling activity, discussions among scientists, and the kitchen table sessions have all played their part in getting this issue on the agenda. To the extent that there is now a greater awareness of the issue, there has been learning. But there is still a great deal of uncertainty about what this learning means for action. The scientific models have been no more successful in identifying the source of this deep nitrogen than the simple models employed by farmers. There is as yet no agreement about how often deep nitrogen will be an issue, and there is the distinct possibility that it is an artefact of the drought. However, to the extent that it has encouraged debate about its value, the discussions have focused attention on the more efficient use of nitrogen. *Rather than providing answers, the discussions that surround the use of scientific models may be an opportunity for learning.* It can be argued that, had the models not been employed on-farm, with their requirement for detailed soil sampling, then the deep bulge of nitrogen would have remained undetected. It is still too early to know whether its detection will have, or indeed should have, any lasting impact on nitrogen fertiliser practice.

Having said that, several issues still remain. First, without our intervention, it is doubtful whether the scientists would have heard the farmers' way of explaining what was going on and how they managed this situation, nor would they have appreciated the simplicity of their solution. The opportunity for learning by scientists would have been lost. Second, the distinction between the value of deep N and information about its current status remains confused; little credence was given by scientists to the notion that such information could have zero value (because it did not lead to a change in behaviour), let alone a negative net value (in relation to the cost of getting it). The case for routine monitoring of soil N, at the level of precision required for scientific models, has still not been made.

4.2.7 More accurate assessment of soil water

It's not over-wet because it's not giving that nice clear suck.

Paddock observation, farmer, Bongeen, August 1994

Until recently, most growers assessed their reserves of soil water by using a probe. The resistance to penetration of the probe increased as the soil dried out. Calibration was vague at best and very much related to the experience of the operator and his knowledge of the moisture-holding characteristics of the soil. However, the assessment of soil water using the probe is never done in isolation; the grower's recollection of rainfall events and flood activity during the recharge period is also integrated into the assessment.

You see to get a full profile of moisture to 2'6" or 3' you would need 15" of good rain wouldn't you?.

Paddock comment, farmer, Bongeen, August 1994

Many farmers use rules of thumb that predict the impact of rainfall on fallow recharge, and these rules provide insights that are remarkably similar to those derived from the models of professional science. What's more, farmers are often able to formulate probabilistic yield projections based on their perception of the current soil water. (Peter Hayman, NSW Agriculture, has obtained empirical evidence of this assertion from experimental trials). The real issue then becomes whether these yield estimates, based on farmers' perceptions and their own rules of thumb, are causing them to miss profitable opportunities which would be realised through greater attention to monitoring and modelling.

...core them to find out how much soil water and nitrogen are there because it's going to be important information to you, but it is also going to provide us with information to get our models running properly.

Scientist, Anchorfield, August 1994

While it is clear that the crop simulation models used as part of the on-farm program require accurate assessment of soil water reserves, it is less clear that the precision required for the model is relevant to farmers managing against a background of seasonal (and market) uncertainty. Coring to specify soil water as 200 mm, to a precision of ± 20 mm, may be no more useful than nominating the profile as 70–80% full when it comes to practical action. Of course, the value of this precision can be partly assessed by scientists using crop simulation models as research tools, but as yet the matter remains unresolved. While it is easy to show that an additional 20 mm of stored water confers a yield advantage, it is much more difficult to demonstrate that improved decisions and outcomes flow from a knowledge of this 20 mm (or that it is really 25 mm!). The scope for any different behaviour is limited. And even where this possible, the pay-off is likely to be increasingly marginal. We have found no evidence of a substantial mismatch between what growers do because of their own rule sets and model-predicted optimal performance: either the models endorsed growers' behaviour, or the models were wrong, or it didn't make much difference.

4.3 Reflections on our approach to acknowledging process

In one sense, the on-farm project was a trap we fell into. When the project started in central Queensland, one of us (PC) was involved in helping to negotiate the parameters within which its interaction would take place. We gave precedence to farmers' own experiments on issues that they thought important. In practice, this could not be maintained,

partly because of Garside's resignation as project officer; partly because of the distance between central Queensland and APSRU's base in Toowoomba; and partly because modelling was seen by other scientists as APSRU's sole contribution and everything else had to fit around that. Thus, the responsibility for setting the research agenda reverted to the modellers rather than being negotiated more widely, both within the project team and between the project team and the farmers.

Yet the scientists claimed on several occasions that the way the on-farm project was carried out was consistent with the guidelines we had set for the interaction. From our point of view, this was not so, because the nature of the interaction failed to build on farmers' current interpretations; because the interaction generally failed to generate guidelines for future action (either for farmers or scientists); because the lack of critical reflection by scientists (at least in a manner that acknowledged what the farmers were saying) meant that scientists merely endorsed motherhood statements about the value of 'participation', 'collaboration' and 'co-learning'; and because other ways of doing things were either not explored or dismissed as 'unscientific'.

Thus, from our point of view, whatever relevant and useful knowledge the project may have generated for both groups of participants was accidental and largely a side-effect of an interaction managed by scientists to display, and seek endorsement for, *their* models. The notion that farmers use models, and more importantly that farmers' models are elegant solutions to the problems of managing open systems, is still not accepted by the scientists involved.

From a methodological point of view, we failed by allowing a situation to develop in which our contribution became marginalised, and where one of us (PC) was effectively excluded from further participation in the project (thus reducing our opportunities for further negotiation of our point of view). It may be that our early attempt to re-define the nature of the project was premature in the circumstances and/or that we should have insisted earlier that this process would not achieve the outcomes we wanted. In the event, we lacked confidence in our point of view: either we were too generous in our interpretation of what was happening or too intimidated to be more assertive. In later episodes this was corrected.

The on-farm episode did provide ample evidence of the processes of resistance and accommodation in the 'dance of agency' (Pickering, 1995).

5 Evaluation of four approaches to decision support

5.1 Introduction

The survey work with farmers and advisers had established the nature and extent of the models farmers use in production. We captured these as rule sets. Participant observation in APSRU had revealed the nature of scientists' models of ostensibly the same systems. These were predominantly deterministic crop and soil simulation models used to transform historical patterns of weather data in the context of a fixed set of crop and soil parameters. As part of our involvement in the on-farm project, we had noted some of the discrepancies between these two very different ways of imposing order on the world. We also wanted to bring these different model formulations together so that a comparison could be made directly by farmers and advisers.

Also, it had become clear that the scientists were not convinced by the interviews and studies we had conducted, or by our interpretation of them. They seemed to prefer a more formal comparison to obtain information of value in the design of DSS products. So we chose to conduct the investigation in a way we thought would convince the scientists—to operate within the scientists' frame of reference.

Two one-day workshops (one with producers, the other with advisers and consultants) were conducted during early 1995 to gauge the usefulness and relevance of four different approaches to decision support. Both workshops were conducted in association with the Communication Research Institute of Australia. The four approaches examined at these workshops were:

1. APSIM—a collection of crop-simulation models which can be used to explore the effects of plant population, planting date, soil water, and nitrogen supply on the productivity of a range of crops, over a range of seasonal outcomes. In addition, the individual crop-simulation models can be combined to examine crop sequencing and rotation effects. Although APSIM was developed for researchers, APSRU is exploring its potential as a learning/decision support tool for agribusiness advisers and consultants. A series of APSIM outputs, in the form of *Excel* spreadsheets and graphs, was used by Peter Carberry (APSRU, Toowoomba) to demonstrate what APSIM could handle.

2. *Wheatman Plus*—a database obtained from winter crop-simulation models, which can explore the effects of planting date, fertiliser applications, stored soil water, and weed control on the yield of wheat, barley and chickpeas. *Wheatman* was originally developed to show farmers how to manage frost risk in wheat by manipulating combinations of planting date and variety. The recent release of *Wheatman (Wheatman Plus* in April 1995) now also includes barley and chickpeas, and offers a comprehensive paddock recording system. This session was presented by Greg Salmond (QDPI Goondiwindi, a member of the *Wheatman* team) to demonstrate the capabilities of *Wheatman Plus* for such matters as fertiliser use, the effect of selecting different wheat varieties/maturity groups on frost risk, the probability of a planting event (and adjustments to this based on the SOI), and their effects on paddock grass margins.
3. Howwet—a simple *Windows*-based program which uses rainfall records to estimate, and graphically display, the build-up of water and available nitrogen under fallows. This session examined the processes (run-off, evaporation and infiltration to depth) that affect the accumulation of water in fallows. David Freebairn, Steve Glanville and John Dimes (APSRU, Toowoomba) jointly presented a hands-on session in which farmers were able to use Howwet to explore how different patterns of rainfall, and soil cover, influenced the accumulation of water in fallows.
4. Rules of Thumb—a variety of simple, readily-communicated models about technical and financial issues which form the working knowledge of producers and advisers. The inclusion of Rules of Thumb was an attempt to assert farmers' own models for comparison with the more formal models of the professional researchers. It built on our understanding of these models derived in part from our previous research. In one sense, these models provide a baseline against which the more formal models can be judged; in another, they provide an indication of the format of a category of model with which the researchers' models will need to articulate if they are to change farm practice. In this session, Peter Ridge (APSRU, Toowoomba) discussed rules about matters as diverse as the cost of owning machinery, converting water to grain for chickpeas and wheat, and the nitrogen requirements of crops.

a statistically representative group of farmers. Rather, we sought farmers who were sufficiently interested in the topic to comment on the various approaches to decision-support. In approaching the Landcare groups, we emphasised that they were undertaking a consultancy on behalf of their industry, which would help R & D agencies to decide how far they should go on investing in decision-support products for farmers. An honorarium of \$100 was credited to the respective Landcare group for each participant.

After the introduction, the farmers were asked to complete a questionnaire about their farm, their farming practices, and their use of computerised decision-support tools and professional advice. These data were used to establish how far this group of farmers was typical of the local farming community. In the questionnaire, producers were also asked to rate a number of technologies for their potential to improve farm incomes. In part, this question was posed to see whether the workshop changed their views about such technologies.

Once the questionnaire was completed, the farmers divided into three groups of six or seven, to which they had been allocated according to their time of arrival. Each group moved to a smaller room to spend a little more than hour with the presenters of each decision support approach. They were provided with a product specification sheet which we had developed in conjunction with the owners of each of the four tools. This described the inputs needed for each one, the outputs it provided, the level of precision in both inputs and outputs, and the cost of using the tool.

Each presentation, and the accompanying discussion, was tape-recorded. In addition, the farmers completed an evaluation sheet for each approach, at the end of each session. Towards the end of the day, the farmers were asked to consider how they might allocate a hypothetical training/management support grant of \$5,000 between a variety of activities, services and products (many of which were integral to the approaches demonstrated). In this way, we tried to determine how they valued each approach to decision-support in relation to its likely costs. Later in the day, farmers were also asked to refer back to the questionnaire in which they rated the technologies and revise the ratings. However, producers either showed no change of view, or failed to complete this part of the questionnaire for lack of time.

Finally, farmers were asked to rate each of the four approaches demonstrated for their usefulness and relevance to: (a) farmers, (b) advisers/consultants, (c) scientists, and (d) R & D Corporations.

5.2 Producers' workshop

Twenty farmers, mainly from Landcare groups in the Dalby–Chinchilla area, were invited, through their local coordinators and chairmen, to evaluate four different approaches to decision-support, in a workshop at Dalby Agricultural College on 5 May 1995. We did not try to gather

5.2.1 Characteristics of participants and their farms

The average size of producers' farms was 1083 hectares, with 724 hectares devoted to cropping (Table 1). Because of the drought, the breakdown of the area devoted to actual plantings, over the last five years.

On average, the areas devoted to summer (sorghum, mung bean, sunflower and cotton) and winter crops (wheat, barley and chickpeas) were similar, at 360 hectares each.

The participating producers had 20 years farming experience on average, and each farm supported 2.9 adults. The annual outlay on professional advice, including accounting, business management, and agronomic advice, was \$3,400.

Half the farmers owned computers and 80% of these were used for bookkeeping. One quarter of the computer owners used them for paddock recording. None of the farmers had used *Wheatman* on their own computer, and only one of the participants had been exposed to *Wheatman* previously. Most (89%) of the farmers participated in professionally facilitated discussion groups.

Outlays on professional advice, and the rate of computer ownership among the participating farmers were high by industry standards. Moreover, dryland cotton, at 13% of the cropped area, was over-represented, in comparison to the 5% of the cropped area currently devoted to this crop on the Northern Downs. The increased emphasis given to cotton appeared to be at the expense of barley, which was under-represented (14% cf. 25% in the statistics for the Northern Downs) among the participants.

5.2.2 Current practices and technologies employed

Most of the farmers were shifting the balance of their cropping towards more summer crops, including dryland cotton: very few were experimenting with winter crops, and there was virtually no interest in ley pastures to improve soil fertility (Table 2).

All the farmers employed minimum tillage and stubble retention, and often used herbicides to control weeds on fallows. Most (94%) of the farmers used nitrogen fertiliser, and most adjusted rates according to soil-test data. The protein history of the paddock and seasonal outlook information were used less frequently to guide nitrogen fertiliser decisions.

Many (61%) of the farmers monitored soil water regularly to estimate crop water use, and most of these people said they were accounting for soil water below 1 metre in these calculations.

Very few farmers were using the SOI to adjust either their cropping programs or the rates of nitrogen fertiliser applied.

5.2.3 Cropping technologies with potential to improve profits

The producers looked again at their current practices and technologies and rated them for their potential to contribute further to farm profitability. Ratings varied from 0 (no potential for improvement) to 3 (lift profitability by at least 20%) (Table 3).

The practices and technologies with the highest ratings on average were: (1) fine tuning minimum tillage practices; (2) changing the balance between winter and summer crops; (3) further adjustments to rates of nitrogen fertiliser; (4) cheaper and more effective herbicides for chemical fallows; (5) use of forward selling and other price contracts; and (6) monitoring crops to improve water use efficiency.

The practices and technologies that were rated poorly for their potential to improve profit were: (1) better control of foliar diseases; (2) the use of the SOI to adjust cropping programs; and (3) the use of ley pastures to improve fertility.

The low ratings given to control of foliar diseases may reflect the recent history of drought, which has masked this problem, or else that these farmers, who are rotating a variety of crops, have already adopted effective control procedures for foliar diseases.

Similarly, the low ratings given to the use of the SOI for adjusting cropping programs, and the introduction of ley pasture to remedy fertility decline, may in part stem from a belief that these approaches are irrelevant during a prolonged drought.

To a large extent, producers were already using the technologies that they believed would improve profitability. (Tables 2 & 3). The only exception to this was the frequent practice of rotating crops to minimise foliar and root disease (Table 2), which may now be practised to such an extent that farmers see little scope for further gains from the control of these diseases (Table 3). On the other hand, producers saw little potential in the use of the SOI to adjust cropping programs (Table 3), and to date have taken little interest in its use (Table 2).

5.2.4 Evaluation of the four approaches to decision support

At the end of each session, producers indicated their disagreement or disagreement with a number of statements about each of the approaches to decision support.

They thought all the approaches dealt with matters of real concern, with APSIM and Rules of Thumb rating slightly better than Howwet and *Wheatman Plus*. There were some reservations about the input requirements (e.g. cost of soil testing) for APSIM. No concern was expressed about the input requirements of the other products.

Table 1 Workshop 1. Characteristics of producers and their farms.

Farm Characteristic	Mean	Range
Total Farm Area (ha)	1083	246–5400
Area Under Crop (ha)	724	220–1680
Sorghum Area (ha)	233	0–900
Mung Bean Area (ha)	23	0–200
Sunflower Area (ha)	5	0–60
Cotton Area (ha)	97	0–400
Wheat Area (ha)	230	0–1000
Barley Area (ha)	100	0–600
Chickpea Area (ha)	35	0–200
Years Farming	20	10–32
No. Adults Dependent on Farm	2.9	2–4
Annual Outlay on Professional Advice	\$3,417	\$500–6000

Table 2 Workshop 1. Percentage of producers employing different practices and technologies

Practice or Technology	Response rate
<i>Cropping system management</i>	
Experimenting with new winter crops	28%
Changing balance between winter and summer crops	83%
Routinely monitor soil water	83%
Take VAM into account in cropping program	67%
Crop options often restricted because of herbicide residues	28%
Use ley pastures to improve fertility	11%
Use nitrogen fertiliser	94%
Vary rate each year	89%
Adjust rate according to seasonal expectations	61%
Adjust rate according to soil test	83%
Adjust rate according to protein levels of previous crop	67%
Employ stubble retention/minimum tillage	100%
Use herbicides for chemical fallow	94%
<i>Rotations to minimise disease effects</i>	
Rotate crops to minimise foliar disease	78%
Rotate crops to minimise root and crown diseases	94%
<i>Monitoring</i>	
Soil water at planting and harvest to calculate water use	61%
Take into account water below 100 cm for this purpose	50%
<i>Marketing/Price management</i>	
Regularly use forward selling	72%
Employ grain marketing consultant	61%
Invested in more on-farm storage over last 5 years	33%
<i>Use the SOI to change</i>	
Crop grown	17%
Area under fallow	22%
Rate of nitrogen fertiliser used	11%

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Table 3 Workshop I. Producers ratings of the potential for different practices and technologies to improve profitability (0 = none; 3 = large)

Practice or technology rating (0–3)	Average rating
<i>Cropping system management</i>	
Grow different winter crops	1.3
Changing balance between winter and summer crops	1.9
Increase cropping frequency through opportunity cropping	1.2
Manage VAM better to improve nutrition (P & Zn)	1.2
Manage crop options around herbicide residues	1.2
Use ley pastures to improve fertility	0.8
<i>Use nitrogen fertiliser</i>	
Adjust rates of nitrogen fertiliser	1.8
<i>Stubble retention/minimum tillage</i>	
Develop and fine-tune minimum tillage practices	2.3
Identify cheaper and more effective herbicides for fallows	1.7
<i>Pest and disease management</i>	
Better control foliar diseases	0.7
Better control of root and crown diseases	0.9
Cheaper and more effective insecticides for summer crops	1.4
<i>Monitoring</i>	
Monitor crops to improve water use efficiency	1.6
Soil coring to greater depth to estimate available water	1.3
Surface sampling to monitor important nutrients	1.0
Soil coring to depth (90 cm) for available nitrogen	1.2
<i>Marketing/Price management</i>	
Subscribe to marketing service for better price information	1.3
Use forward selling and other price contracts	1.7
Invest in on-farm grain storage	1.1
Use the SOI to adjust aspects of the cropping program	0.8
<i>Learning/Decision support</i>	
Discussion groups to refine and develop rules of thumb	1.5

The participants rated APSIM as the best product for showing clearly what needs to be done to make more money; Rules of Thumb rated very poorly in this regard. APSIM may have been rated highly because it was promoted as a tool for skilled consultants and advisers who would be able to point out potential opportunities, and interpret the output for specific issues raised with farmers. APSIM, of course, does not spell out what should be done, but this response could also stem from the perception that it precisely estimates the profit from alternative courses of action. The other approaches that were demonstrated did not assume that there would be a consultant on hand to assist with interpretation but were promoted as tools to help farmers learn in isolation, or occasionally in groups. It is therefore difficult to decide how far APSIM gained a high rating for its ability to predict higher profits and how far for consultant input and interpretation. APSIM rated slightly better than the other approaches for its potential to improve farmers'

management of cropping but again this response cannot be divorced from its dependence on consultant input for interpretation.

The producers generally agreed that all the approaches, except APSIM, handled issues which could be tackled in a variety of other ways. However, two thirds of respondents believed that APSIM's approach to many issues was unique.

Most respondents agreed that all the approaches extended the range of possibilities for their farming practice. However, there were a few dissenters in the case of *Wheatman Plus*, and this pulled down its rating.

5.2.5 Allocation of \$5,000 management/training grant

The producers allocated a hypothetical management/training grant of \$5,000 between the alternative decision

Table 4 Workshop I. Allocation of \$5,000 management/training grant between decision support activities, services and products.

Decision Support Activity, Service or Product	Average \$ allocation for 1995–96	% positive responses
Soil testing for nitrate and water to depth @ \$200/paddock	1044	94
General agronomic advice from consultant @ \$120/hr	1057	100
Grain marketing consultant including newsletter @ \$120/hr	438	65
More use of an accountant for management advice @\$120/hr	357	65
Access to APSIM bureau service @ \$120/hr (plus soil tests)	789	94
Access to <i>Wheatman</i> bureau service @ \$120/hr	292	71
Purchase of Howwet program @ \$50	59	100
Subscription to facilitated discussion group @ \$500/yr	324	65
Contribution for research on local issues @ \$300/issue	215	71
Purchase of a automatic weather station @ \$5,000	294	12
Donation to local institute for farming systems research	371	47
Total	\$5,240	

support activities, services and products listed (Table 4). Realistic commercial costs were attached to each alternative.

The allocations between the listed alternatives were highly variable, but on average, the largest allocations were directed to: (1) general agronomic advice from a consultant; (2) soil testing for nitrate and water; and (3) access to APSIM through a bureau service.

Despite the fact that most farmers believed that they could benefit from fine-tuning their minimum tillage practices (Table 3), those few farmers who did not share this view allocated significantly ($P < 0.0002$) more to the use of an APSIM bureau service. These same producers were also more aware ($P < 0.01$) of the potential contribution of VAM, and gave a higher ($P < 0.005$) rating to the potential gains to be had from improved control of foliar diseases. Therefore, the profile of a potential APSIM user is one who is already confident in the practice of minimum tillage and is more aware than average of the threats posed by foliar diseases and inadequate levels of VAM.

There was no correlation between allocations to soil testing, and allocations to an APSIM bureau service. This was surprising in view of the need to measure soil nitrate and available water in order to exploit APSIM fully at the paddock level. Participants may have recognised the value of monitoring soil water and nitrogen without being interested in APSIM. Alternatively, they may not understand the need for these inputs in order to use APSIM effectively.

5.2.6 Relevance of approaches to producers and advisers

Producers rated Rules of Thumb and Howwet as most relevant to *their* needs, and discounted the value of *Wheatman Plus* and particularly APSIM in this regard. Those few who rated APSIM as most useful and relevant to farmers allocated more dollars than average ($P < 0.1$) for access to it through a bureau service. However, farmers generally rated APSIM as most relevant to advisers. Producers also saw *Wheatman Plus* as more useful to advisers than to themselves. Howwet and Rules of Thumb were viewed as equally useful to farmers and advisers.

5.3 Advisers' and consultants' workshop

Eighteen advisers from the QDPI, agribusiness, and independent consultants operating on the Darling Downs, attended a workshop we conducted in Toowoomba on 6 June 1995. The format of the workshop was similar to the one for producers held in Dalby one month earlier. Again, it was emphasised that the major objective of the workshop was to assess the relevance of four different approaches to decision support in order to guide R & D organisations and agencies contemplating further investment in the development of decision-support products. The organisers offered to pay a sitting fee and meet the travelling expenses of independent consultants, but none took up this offer.

The participants first completed a questionnaire about the nature of their work, their contact with farmers, and

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their previous use of software and decision-support products. They also said what technologies they thought would increase farm profitability, and they reviewed this at the end of the workshop to see whether their views had changed.

As well as evaluating each decision-support approach, the advisers/consultants allocated a hypothetical \$30,000 grant from a R & D agency to a variety of activities intended to improve their skills and those of farmers. (The advisers were offered much more than the producers because of their professional responsibility for the performance of a group of farms and farmers.) Of the \$30,000 only \$8,000 could be allocated to adviser training; the remainder had to be spent on activities with farmers. In all cases, the training and producer activities were realistically costed so that the allocations reflected advisers' views on which approach was worth how much.

As with the producers' workshop, the advisers were divided into three groups, and each group spent just over an hour with the presenters of each decision-support approach. The same products were demonstrated as before.

5.3.1 Characteristics of participating advisers and consultants

Most of the adviser/consultant participants gave advice on production and just over half of them offered advice on

natural resource management. Sixty percent had some commitment to research and development (Table 5). Most (53%) were employed in the agribusiness sector, and a further 27% were drawn from the QDPI; the remainder saw themselves as independent consultants.

On average, each participant regularly dealt with 56 farmers, made 196 farm visits, and handled 460 telephone enquiries each year. They addressed an average of 21 meetings each year, with each meeting typically attracting 10–11 farmers.

Spreadsheets were the most frequently used software package among advisers, but public sector advisers tended to use them less than agribusiness advisers. On the other hand, 75% of public sector advisers used *Wheatman*, whereas only 17% of agribusiness advisers used it.

5.3.2 Cropping technologies with potential to improve farm profitability

Choosing different crops, changing the balance between summer and winter crops, adopting the principles of opportunity cropping, response farming (changing the cropping program according to SOI movements or the timing of the seasonal break), and adjusting rates of nitrogen fertiliser, were all rated highly for their potential to increase farm profitability. The ratings of these did not change

Table 5 Workshop 2. Characteristics of participating advisers and consultants

Characteristic	Response
<i>Nature of Work</i>	
Advise on production issues	93%
Advise on natural resource management	53%
Undertake research & development	60%
Work in administration & training	33%
<i>Employment</i>	
Independent consultant	20%
Public sector adviser	27%
Agribusiness adviser	53%
<i>Number of Contacts with Farmers</i>	
Farmers on one-to-one basis	56
Number of farm visits per year	196
Number of telephone enquiries per year	460
Number of farmer meetings addressed	21
Total number of farmers at these meetings	221
<i>Use of Software and Decision Support Packages</i>	
Rainman	20%
Wheatman	53%
Padfert I	3%
Spreadsheets	67%
Water scheduling program	20%

significantly as a result of the workshop (Table 6). The major difference between the previous ratings of producers and those of advisers related to the fine-tuning of minimum tillage: producers rated this highly at 2.3 (scale 0–3), whereas advisers rated it at 1.4 (scale 0–3).

The largest positive shifts in ratings concerned business planning and the management of cash flows, with their ratings shifting from 1.8 to 2.3, and 1.1 to 1.5 respectively (Table 6). Only one respondent commented specifically about his emerging realisation of the importance of business planning, but the shift in ratings was clear. This was most pronounced among respondents who had given business planning a low rating at the beginning.

Two technologies were discounted consistently by advisers through the course of the workshop. Advisers rated ley pastures highly (rating 2) at the beginning of the workshop, but this dropped to 1.5 at the end. This may have stemmed from the emphasis on manipulating nitrogen supply with fertiliser, and giving much less attention to alternative approaches, including the use of legume leys. Similarly, advisers downgraded the potential value of a push probe from an initial rating of 1.4 to 0.9 at the end. Again, there was during the workshop a strong emphasis on more rigorous and scientific procedures for assessing soil water, and this may have caused advisers to discount the push probe.

5.3.3 Evaluation of the four approaches to decision support

Advisers and consultants, showed by their responses that they thought that all four approaches would help in the sustainable management of farms. In addition, while they thought that APSIM, *Wheatman Plus* and Howwet included all relevant factors, they were less sure about Rules of Thumb. The advisers, like the producers, had some reservations about the input requirements of APSIM.

The advisers shared the farmers' enthusiasm for APSIM as the best product for showing how to make more money and increase sustainability. Most advisers dismissed Rules of Thumb in this regard. *Wheatman Plus* and Howwet enjoyed intermediate ratings. Again, it is not clear whether this high rating for APSIM stems from the novelty of the product, or from its requirement for a skilled researcher, adviser or consultant to translate its output.

Advisers were divided about whether APSIM provided a unique way to analyse issues: forty percent disagreed while the remainder agreed, or agreed strongly. The precision of APSIM in reviewing past performance was rated as important, particularly if it is used to help decision-making about the future.

Most respondents agreed that all approaches could help advisers and producers to learn from each other, and that

there was sufficient exposure of the underlying logic for the purpose.

Most advisers rated precision highly, and saw it as the key to the beneficial use of APSIM and Howwet. Accordingly, pursuing precision further would increase their value by 10–20%. However, just under half the respondents acknowledged that the pursuit of precision could diminish the transparency of the underlying logic, with consequent difficulties in communication.

Advisers generally ranked the approaches in the order: APSIM, *Wheatman Plus*, Howwet and Rules of Thumb, as aids to understanding farming processes and as means of encouraging advisers and producers to think about issues beyond the paddock level.

5.3.4 Allocation of \$30,000 R&D grant

Most advisers were sufficiently impressed with APSIM by the end of the workshop to allocate a hypothetical \$4,500 to training in its use. Two thirds of them were also keen to advance their skills in the analysis of cropping systems through further training in the application of *Excel* spreadsheets (Table 7). Training in group facilitation skills and in grain marketing rated poorly.

In their allocation of funding to activities and services for farmers, advisers gave a high priority to the formation of farmer discussion groups, the use of crop monitoring techniques in groups, the purchase of a licence to operate APSIM, and subsidies for the soil testing needed to run APSIM (Table 7). Just under 50% of respondents allocated funds to on-farm group research. There was little interest in subsidies to start up a *Wheatman Plus* bureau service.

The few respondents who failed to allocate funds to the purchase of an APSIM licence were those who rated business planning more highly ($P < 0.005$) than average, both at the beginning and at the end of the workshop.

5.3.5 Relevance of approaches to producers, advisers and scientists

The advisers rated *Wheatman Plus*, Howwet and Rules of Thumb as appropriate to the decision support and learning needs of *producers*, and rated APSIM as inappropriate for this group.

APSIM, *Wheatman Plus* and Howwet were all rated as appropriate, to highly appropriate, to the needs of *advisers*, whereas Rules of Thumb were rated as appropriate for this group.

APSIM was rated as most appropriate (score 1.9 on scale –1 to 2) to the needs of *researchers*, while Rules of Thumb were rated as barely appropriate for this group.

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Table 6 Workshop 2. Advisers' ratings of the potential for different practices and technologies to improve farm profitability before and after the workshop (0 = none; 3 = large)

Practice or Technology	Average Rating Before (0–3)	Average Rating After (0–3)
<i>Cropping system management</i>		
Choosing different winter or summer crops	1.7	2.0
Changing balance between winter and summer crops	1.8	1.8
Adoption of principles of opportunity cropping	1.9	2.1
Refinement of novel planting techniques	1.2	1.3
Use crop models to better explain seasonal effects	1.5	1.8
Develop practice of response farming	1.9	1.9
Adjust N rates in response to soil tests etc	2.0	1.8
Fine tune minimum tillage practices	1.4	1.4
Better manage VAM to improve nutrition	1.6	1.4
Address declining fertility with legume ley pastures	2.0	1.5
<i>Management of pests and diseases</i>		
Rotations to reduce the incidence of foliar diseases	1.1	1.1
Rotations to reduce root and crown diseases	1.4	1.3
More cost effective herbicides for chemical fallows	1.1	1.3
Better knowledge of herbicide residues	1.1	1.1
<i>Product marketing and price management</i>		
Use forward selling & options to manage price risk	1.8	2.1
Increased investment in on-farm storage	1.2	1.5
<i>Financial management</i>		
Better business planning that includes all resources	1.8	2.3
Monitoring of farm cash flow	1.1	1.5
<i>Physical monitoring for improved management</i>		
Crop growth, water use and water use efficiency	1.3	1.7
Monitor SOI in order to adjust cropping program	0.9	1.2
Monitor insects for integrated pest management	1.7	1.7
Monitor soil water and nitrate at depth	1.8	2.0
Use push probe for estimates of soil water	1.4	0.9

5.4 Discussion and conclusions

A surprising finding from these workshops was the low level of previous exposure to *Wheatman* which had been actively promoted, through the press and through small workshop sessions, for at least five years since its release in 1989. Our evidence suggests that its use has been largely confined to QDPI advisers, with little use by either agribusiness advisers or farmers. Despite the fact that computer ownership was above average among the farmers involved at the Dalby workshop (50% cf. an average of 30%), not one producer had acquired or used *Wheatman*. The evidence presented here suggests that decision-support

software of this type is *not* an efficient vehicle for delivery of insights from research organisations to the wider farming community.

Despite the fact that none of the farmers had used *Wheatman*, participants were generous in their assessment of its potential, as of other software approaches, to contribute to the improved management of their cropping programs. However, this assessment did not exclude other approaches, particularly those which supported learning in a group setting. Discussions about APSIM and about the refinement of Rules of Thumb were also valued.

Table 7 Workshop 2. Allocation of \$30,000 grant between training activities for advisers, and activities and services for producers

Activity or Service	Average \$ allocated	% Positive response
<i>Training activities for advisers and consultants</i>		
Training in group facilitation (\$1,800)	720	40
Training in cropping systems analysis using Excel (\$1,800)	1200	67
Training in the use of Excel tailored to needs (\$1,800)	960	53
Training in the use of APSIM to gain accreditation (\$4,500)	3600	80
Training in grain marketing, futures & options (\$1,800)	360	20
<i>Activities and services for producers</i>		
Grant to subsidise formation of groups (\$5,000/group)	5807	73
Grant for on-farm research with groups (\$5,000/group)	3047	47
Grant for crop monitoring in groups (\$5,000/group)	4813	67
Subsidy for soil sampling needed for APSIM (\$100/paddock)	2827	75
Grant to fund start-up <i>Wheatman</i> bureau (\$5,000/area)	1333	27
Purchase APSIM licence with professional support (\$5,000)	4000	75
Total of allocations	\$28,667	

Producers and advisers rated APSIM highly for its capacity to show what changes are needed for a better result. Since the outputs usually take the form of yield distributions for two courses of action (e.g. with and without applied nitrogen), it is difficult to see how APSIM is superior in pointing to more profitable strategies and tactics: certainly its outputs are not inherently different from those of *Wheatman Plus*, although the quality of the *Excel* graphics used by APSIM was markedly superior to that of the *Wheatman Plus* graphics. Possibly APSIM was highly rated because it was thought to be more precise than alternative approaches. This belief may derive from APSIM's high requirement for input data, the fact that it simulates crop growth on a daily time-step basis, and that it provides detailed, daily data on crop growth and nutrient uptake.

The producers were adamant that precision was an essential prerequisite for any decision-support software. This may partly have led to the favourable response to the APSIM demonstration. They did not recognise that increased precision calls for expensive software development with increasingly complex models; and exacts opportunity costs because of the increasing difficulty in interpreting model output and the restriction of the search space. We failed to convince them that there were definite limitations to the number of variables that could be handled by computerised decision-support packages, particularly when they were built to respond to weather variables on a daily time-step basis. The real costs of increasing precision seem to be largely hidden. The farmers also commented on the need to incorporate a sophisticated paddock recording system into

decision-support packages: the recording system included with *Wheatman Plus* was judged inadequate for their needs.

The advisers and consultants believed that the value of models such as APSIM in decision support depended on precision. Precision is often argued on the basis of good agreement between 'observed' and 'predicted' yields, with an index of determination (R^2) between simulated and observed yields in the range 60–75%, and the slope of the regression line close to one. However, it is not clear that increasing the R^2 , for example by the inclusion of more variables, necessarily leads to a better decision-support product. This is particularly the case when the complexity of the underlying model increases to such an extent that it becomes difficult to discern the linkages between inputs and outputs, and the essential ideas needed to guide action and promote change become increasingly difficult to communicate. Only 50% of advisers recognised these trade-offs as costs that are inseparable from the quest for greater precision.

The alternative path to achieving precision is through more sophisticated and rigorous measurement of those input variables that clearly have the greatest impact on the output variable(s) (e.g. yield) of interest. In the case of APSIM, precise measurement of soil water, nitrate nitrogen, rainfall, and temperatures is essential to precision. However, it is yet to be established that the precision in input specification needed to maximise the predictive performance of the crop-simulation models is as relevant to farmers who want higher profits. In practice, the increased precision in outputs from models of increasing complexity is small. We suspect that

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the marginal value of increased precision in model output, against a background of very uncertain future weather, is quite small if not negative.

There were some significant differences between the two workshops. The farmers were more forthright in questioning the different approaches to decision support (and more insightful in their comments) than the advisers, perhaps because of differences in their skills and formal scientific training. With a few exceptions, both groups (farmers and advisers) appeared to undervalue their own models as against the 'scientific' models which were presented. Advisers particularly did not admit to using rules of thumb in their work. The producers endorsed the value of computer-based DSS—for advisers and researchers. The advisers endorsed the development of DSS—primarily by and for researchers, just maybe for advisers. The buck was being passed back along the traditional farmer–extension–research continuum.

The farmers recognised that routine assessments of soil water and available nitrogen could be useful in managing their cropping programs, and showed the strength of their feeling by allocating \$1044 to this from their hypothetical allocation of \$5000. That there was no relationship between their allocation to soil testing and their interest in APSIM, suggests that they are confident that interpretation and better outcomes are possible without access to a crop-simulation model. The challenge for the researchers is to demonstrate that the use of crop-simulation models can add value to soil test data and so generate even better outcomes for farmers.

5.5 Reflections on our approach to the evaluation of workshops

These workshops gave us a great deal of trouble. The appearance of an objective comparison between the four different approaches was deliberately contrived in order to raise certain issues to do with the design of DSS products: whether they should be backward or forward-looking, the requisite precision in output variables (in order to facilitate decision-making), and the necessary precision in inputs to achieve this. The use of product description sheets did assist in raising these issues with the various model developers; indeed, it became clear that these were issues they had not considered. So, to that extent, we were successful in beginning to negotiate a common design language. The use of four approaches, in a comparative setting, was appreciated by farmers because it was clear that we were not trying to sell any one approach; our attempt to seek the advice of producers and advisers was genuine and seen to be so. Our payment of an honorarium to farmers helped to establish this.

Certain key insights did emerge at the workshops: the claim for increased precision made for the more complex model formulations (APSIM) was questioned; and the irrelevance of some model outputs noted (why would one want to run *Wheatman Plus* with the frost risk turned off?). We tried to establish a distinction between looking backwards and looking forwards (which seemed to us to be quite distinct ways of using models), but this distinction did not seem important to the other participants. Some producers were vocal in their endorsement of APSIM, but it was not clear why. What they saw in the presentation was *Excel* graphics of APSIM output: was it APSIM, or *Excel*, or the topicality of the story, or Peter Carberry's energetic presentation that they were responding to? Is looking backwards (re-working past experiences) sufficient to guide future decision-making, or is changing our focus from looking backwards to looking forwards an important use of a DSS such as *Wheatman*?

Thus, from our point of view, we were unable, using the workshop sessions, to achieve the level of critical reflection we would have liked. They were an ambiguous experience for us. The history of SIRATAC (Cox, 1996) suggests that researchers should not just respond to an apparent demand for these products but should seek to be user-relevant, not user-driven. Granted the substantial gap between systems of thought and systems of action which we have documented, R&D planners need to be particularly wary of encouraging an activity where these different perspectives meet as if by accident. We are asking researchers to point out why these tools are *not relevant* to the needs of their clients, and to refrain from using this kind of consultation as a substitute for critical reflection about how DSS products might bring about beneficial change in production practice. We recognise that this is a big ask, but failure to meet this issue head on will only lead to further organisational commitment to an activity that is holding up more important innovation in R,D&E practice. The opportunity costs are high. Still, the scientists liked the workshops. And that helped to re-establish our credibility with them.

6 Bridging the model gap

6.1 Introduction

During this project we have tried to learn about and describe the models that farmers use to manage their broadacre, dryland, agricultural, production systems, and those that scientists use ostensibly to describe the same systems. We have argued that farmers' models (captured as rule sets, or rules of thumb) are comprehensive, transparent, stable and adaptive. They are appropriate model structures for guiding the management of a broadacre, dryland, cropping system characterised as much by uncertainty in outcome as by complexity in configuration. Scientists' models, on the other hand, are partial, opaque, unstable (brittle), and non-adaptive. They may be suitable for research purposes (that is a separate issue), but there are major questions to be raised about their proposed (and attempted) use to change the ways in which farmers manage their production systems. There is a substantial model gap. We have also attempted to discuss how this model gap may be bridged.

APSRU was set up to exploit the new ability of scientists to simulate the performance of crops and soils. At least in part, this was based on the perceived success of *Wheatman* and SIRATAC in helping to improve decision-making on the farm. Yet this research has led us to question the validity of this perception. Cox (1996) argues that SIRATAC was in many ways a special case, reflecting a political debate peculiar to the cotton industry. In any case, the marginal value of the recommendations generated by SIRATAC compared with other simpler formulations is questionable. Similar considerations apply to *Wheatman*: the rules for varietal choice are simple enough (they relate to differences in maturity) and can be expressed readily outside the model framework (as rules of thumb); and there appears to be some justification for querying the assumptions about risk management behaviour on which *Wheatman* is based (this view was expressed by at least one private-sector adviser). Thus, the exemplars of this approach turn out to be poorly justified. Pannell *et al.* also propose that the marginal gains from complex model formulations are small and may indeed be negative in the context of the management of open systems. The case for using simulation models in this way is not self-evident on the basis of recent experience, and has still to be made. To some extent, that was the reason why APSRU proposed this research project. APSRU asserted its desire, indeed determination, to be relevant to a range of stakeholders including farmers, advisers and policy-makers; but it has largely restricted itself to one type of contribution (APSIM), and this largely thwarts its purpose.

Our contribution has been to raise some of these considerations, to question the assumptions on which they

are based, and to suggest ways of resolving, or at least ameliorating, them. The current situation is clearly absurd: scientists are trying to justify expenditure on the development and application of their models by insisting on their use by farmers and advisers. This is a category mistake of some importance (see Cox, 1996) because prevents agricultural R&D from tackling management decision-making in an effective, efficient and expeditious manner. The simple assertion of a particular point of view (based primarily on consideration of water and nitrogen) is not good enough if we are intent, as we believe we should be as professional researchers, on effecting change. It fails to recognise where farmers are currently at, where gains in production efficiency can be expected to be made, and what different ways there may be of going about this. The development of models is masquerading as the analysis of real issues, and getting in the way of the more fundamental change that we see as necessary if professional science is to help discover the real problems in practical agriculture, and to do something about them. We have got caught up, however unwittingly, in 'group think'². The choice of research paradigm, the selection of appropriate representations, and the negotiation of criteria by which to judge the success or otherwise of this activity are all up for grabs. There are other ways of doing things.

6.2 Communication of failure

They've got a long way to go to develop those sort of things...but I think it's a bit too restrictive...As the computers get more powerful and are able to take into account more factors, well you see we're already doing that, I suppose they're good for putting down on paper what we already know.

Producer on crop simulation models, Dalby, September 1994

...it is a very different approach than just any of the judgements that just another consultant has made. It's more measuring things and using this scientific approach.

APSRU scientist

There is a bias here that models aren't really needed.

Scientist on Cox's performance when reviewing the on-farm project, 8 September 1994,

We haven't got credibility, even within APSRU, for the models at the moment. ...These aren't trials to answer a question. To me these are trials to create credibility.

Scientists, reviewing the on-farm project, 8 September 1994

² Groupthink: groupthink is a term used to signify a syndrome of ineffective decision-making by a group. Elements of this syndrome include: limited information search, misperceptions of data, and a false sense of a group's righteousness.

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A general issue emerged from this project about the different ways in which 'failure' is appreciated and communicated by scientists and farmers. It was strongly impressed upon the writers that failure is not something to be countenanced: the notion that APSRU could be a failure (because it was established on faulty premises, and seemed intent on locking itself into a course of action that guaranteed minimal impact) was out of bounds. Yet this kind of 'double loop learning' (questioning the paradigm within which an activity is conducted) can ultimately be the basis of significant progress so long as we are prepared to learn and move on. On the other hand, the farmers with whom we interacted showed considerable evidence of skills in double loop learning: many questioned the advisability of applying chemicals and long-term dependence on nitrogen fertiliser (whether this was a good thing or not with a view to the long-term prospects for improved performance). Farmers appeared to value information about the things that didn't work, such as an experiment they had tried. Perhaps scientists' relative inability to value negative or inconclusive results is a characteristic of professional agricultural science which has been encouraged by the use of publications (preferentially recounting positive results—the experiment that worked) as a criterion for advancement. This theme is expanded upon by Shulman (1995).

We attempted to communicate about failure: by stressing the opportunities for learning that this provides; that differences in point of view/interpretation help to identify potential opportunities for learning by all participants; that science offers just one point of view when it comes to management; that the discussion of a management issue ('thinking through' the process) may be more important than trying to identify a single best course of action. Shulman assisted Cox in writing the SIRATAC case study (Cox, 1996) so that it more-clearly valued the SIRATAC experience: that there were positive aspects to it; that the actors had got unwittingly caught up in a cycle of escalation; that much can still be learned from its eventual 'failure'; and that recognition of its eventual 'failure' was an indication of its success. We tried.

6.3 Articulation of simulation and heuristic models

Models have many purposes: to help think through an issue; to reveal the most important factors that are likely to influence the outcome (the boundary of an issue); to engage people in dialogue, and negotiations of meanings that (a) there is an issue, and (b) that there are opportunities for a solution; and to draw out the practical implications for action. What constitutes an issue depends on who you talk with. The choice of model depends on who you are talking to and what you are talking about. The discussion in this section comes largely from Cox *et al.* (1995).

Crop-simulation models do much of the above for scientists engaging with other scientists, but there are many instances where the factors incorporated and the boundaries drawn are entirely inappropriate for the practical manager. Even for scientists, they should be focused on an issue that needs to be resolved; usually they are not. Does integrating many bits of specialist knowledge into crop-simulation models necessarily lead to new insights for managers? Scientists argue that there is no other way for them to integrate all the relevant environmental factors. That may be so for them, but their set of 'all relevant factors' is merely a sub-set of those recognised by the manager. One of the problems with simulation models is not that they are integrated, but that they are partial; not that they do not take into account the right factors to 'explain' a situation (i.e. describe it) but that they ignore the distinction between controllable and uncontrollable factors and hence fail to provide guidelines for action.

This argument has several ramifications. First, we value multiple models for use by different people for different purposes; different models will be used anyway, and it seems perverse to insist on a unitary model structure ('one size fits all') irrespective of the context of model use. Second, recognition of different model structures for different purposes emphasises that practitioners already use powerful representations that have been adapted to handle the issues they face. Assertion of a different category of model has to be evaluated in comparison with how these existing processes fulfil their purpose, not in any absolute sense. Third, models should be valued as process tools at least as much as products (whether descriptive or analytical), i.e. negotiation of a model structure by different actors can facilitate communication and generate novel options. The model can be discarded once the actors have learned from the process of building it. The existing simulation technology seems intent on describing an objective world of biophysical processes that is almost inaccessible to practitioners who are looking for things that they can do differently to obtain better outcomes. The practical world is occupied largely with continual re-adjustment at the margins to ever-changing circumstances. Any articulation of the models of scientists and farmers is, at present, accidental.

The evaluation of alternative model formulations is a critical issue. The bald assertion that a model captures the best available scientific knowledge just will not do if we are intent, as we believe we should be, in bringing about change in the management of agricultural production systems. We have to be concerned about the contribution *at the margin* of alternative model formulations for different uses by different users. There are rapidly diminishing marginal returns to increasing complexity. For many purposes, we may have already gone past the optimal level of complexity (because of a computational problem to do with a combinatorial explosion of input specifications; because we are not restricting the search space to isolate likely solutions;

and because the input requirements are too onerous to collect, and hence are poorly specified). We have gone too far in chasing marginal improvements in precision (required to satisfy a scientific audience) at the expense of explanatory power, creating dependence when we should be empowering.

Perhaps our current preoccupation with the decision-making process itself is misplaced. Pfeffer (1992) offers an alternative way of thinking about the decision-making process. According to him there are three important things to remember about decisions: a decision by itself changes nothing (a decision needs to be implemented before it can take effect); at the moment a decision is made, we cannot possibly know whether it is good or bad (we must wait for the consequences to become clear before we can know this); and we almost invariably spend more time living with the consequences of our decisions than we do in making them. Pfeffer puts it this way:

If decisions by themselves change nothing; if, at the time a decision is made, we cannot know its consequences; and if we spend, in any event, more time living with our decisions than we do making them, then it seems evident that the emphasis in much management training and practice has been misplaced. Rather than spending inordinate amounts of time and effort in the decision-making process, it would seem at least as useful to spend time implementing decisions [working through the remaining options after decisions are made] and dealing with their ramifications.

This argues for greater practical engagement by researchers.

The criteria for success in modelling activities are thus changing: towards greater emphasis on achieving outcomes (changes in the behaviour of others), not outputs (residual artefacts of our own behaviour); and towards acceptance of modelling as a process for achieving outcomes, not as a product which is an end in itself. The more immediate question we face is how two very different categories of model (those of scientists and farmers) can be articulated in order to bring about purposeful change in the behaviour of both communities. As researchers, we have proposed various ways of overcoming this problem: working with farmers' models; using alternative research model formulations (such as mathematical programming); using translation models (to move between model categories); using sequential processes (construct/deconstruct); or all of these as part of a tool-kit approach. No one solution will be everywhere the best. In all cases, what we do will depend on the issues we face. Choices will need to be made about how and how far we do (or do not) question the purposes of farmers and scientists, and whether we use old or new tools to help bring about change.

We argue for the simultaneous use of, and fluency in, multiple representations by professional researchers intent on effecting change in the management of agricultural

production systems. The first thing is to recognise the value of farmers' models, and the limitations of researchers' own models, for action. We need to demonstrate how professional models can lead to practical innovation rather than just providing analytical ('objectively-derived') justification for knowledge already incorporated into practical models. Part of this cultural change will be brought about by participation in model development, starting over from scratch; part by taking responsibility for deconstructing model output into practical guidelines; and part by learning to construct entirely new categories of model. We argue the need to re-engineer R,D&E processes if we are to realise the potential of researchers' models to change production practice (Cox *et al.*, 1996). Models become tools for managing within the communication process as we begin the delicate task of re-articulating two cultures that have grown apart.

6.4 Re-engineering R,D&E

We suggest in Cox *et al.* (1996), from which the following discussion is largely drawn, that agricultural R,D&E, while paying increasing attention to stakeholder interests, has got stuck in the transition between two cultural peaks; now, it is neither one nor the other, neither science nor management. The far peak, rather dimly perceived by scientists, is inhabited by professional agricultural managers and other stakeholders trying to cope with the realities of performing in a complex, and constantly changing, physical, economic and social environment.

There are many symptoms of this malaise in both the APSRU and GLASS projects:⁴ communication is seen as a separate activity, added on after the research is done; a poor feel for the value of information, either at the margin, or in relation to the cost of getting it; grand visions are substituted for realisable projects; projects are inconsistent with objectives; because of the mismatch between rhetoric and reality, commitment to outmoded ways of operating continues to be supported; how we do our research does not respond to the various requirements of different stakeholders; and scientists are rewarded for output (software products and scientific papers) rather than outcomes, so long as scientists remain focused on outputs. Failure is engineered into the way they do their work. Researchers are willing to tackle issues of concern to stakeholders (to be relevant), but do not appear to know what that means nor how to go about it. The push for outcomes comes from inside the organisations of R&D providers as much as it is imposed; and there is a renewed commitment to action. But there is still poor recognition of how sick the patient is, or the implications of the proposed changes in customer focus for how to do science. Re-

³ For an account of the GLASS project, see the Project 3 report by Neil MacLeod

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engineering suggests that the big pay-offs will be achieved by pressing on with this transformation, and by pursuing it more actively and overtly.

Business process re-engineering typically takes a high level view, surveying what current institutional arrangements are meant to deliver. It focuses on outcomes rather than outputs, since much of the value of re-engineering comes from the obsessive pursuit of customer value. And it sets ambitious goals, as it is chasing entirely new ways to achieve substantial results. Re-engineering provides one framework for developing a new model of R,D&E designed to support management decision-making.

Re-engineered processes are much simpler and significantly more customer-focused than those they replace. Re-engineering seeks out simple, effective ways to deliver value to customers by re-constructing processes without the baggage of history. There are really no rules to the process, everything should be questioned, and it is not a once-off affair. Rather, there is a set of basic questions, the repetitive review of which will drive organisational change in a direction consistent with satisfying customer (stakeholder) wishes. These are questions of purpose ('What are we in business for?'); culture ('How do we generate another, better organisational environment?'); process and performance ('What process is most effective in getting the results that customers want?'); and people ('Who do we want to work with?').

Re-engineering attempts to replace perfectionist organisational thinking ('Get it right then keep it going') with 'Make it something else'. It affirms our faith in human beings: replacing *ex officio* authority with existential authority; overthrowing the tyranny of numerical accounting; and complementing the old adversarial/competitive strategy with a supportive strategy. It actively pursues growth and service through pluralistic thinking within a culture of learned willingness and individual accountability. The hardest lesson of all is that the only way to gain control is to give it up.

In short, business process re-engineering is about achieving outcomes for stakeholders rather than simply generating outputs which they may or may not take up. It integrates different functions within the context of the whole organisation. Thus, even though traditional sections may have been performing within their own domain, this may not be consistent with the goals of the organisation as a whole or in the context of an integrated process. Significant opportunities may have been missed because they 'fell between the cracks' that are left between the boundaries of existing institutional structures/functions. This reaffirmation of the determination of organisations to achieve outcomes for stakeholders, rather than self-serving outputs, takes place at the same time as our conception is also changing about which groups constitute legitimate stakeholders.

It could be argued that the formation and operation of APSRU has been affected by some elements of the re-engineering movement. It has resisted the temptation to be totally absorbed by the design and provision of DSS. However, the opportunity to make further gains, and gains of immediate relevance to clients, through the collaborative development of new ways of doing things has not been thoroughly exploited; this despite the rhetoric that has surrounded the on-farm project and the new Farmscape project. The opportunities to substitute information for physical inputs to get a better match between input use and opportunities for gain, thus improving farm performance and sustainability, are not being seized. Yet surely this is where the main contribution of a group such as APSRU lies.

6.5 Renegotiating the criteria for success in DSS development

Up to now, information technology has had a poor record for facilitating social change. Indeed, Wiener (1993) refers to the issues to do with software reliability, the software crisis, as 'digital woes'. Cox (1996) raises several issues in the design of agricultural DSS to do with the appropriateness of this technology for inducing behavioural change in others at a distance. Ethics in modelling is emerging as a significant issue (Wallace, 1994; Forester and Morison, 1994). These issues are discussed also in Cox *et al.* (1995).

APSRU has adopted a systems analytical approach to soil and crop management based on their expertise in the development and application of simulation models of crop and soil processes. This provides one way of comparing options such as different land uses or land management practices. It does not discover novel opportunities outside the boundaries of the simulation model. The process models of the systems analysts may have a place, perhaps as decision-support systems for professional researchers engaged with others in participatory technology development. The development of DSS should be encouraged within that context rather than as an end in itself. However, we must find a way to share the learning achieved by the researchers through their development of models.

Many problems can be solved very well without DSS, and the marginal benefit does not justify the cost of developing and maintaining them. But, in other applications, it is doubtful whether the computer simulation models on which DSS are based have sufficient resolution to be used in the way we want, for example to allow professional researchers to contribute to farmers' experiments. Our rigid adherence to the one path (use of information technology in an attempt to buttress an outdated linear model of agricultural extension) is a blind alley. The other (use of model construction as a process tool) can offer potential for substantial pay-offs because of the way it broadens the scope

for shared experience and captures the synergy that comes from combining perspectives.

The construction, application, and modification of models of various kinds may help to bridge the gap between traditional systems of scientific thought and emerging systems of action. Professional researchers are only just beginning to explore the potential for introducing wider social arrangements within our systems modelling in order to stimulate both thought and action. But it does not follow that the scientists' models are the most effective vehicle for effecting purposeful change in the management of agricultural production systems. They might be used to explore fruitful avenues, or to define the likely shape of response surfaces. The exploitation and communication of such insights may best be handled in ways other than by duplicating the representations through which they were developed. We propose working with parallel models and multiple representations, embracing modelling in its broadest sense.

Our main concern is not that DSS technology has failed to live up to initial expectations, but that the underlying skills in systems analysis have not been adequately exploited. The side-effects of the development of some DSS technologies have sometimes been beneficial and significant, but the opportunity to learn from them, and move on, has not been taken. We need to capture repeatedly the benefits deriving from DSS development, not the unthinking replication of artefacts that do nothing very much. It is time to renegotiate the criteria for success in DSS research, and to begin to value models as process tools rather than unwanted artefacts. Information technology, including DSS (if this is kept in perspective), can do much to fulfil the increasingly urgent need for business-process re-engineering in agricultural R,D&E.

The criteria for success should not be related to the number of units of a DSS sold since, as we have argued, this is an inappropriate use of the underlying modelling skills. Rather, they should relate to the critical insights gained from the improved communication of the different perspectives of scientist and farmer, and the changed behaviour (of both actors) that followed. The beneficial outcomes of model-based research will come from using information technology

to support participation in designing better (more productive, more sustainable) agricultural production systems, not in the routine (and unthinking) delivery of output of the same models in an attempt to influence the behaviour of others who have not been involved in their development.

This shifts the focus to the joint responsibility to generate, test and implement critical insights in an effective, efficient and expeditious manner, and away from the provision of mundane management tools with no particular message or computational advantage. The short life of many DSS may then be evidence of success (if desired change has been quickly achieved), not failure. Consideration can be focused on stopping an intervention at the right time, rather than on how to ensure continuing commitment to a technology which has achieved what it set out to do. The tendencies towards escalation of commitment, and to ever-increasing complexity, are curtailed. The trick is to do this while simultaneously capturing the primary benefits of participation in modelling.

The role of models, like that of communication more generally, is: to facilitate the negotiation of a common framework for communication between groups of people who *see* the world differently; to open up possibilities for *doing* things differently, for ourselves and others; and to *change* the world in a purposeful way so that it is a different place for all of us. That is also our concern.

The original objectives of the market research study left the purposes of both farmers and scientists largely unquestioned. The transfer of DSS products was envisaged as a substitute for communication between these two very different sets of actors, but the nature of that communication was not seen as in any way problematic. Our project challenges, and has begun to change, this misperception. The issues are not about *packaging* insights that are in any case unproblematic and generally accepted. They are about *transparencies* that facilitate the recognition and exploitation of alternative opportunities. Unless these tools facilitate practical engagement, it is unlikely that we will be developing new options—rather we will only be re-inventing old ones. Current DSS technology is an ineffective way of re-inventing the square wheel.

7 Summary and recommendations

- There is an urgent need to harness the potential for learning at a community level by facilitating the interpretation and exchange of information between growers. This can best be achieved by their working within small facilitated groups, under the umbrella of a larger organisation that can expedite exchanges between groups, and across regions. In addition, if communities are fully to exploit the potential for learning that exists, there needs to be an attempt to collect some additional data e.g. from chemical analyses of soil and tissue, and through the use of weather stations. In this way, it should be possible to interpret these experiments better and accelerate the learning that can come from linking the results from farmers' experiments with those of professional science.
- There seems little point in better specifying production risks, with a view to managing them better, unless marketing risk is tackled at the same time. The outcome of importance to growers is the product of price and yield (less costs), and there appears to be little justification for focusing on one factor to the exclusion of the other.
- Models are essential tools for helping us construct the world in which we live, to negotiate common meanings with others, and to bring about change. This applies as much in the management of broadacre dryland farming systems as elsewhere.
- Discussion about the most appropriate type of model to do this is a continuous process. The most appropriate model depends on the issue faced, who the stakeholders are, and what they are trying to do. Selection of model type is central to the negotiations.
- Models should be used to open up possibilities, not close them off. This suggests an approach that values multiple representations of ostensibly the same situation, and respect for other points of view.
- DSS technology is largely an artefact of scientific modelling efforts. It encapsulates one particular view of the world, one that values a limiting scientific understanding of the behaviour of natural processes. It can be dangerous in a management context if it excludes other forms of understandings.
- Farmers' models and scientists' models differ in important respects (scope, complexity, transparency, re-usability).
- Farmers' models are appropriate for: the management of biological production processes, in the face of considerable uncertainty in outcomes, in order to make a living now and in the future. They can be expressed as rule sets. But there is always scope to negotiate their improvement.
- Scientists' models are appropriate for the description and understanding of underlying biophysical processes in order to predict the outcome of a particular combination of circumstances. Simulation using deterministic crop and soil process models is one way of doing this.
- There may be scope for improving the performance of farmers' models through: the application of existing rules to additional information about the status of the system (e.g. through soil and plant monitoring); the development and application of novel rules (e.g. relating to the use of novel technological components); and enhancements to the communication processes through which new rules are developed (e.g. through the development of relationships between different stakeholder groups—farmers and scientists—in order to promote joint learning).
- DSS technology largely sidetracks these issues: by making assumptions about input requirements for decision-making; by asserting a single (scientific) point of view; and by substituting a product for a relationship. There are substantial issues to do with failure to negotiate fundamental constructs for the structure of a decision, the options available, the appropriate form of analysis, the comparison of alternative strategies, and the evaluation of outcomes.
- Investment in the development of DSS products is predicated on largely unsupported assumptions that the performance of agricultural production systems is information-limited, that current decision-making behaviour is badly deficient because of inadequate information processing, and that DSS products can correct both these deficiencies. We have seen scant evidence to support these assumptions. What is lacking is a shared vision for using available information, and transforming it in novel ways, to create better possibilities.
- Although there may be scope for substituting information for physical inputs (thereby improving production efficiency), there is a real danger that such information is over-valued in an economic sense—that people already have sufficient information to make a decision, and the decision will not change with the accumulation of additional information (particularly if it is focused on one or two variables only). Indeed, the search for additional information may be detrimental because it predisposes to prevarication. The art is to know the difference between information that is vital to the issue at hand and that which can be ignored. This depends on what we are trying to do.

- The issues are not about *packaging* insights that are in any case unproblematic and generally accepted. They are about *transparencies* that facilitate the recognition and exploitation of alternative opportunities. Unless these tools facilitate practical engagement, it is unlikely that we will be developing new options—rather we will only be re-inventing old ones.
- There may be scope for developing and using information technology as a process tool for continually (iteratively) re-negotiating our various model structures, and improving the way in which they impinge on each other in order to bring about change in the performance of different groups of stakeholders on their own terms. Use of models in this way will open up possibilities, not close them off. Rather than providing answers, the discussions that surround the use of scientific models may be an opportunity for learning.
- We are arguing then, on the one hand for researchers to become fluent in the use of multiple model structures (not just simulation), and on the other for participation in technology development in a collegiate manner. We are looking for a more substantial customer-focus, and explicit concern for achieving outcomes for, and with, customers. The scientific project stops short of this.
- The achievement of these goals will require a cultural shift in our institutional R&D providers in order to bring about changes in the way in which professional R,D&E is currently done. The current debate on business process re-engineering is one way of framing this cultural transition. Because of the inertia of existing institutional arrangements, this will be very difficult to bring about.

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Note: This bibliography is provided for reference purposes only, as a starting point for other researchers.

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Appendix I

Commentary on the Final Report for the LWRDC/GRDC/RIRDC Project No. CTC3, “Market Research for Decision Support for Dryland Crop Production”, R.L. McCown (former CSIRO Leader, APSRU; designer of this project and the sister on-farm project studied by this project), and Peter Carberry and Mike Foale (leading APSRU scientists in the on-farm project).

Introduction

The report by Ridge and Cox on the project “Market research for decision support for dryland production” (hereafter, the “Report” on the “Market research project”) has aroused intense controversy and debate. The dominant theme in this Report is the conflict between two groups — two “contending coalitions” (Biggs, 1995) — within projects within a single research organisation. Yet, as indicated in the Introduction and Peter Cox’s story, we started out with shared vision and commitment to reforming the way research in this field is conducted. To Cox, those were the days when “APSRU was open to different ways of seeing the world”. Although we don’t think APSRU’s openness declined, the original unanimity certainly did, and the Report is essentially a story of emergent conflict from the viewpoint of one contending coalition. The debate revealed by the story is important beyond the project because of the importance of the subject, ie. how scientific intervention in farm planning and decision-making might be provided effectively and appropriately. The conflict itself may or may not be important more generally, depending on whether the cause concerned matters of substance or resulted from conflicts of personalities and coalition interests.

As a research product, the Report is extraordinary, first in that the story of conflict is so central and, second in that there is no inclusion of invited input from the contending viewpoint. At the time the Report was released, exclusion of the views of the other contending coalition prompted us to negotiate with the LWRDC Coordinator for inclusion — in the interest of balance in the story and control of damage to our coalition’s reputation — of a substantial ‘commentary’ by those under attack. But now, in 2000, redress of omission and distortion seems less important than it did at the time. Much has happened in the 4–5 years since the Report was written that makes redundant many earlier conflicts in perceptions, interpretations, and predictions. As a result, we have deleted much of our original commentary and added a summary of developments after the Report that create an important new backdrop for the debate.

The debate is about attempts by a research team to understand and change a system. The system includes *farmers* farming and trying to find ways to farm better as well as *researchers* trying to find ways to assist farmers to farm better through innovations in communication technology. APSRU was established by the Queensland DPI and CSIRO to create a critical mass of expertise concerning simulation of cropping systems. There were good grounds for believing that the capability to simulate the production for any situation for which there are appropriate weather records and soil data was potentially very useful in farm production planning and decision-making. Up until 1992 tests of this hypothesis had been mainly through production of decision support systems (DSSs), but by this time it was becoming worryingly clear that very few farmers were using these products. The Market research project and the On-farm project were designed to find explanations for this communication failure and to seek a basis for redesign of scientific support for planning and decision-making in a risky climate.

An alternative account of the On-farm research

Critique of the On-farm project became the central theme of the Market research project and was central to the Report’s conclusions. We submit that this makes it important to readers of the Report that the On-farm project is adequately represented. Ridge and Cox acknowledged that their Report is, and must be, a biased account. This commentary stands to benefit readers’ appreciation of this activity by providing a contending account.

The approach taken in the On-farm project began with a *hypothesis*: in this region where uncertainty of rainfall dominates decision-making, *a farmer would welcome a tool* which could simulate accurately crop yields (a) for specific farm conditions and (b) in response to his ‘what if?’ questions about management actions. As a hypothesis not amenable to scientific testing, testing had to be undertaken in an *action research* paradigm, working with farmers and their advisers within the farm’s management system. The first step was to negotiate plans with farmers for joint investigation of production issues that they nominated as pressing and within the domain of crop and soil management in which the researchers had expertise. The second step was to undertake simple field experiments that featured soil water and nitrogen monitoring for the full rooting depth — new territory for most farmers. While this provided soil information that proved to be valued highly in its own right, it also laid the foundation for the trial of simulation as a planning tool.

With the testing of the above hypothesis in mind, much of the On-farm project activity was designed to remove barriers to (a) using the simulation software correctly and

efficiently and (b) customising the simulation model for specific paddock situations. The research team provided the computer, the software and the operator; farmers, advisers, and researchers worked together in commercial crops to get soil and weather data to enable making the simulator 'look like' a particular paddock; and associated crop data were collected to test/demonstrate the model's accuracy — to establish credibility of the tool for evaluating consequences in 'what if?' planning discussions. Crucial to this approach is a simulator that is up to the task of simulating performance of the range of crops in the farming system on the particular soils of the region and with great flexibility in mimicking management actions and strategies imposed. APSRU's simulator, APSIM, qualified as software for such an application.

The crucial *test* of our hypothesis that a good farmer would welcome a tool that reliably predicted risky consequences of a contemplated change in management was carried out using APSIM-assisted discussions among farmers, advisers, and researchers in the 'kitchen table session', which later became the more functionally-meaningful 'What if? Analyses and Discussions' (WifAD). The evolution of the WifAD took place in an action research cycle over several years. At the outset, every farmer was sceptical about APSIM being of any value to their management, but they were tolerant of the scientists' wish to keep simulation 'on the back burner'. Repeatedly, the opportunity for demonstrating the relevance of APSIM for farmer management arose at the stage in which results from field monitoring in commercial crops were discussed and interpreted. Many farmers were impressed with the value to their decision-making of enhanced monitoring of soil water and nitrogen. But the fact that 'this was *this* season and seasons differ so greatly' inevitably discounted value for drawing more general inferences for action. This opened up the opportunity to use simulation and weather records to see what might have been the inquiry outcome in a different type of season. The soil data from individual paddocks were used to specify the simulator and crop data to compare with crop simulations. Farmers were impressed with how well APSIM outputs agreed with what we had found out together in the field. After seeing that APSIM could mimic what we had done together, farmers became enthusiastic about 'doing experiments' using the simulator over decades of weather records to get a better appreciation of how often relevant outcomes could be expected.

Ridge and Cox make much of the importance *scientists* place on 'credibility' of simulations. To them, this is indicative of scientists' professional preoccupation with a precision that is much greater than that needed by a farmer in planning and decision-making. Our consistent experience is that *farmers* demand a high accuracy of simulation in order to establish for themselves whether this is worthy of their serious attention. Many farmers became very involved in WifADs concerning important aspects of their production systems — but only after they were satisfied that the simulations realistically matched known performance in

their situations. Since the function of 'simulation' in the project's hypothesis (stated at the beginning of this section) is to provide predictions of likely consequences of the farmer's contemplated actions, we submit that a good farmer will seriously contemplate use of the simulator in planning only after cognitive demands for credibility are satisfied. Conversely, a good indicator that a farmer is *not* viewing simulation as relevant to his/her management is *indifference* to simulator performance.

The falling out

While confirmation of the hypothesis that farmers could value simulation was a very exciting development for the project team, members became exasperated with the unwillingness of Cox and Ridge to see farmers' enthusiasm in this way, attributing it, instead, to the quality of the social interaction. For a time this stimulated worthwhile debate. But this ceased to be the case after it was discovered that Cox and Ridge had submitted a report to LWRRDC that had recommended that the scientists' model be "kept in a back room" — and this in a period of high demand from farmer groups for these discussions. (No farmer or adviser ever suggested leaving the computer at home, and few were shy about expressing views and preferences.)

Contrary to the impression given in the report about the APSRU researchers' single-minded aim to impose their technology on farmer and adviser communities, we were single-minded about an *adequate test of our hypothesis*. In our judgment, APSIM was crucial to our search for even *one* farmer who found simulation genuinely relevant and significant to his/her management. An evaluation program was put in place to both (a) provide feedback on project processes and (b) to provide assessment by people with special expertise and who were external to any project team bias. Cox and Ridge led (a). For (b), we contracted Jeff Coutts, Rural Extension Centre, University of Queensland, Gatton.

The report by Coutts (1995), which featured farmers' and advisers' expressed views and intentions growing out of their On-farm project involvement, confirmed our hypothesis that simulation could be valuable to management to a degree not evident in previous DSS experience. We attribute this outcome to a shift in paradigms of the systems approach taken by the research team from 'hard' to 'soft,' but, importantly, a shift that did not abandon powerful 'hard' systems tools. This combination of intensified paddock monitoring, 'what if?' analyses and discussions aided by a flexible simulator, and evaluation was later termed the 'FARMSCAPE approach'. (Farmers'—Advisers'—Researchers', Monitoring, Simulation, Communication, And Performance Evaluation) (McCown *et al.*, 1998; Hochman *et al.*, 2000).

Our analysis of the conflict

The crux of the reported debate concerns the nature of APSIM and its use in FARMSCAPE. To Cox and Ridge, APSIM was just one type of model among several and one that is inferior for aiding farm management because of its descriptive nature, large size and high complexity. They consistently portray our approach as a commitment to using a scandalously expensive APSIM in a choreographed scientific ritual enacted with little cognisance of farmers' realities and preferences. To the APSRU research team, APSIM enabled an unprecedented opportunity for facilitating farmers' exploration of significant management possibilities quickly and cheaply. From this point of view, investment in the enhancement of APSIM was of high priority. Our vision for the sort of simulator needed for this task developed from previous work with farmers on risky planning using simple models and being frustrated by the difficulties of making a simple model specific for a situation.

Cox and Ridge are committed to the proposition that scientists' models are *a priori inappropriate* to the practice of farm management. We agree with them that the designed DSS is generally inappropriate for the reasons that they list in their dot points 6 and 11, p.175. But they failed to see, or welcome, the possibility that a complex model could function as a simulator of actual farm situations in way that was relevant and significant to involved farmers. The metaphor for this role for APSIM is the 'flight simulator' for managers. The way this contributes to action research was described by Bakken *et al.* (1994, p. 250).

If we view learning as a process where an action → result → reflection → learning leads back to further action, flight simulators can facilitate learning by shortening the delay between action → results. The simulator also demands structural explanations of the action → result link that will force participants to search for a better understanding of the underlying forces that produce a given set of outcomes.

Cox and Ridge refer to various types of models, but they place a high premium on attributes of *conceptual* and *heuristic* models and, especially, simplicity of such models. With a simulator made up of scientific models, complexity is both expected and necessary. However, lack of ready transparency is tolerable to a farmer or adviser as long as (a) limitations in terms of what the simulator takes into account are explained and (b) specific simulations check out favourably against a farmer's experience. In a flight simulator, what matters to the practising pilot is not its cognitive transparency, but its realistic performance. Simulators are *transparent* only to the engineers.

Ridge and Cox make much of the proper relationships between models of farmers and scientists. The experience of the On-farm project indicated that, while a farmer's model embodies his best 'theory of action', APSIM's main function was to simulate what would be the outcome if that (or other)

action were taken (this season, last season, or in every season for which rainfall records exist) and in comparison with some other action or time of action. By specifying the APSIM Manager module using a given rule of a farmer (or using a modification which the farmer is considering), an evaluation of the rule using all seasons for which there are rainfall records can be made quickly and cheaply. Of course, the evaluation is only partial since the model does not simulate the 'whole system'. But if the factors dealt with by the simulator are ones that are problematic for farmers with their existing mental models, and they understand what the simulator does and does not take into account, farmers are quite prepared to adjust for factors that are often difficult to *simulate* but with which their cognitive models are quite powerful. This is the beauty of this alternative to DSS in making scientific models useful in real agriculture.

This Market research project was one of a family of projects. LWRRDC and its partners, GRDC and RIRDC, had their own goals, policies to guide activities in achieving these goals, and coordinator (Art Shulman). On the other hand, APSRU initiated and designed both the Market research project, one of the LWRRDC family, and the GRDC On-farm project to serve an important objective in its strategic plan. While both organisations in this dual structure were sympathetic with the other's aims, unavoidable ambivalence in the line of management created opportunity for great 'flexibility' on the part of a project manager. In this case, the principle scientist recruited by APSRU (Cox) to carry out its objectives took advantage of the ambiguity in the dual arrangement and naivety of the APSRU manager to 'quietly' take the project in the direction that best suited his personal agenda. This resulted in a change from a project originally pursuing the aims of APSRU to a project in which the study and critique APSRU was 'the problem' — with LWRRDC replacing APSRU as the principal stakeholder. The methodology used was a form of 'critical ethnography' that is used to undermine institutional structures of management authority to achieve a 'greater good,' in terms of the agent's personal values. We don't reject a 'critical systems' paradigm in principle; there are undoubtedly times and places in which it is justified. But we submit that its high potential for damage when invoked *mistakenly*, ie. with inadequate justification, makes it a risky option for social research in contemporary Australian agricultural R&D institutions.

Implicit in a 'critical' stance is rhetoric about 'power' relations. The authors warn against the threat of the APSRU researchers with their APSIM-centric approach *disempowering* farmers by creating dependence on the technology and those who support the technology. Time has shown that farmers and advisers have become pro-active about the power of the FARMSCAPE approach in reducing uncertainty in their planning and decision-making and they have continued high expectations of the special 'comparative advantage' which the science brings to these partnerships. But we hasten to add that we acknowledge the potential for

socio-technical changes to disempower and the need for vigilant and reflective systems practice.

Scientists are not unaccustomed to conflict in the forms of rivalry within their community and conflicts over social values and science, and there is reason to believe that such conflict will increase as agricultural scientists attempt to mesh their scientific research with the world of human affairs. Human systems *are* different, and engagement with them does require a willingness to see the world differently and to change our systems practice. The remarkable aspect of this case of ‘contending coalitions’ is that *both* parties recognise that a paradigm shift, epitomised by a shift from the DSS produced by professionals for practitioners to social engagement of practitioners and professionals, is essential if research about management is to be significant in management of farms. We judge that APSRU has largely made that shift (with important contributions from Peter Cox in happier times). But, presumably because we have not shared Cox’s propensity to abandon the possibility of ‘the power of science’ contributing to management, he judges that we have *not yet* made the shift. This seems to be an important, but probably partial, explanation of the conflict. In important respects, the debate in these terms could be resolved, in time, either by (a) FARMSCAPE becoming an unambiguously significant innovation in farm management in which hard systems tools are used in a soft systems process to achieve empowering outcomes for farmers, or (b) by being comprehensively ignored by farmers and advisers.

Further explanation for conflict might be found in the social concept of ‘contending coalitions’ — entities that formed, in this case, as individuals’ expectations of colleagues failed to be met and personal interests diverged. Such disaffection may be a natural precursor for adoption of the ‘critical’ approach in circumstances where it is not justified by primary system relationships. But the degree to which the Report represents an attempt to ‘force square pegs into round holes’ may have been the result of cumulative pressures that came from (a) problems in delivering the outcomes of the project as originally designed, (b) growing realisation that the objectives of the original project were misguided (for which McCown shares blame), and (c) disagreements between Cox and next-level management (McCown) about styles and standards in professional practice in APSRU. In any case, the potential consequences of a ‘critical’ approach are of sufficient moment that elimination of the possibility that offending ‘power problems’ might be explained more simply by ‘contending coalitions’ seems prudent.

Developments relevant to the debate since the Report

We claim above that one test of many of the Report’s critical inferences may be the responses of farmers and advisers over time to their experience in FARMSCAPE; responses that in turn can be expected to influence R&D funding bodies in their support for this approach. Listed below are indications in 2000 that conflict with the prediction made in the Report, in 1995, of failure for FARMSCAPE, both in terms of maintaining farmer interest and in achieving industry impacts:

1. strong industry support for developing and using this approach — 15 FARMSCAPE-related projects have been funded by four different industry R&D funding bodies over the past nine years, several of them initiated by farmer and agribusiness collaborators;
2. innovative changes to farming practice resulting directly from use of a FARMSCAPE approach for revealing new possibilities with APSIM and testing them in practice: (a) planting mungbean in spring rather than summer (>20% of area planted), and (b) increased interest in dryland maize resulting from APSIM-assisted adjustment to risk perceptions;
3. spread of soil monitoring as a key management practice in the northern cropping region — the number of deep soil samples commercially analysed for nitrogen has increased exponentially since 1993;
4. numerous documented testimonials from farmers who have made significant changes in practice stimulated or guided by insights gained in FARMSCAPE interactions; and
5. a FARMSCAPE accreditation scheme offered by APSRU to commercial consultants and public sector advisers. Four agribusiness firms and ten individuals make up the first intake. The high commitments of agribusiness in time and money reflect evidence of farmers’ willingness to pay for FARMSCAPE interactions.

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Case Study 4

Effective Strategies for Increasing the Suitability and Adoption of Complex Technologies for Sustainable Grazing Land Management

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Effective Strategies for Increasing the Suitability and Adoption of Complex Technologies for Sustainable Grazing Land Management

Abstract

Poor technology transfer performance is a widespread and major concern for R,D&E managers and their clients. The principal aim of CTC2 was to apply contemporary 'best practice' in agricultural extension systems theory to R,D&E focused on the complex domain of sustainable land resource management. It sought to do this within the context of beef cattle grazing management systems through two case-study R&D projects being jointly conducted by the CSIRO Division of Tropical Pastures (CSIRO) and Queensland Department of Primary Industries (DPI) in two geo-climatically distinct regions of Queensland.

CTC2 had two major phases:

- Phase 1: The operational activities conducted up to August 1994. For a number of reasons of both a project-specific and a broader organisational nature, the project was officially abandoned as an 'operational' project from that time.
- Phase 2: Project activities beyond August 1994 were confined to a review of the project's performance to that time, an assessment of the implications of that performance for future communication and technology transfer initiatives, and consideration of alternative approaches to R&D technology transfer management.

These phases are analysed as separate sections of the report.

Phase 1: The operational performance problems that were encountered in the first phase of CTC2 included:

- lack of a clear methodology, including evaluation methods and assessment of baselines;
- lack of a unified management structure;
- lack of decentralised power to effect change in response to unforeseen adverse developments;
- poor pre-initiation management of ownership and resourcing;
- use of an untested and excessively rigid design;
- insufficient resources relative to the scope of the project;
- overconfidence in the ability of the case-study R&D projects to proceed according to their operational plans; and
- excessively 'tight coupling' of many CTC2 activities to those envisaged for the case-study R&D projects.

While many aspects of the project did not proceed smoothly according to the initial plan, there were many valuable insights obtained from CTC2. The following were the key 'learnings' from Phase 1.

- Beef producers positively value 'negative' information.
- R,D&E managers may also value 'negative' information.
- External stakeholder involvement can improve R,D&E performance.
- Open communication with stakeholders can increase their appreciation of the risks and uncertainties associated with science.
- We were able to more clearly identify and conceptualise barriers to R,D&E in a different and more integrative way.

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- Evaluation methods have to be appropriate to the intended aims of the project. When these aims are consistent with an emerging focus of 'outcome-orientation' the evaluation criteria more traditionally applied to 'output' performance are no longer appropriate.

Phase 2: The review had three objectives:

- to systematically examine factors underlying the projects performance;
- to critically appraise the appropriateness of the guiding theoretical models; and
- to examine alternative approaches and models for pursuing more cost effective solutions to technology transfer problems.

A prototype framework was developed to evaluate the design and operational performance of both CTC2 and the case-study projects. Case evidence was collected from the experiences of the CTC2 managers and the case-study R&D teams. This case material was also supported by data collected through a series of semi-structured interviews with a sub-set of stakeholders.

The following were the key 'learnings' from Phase 2.

- Escalation of commitment is a powerful phenomenon that can reinforce unwarranted allocation of resources to particular research and extension activities. Moreover, factors contributing to unwarranted escalation can be identified and addressed.
- 'Complexity' which is assumed to be a key feature of both sustainable land resource use problems and R,D&E endeavours to address them is itself a 'complex' phenomenon whose poor articulation and understanding can compound research and communication failures.
- Poor appreciation of the difference between human infrastructure and technical infrastructure can lead to R,D&E communication problems. Because of the differences between the human and technical infrastructures, research designs for testing principles of best practice R,D&E require replications, not duplications. The notion of replication within participatory R,D&E endeavours is not well understood.
- Multidisciplinary R,D&E efforts are not in themselves sufficient to guarantee integrative outcomes for complex land resource management problems.
- 'Complexity' and 'tight coupling' of project 'elements' can reduce the likelihood of achieving successful project 'outcomes'. In fact, such coupling can actually increase the probability of achieving a 'failure' outcome.
- 'Complexity' and 'tight coupling' of project 'elements' can reduce the likelihood of achieving successful project 'outcomes'. In fact, such coupling can actually increase the probability of achieving a 'failure' outcome.
- The issue of 'tacking' extension and commercialisation strategies onto pre-designed R&D projects requires serious rethinking. These issues need to be addressed and resolved early on in the project planning process.
- The existing state-based extension infrastructure, while staffed by some very good and committed personnel, is generally inadequate for conducting innovative and integrative technology transfer programs for sustainable land resource management R&D projects.
- Entrenched norms within the institutional or organisational 'culture' of R&D agencies remains a significant source of technology transfer failure.

From the viewpoints of efficacy and cost-effectiveness the operational value of the CTC2 model as proposed is doubtful. A substantive modification of the model which is described as a Punctuated Arena Model is proposed (Section D) that aims to overcome many of these problems.

The report concludes (Section E) with a proposal to extend both the 'learnings' from Phase 1 and 2 of the project and the revised model with an aim to promoting a shift in the traditional R,D&E paradigm towards a new approach that is centred on an 'organisational learning' culture.

Effective Strategies for Increasing the Suitability and Adoption of Complex Technologies for Sustainable Grazing Land Management

Neil MacLeod

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Acknowledgments

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Introduction

As originally proposed, CTC2 had a projected operational life of three years, with completion due on 30 June 1995, but for various reasons, it was officially abandoned as an 'operational' project in August 1994. Activities associated with the project beyond that date were confined to a review of the project's performance to that time, an assessment of the implications of that performance for future communication and technology transfer initiatives, and consideration of alternative approaches to the management of R&D and technology transfer.

Therefore, following a brief scene-setting section which details the background to the project (Section A), the report is structured around the two basic 'phases' of the project—the operational phase (Section B) and the review phase (Section C). Key 'learnings' from both phases of the project are presented in this report. These will represent significant value for the conduct of future R,D&E initiatives in both technology transfer and sustainable management of land and water resources. A third section (Section D) draws the material from the other sections together and develops a potential model for improving the communication and technology transfer performance of sustainable land resource use R,D&E projects. A final section (Section E) briefly proposes a set of future activities to promote a shift in the prevailing R,D&E culture towards a position that is more conducive to sustained improvement in technology transfer performance.

Section A Background

At the time that it was proposed, CTC2 was recognised to be an ambitious initiative whose principal aim was to apply contemporary 'best practice' in agricultural extension systems theory to R,D&E focused on the complex domain of sustainable land resource management. It sought to do this within the context of beef-cattle grazing-management systems through two case-study R&D projects being jointly conducted by the CSIRO Division of Tropical Pastures¹ and Queensland Department of Primary Industries (DPI) in two geographically distinct regions of Queensland.

Case-study #1 was the GLASS² project which was located in the Burnett River catchment of southern Queensland. This large project had commenced in 1989 and was, at the time it was commissioned, expected to run for approximately 10 years. GLASS operated from a single site on leased commercial grazing land adjacent to the CSIRO Narayen Research Station (50 km west of Mundubbera) and involved a large multi-disciplinary team drawn from CSIRO and two branches of the DPI (Pasture Management and Soil Conservation).

Case-study #2 was an unnamed project located in the Burdekin River catchment of northern Queensland. Unlike GLASS, the project was to be located at several sites within the region, with each site separately operated by research and technical staff from CSIRO, DPI and Department of Lands. At the time that the CTC2 proposal was being developed, planning for this multi-site project had not been finalised and funding for that project was still being negotiated between the partner agencies and the Meat Research Corporation (MRC). A major rationale for its selection as a case-study was that, because it was still in the design stage, it was more closely consistent with the ideals of CTC2 which sought to influence both the design and conduct of R,D&E projects as opposed to their conduct per se. It was also seen to provide an opportunity to 'replicate' the interventions as well as provide greater scope for generalisation to other cases.

The development of CTC2 largely grew from initiatives taken by the GLASS project managers who were seeking to address and overcome shortcomings that had been identified in the 'technology transfer' strategy for that project. To that time, technology transfer had been fairly much left as an afterthought which would most likely follow a traditional pattern of formal publications, field days, press releases and industry displays (eg. AgShow, Toowoomba). Some additional initiatives, such as producer demonstration sites and the development of decision-support packages, had also been

¹ Unless otherwise specified, for the remainder of this report 'CSIRO' refers specifically to the Division of Tropical Crops & Pastures, now called CSIRO Tropical Agriculture.

² GLASS is an acronym for Grazing Legumes/Landscapes and Sustainability of pastures in the Subtropics.

canvassed but not specifically planned. The revised communication outlook occurred within the context of a growing recognition of difficulties encountered by past pasture and land resource R&D initiatives in transforming project 'outputs' to industry 'outcomes' (MacLeod and Van Beek 1993), increased recognition of a diverse set of stakeholders to the R&D with potentially conflicting interests and 'outcome' expectations (MacLeod and Taylor 1995), and the 'systems approach' underlying the GLASS design and management philosophy. Personnel and the prototype design of the second case-study had limited influence on the planning and design of CTC2.

Section B

Operational phase (Phase I)

This section of the report relates to activities undertaken between the period from July 1992, when the various activities associated with CTC2 commenced, until August 1994 when the operational phase was terminated

B.1 Project objectives

The major objective was to devise an effective communication and technology transfer framework or model to adjust R&D work to better meet the needs of resource managers and to improve the adoption of complex land management innovations. The actual project objectives were modified during the operational life of the project. As of February 1994, following negotiation and agreement with the Resource Management Committee, the objectives were as follows³:

1. To use a case-study approach to devise and test, within an integrated framework, a suite of communication and technology transfer strategies to optimise the potential for adoption of products of multi-disciplinary R&D projects focused on sustainable grazing land management; by
 - (a) promoting frequent and directed interaction between individual members of the R&D project teams throughout the various stages of the project cycle;
 - (b) promoting frequent and directed interaction between the R&D project team and key stakeholder groups;
 - (c) ensuring that the research questions, approach and outputs are relevant to the interests of key stakeholder groups at all stages of the R&D project cycle;
2. To identify perceptions held by potential stakeholders of issues relating to sustainable grazing land management and the relevance of the case-study R&D projects;
3. To obtain an understanding of the major biophysical and socio-economic factors that might promote or restrain the rapid integration of the outputs of the R&D projects into sustainable land management systems;
4. To offer insights to the R&D project teams into appropriate forms of packaging R&D outputs (eg. data, information) to promote their conversion to successful outcomes (ie. adopted practice);
5. To identify the relevance of the findings to other resource management-orientated R&D projects and extend them accordingly.

³ The original project objectives, as detailed in the initial proposal put to IWRRDC, are listed in Appendix A.

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In short, the project sought a mechanism to raise the probability of achieving successful technology transfer outcomes for R&D projects in the sustainable resource management field. The objectives should be viewed with the following two points in mind:

- That the specific project interventions were intended to apply and evaluate a specific model (framework of interventions) to drive the technology transfer process for specific case-study R&D projects. In this sense, they would be operating within the context of technologies that were specific to the case-study projects.
- The project and its interventions were specifically directed at large-scale projects operating at the 'complex' end of the technology spectrum. This was considered to include such issues as providing ecological insights into the longer-term functioning of grazed pasture ecosystems in highly variable climates.

These two aspects of the function and operation of the project as envisaged at the time it was proposed have not always been clearly recognised. However, their continued validity is also a key issue with respect to the ultimate 'learnings'. In particular, much was made of the 'complexity' of agro-environmental R,D&E which in hindsight was in itself a simplification of the reality of dealing with complex systems such as R,D&E processes within this domain.

B.2 *A priori* premises of technology transfer

A number of premises underpinned the approach taken by CTC2 to improve the technology transfer performance for the targeted case-study R&D projects:

1. R&D projects seeking to address sustainable land resource management issues are generally, if not by necessity, large-scale, long-term and best conducted by multi-disciplinary teams. This suggests that they will be expensive to conduct and that the maximum value should be extracted from them.
2. the large investment in these projects will provide benefits only if the R&D 'outputs' are converted to 'outcomes', ie. the information or technologies are incorporated within plans of action that change significantly the way that things are done and land resources are managed.
3. natural processes occurring within managed rangeland ecosystems are 'complex'. When these are combined with human systems which are also 'complex' the result will, ultimately, also be 'complex' management prescriptions. A single identifiable technology or system of recommended practices is unlikely to emerge from the R&D.
4. the past adoption record for many R&D-sourced agricultural technologies has been variable, but adoption rates have generally been lower for 'complex' technologies.

5. the stakeholders in such R&D are not only farmers (eg. beef cattle producers), although it is acknowledged that they are one of the major target groups for the R&D outputs, and a major vehicle through which outputs are converted to outcomes. Other groups within the community have recognised and legitimate interests in the sustainable management of land resources and those groups should have a say in how R&D funds are invested.
6. adoption of 'complex' land management technologies or packages is influenced both by the biophysical and socio-economic environment prevailing in a region, regardless of whether a stakeholder is classed as belonging to a common industry aggregation—eg. beef cattle grazing.
7. while many of the newly emerging communication processes that involve interaction between stakeholder groups and R&D teams may reduce the probability of a technology transfer failure, they may also be of limited value in isolation. This is consistent with a view that for a heterogenous stakeholder population facing a plethora of 'complex' decision problems, there is not likely to be a 'universal solution'.
8. technology transfer failures, although commonly viewed as such by R&D practitioners, are not necessarily 'extension' failures. Rather, poor adoption performance of a technology or suite of recommendations may represent 'R&D' failures, or a combination of shortcomings in both R&D and extension.
9. while technology generation and diffusion proceeds according to certain stages, the process is essentially 'linear'.
10. an integrated framework of interventions targeting specific aspects of communication failures at specific stages of the technology generation and diffusion process is more likely to be effective than one-off interventions.

B.3 The intended approach and evolution of CTC2

This section details the basic approach planned for the project. It also documents the evolutionary history of the project. While this history is relatively detailed, it is intended to provide a rich picture of the context within which the CTC2 approach evolved. This also has a significant bearing on the subsequent performance of the project and the opportunities for learning that were ultimately derived from it.

B.3.1 The CTC2 approach

There is no clearly definable single methodology that can be attributed to CTC2. As the project was designed and proposed, it would be more accurate to think in terms of underlying philosophies or general approaches.

Two basic approaches that were proposed for CTC2 were to engage in a participatory and empowering dialogue with different stakeholder groups, and in a manner consistent with an AKIS (Agricultural Knowledge Information Systems) approach (Röling 1990, 1992; Van Beek 1991). The AKIS model recognises that communication patterns relating to different issues within an agricultural context and community will involve many stakeholders and may be complex. AKIS proponents argue that ‘mapping’ the prevailing communication networks provides a key to more effectively targeting messages on important issues; is an effective vehicle for exchanging valuable technical and social data; and, by recognising the potential existence of multiple stakeholders, can increase the extent of ‘ownership’ of resource management problems and their solutions. The extent to which AKIS can actually achieve this ideal is a project ‘learning’ canvassed in a later sections (Section C.6).

B.3.2 The CTC2 framework

The model to be trialed consisted of an integrated suite of communication interventions, each of which was believed to offer a unique contribution to addressing one or more important aspects of the overall problem of technology transfer failure for ‘complex’ R&D projects. To the extent that each of the interventions was perceived to have attributes that would reinforce the other interventions, the sequential combination was thought to comprise a package which would ensure success in terms of promoting a greater adoption of the case-study outputs than would reasonably be expected if the various interventions were applied singly. For this reason, the specific ordering and coupling of the individual interventions was a conscious component of the project design. The output from each intervention was intended to provide a basis for subsequent interventions. A key assumption that was not made explicit in the original proposal was that the technology(ies) to be developed and ‘transferred’ for the case-study R&D projects had either already been, or could be, identified by the respective R&D teams. The validity of this assumption is further discussed in Section B.6.

The interventions were to be applied as part of a four-stage process, viz:

- Stage 1—*focus groups* representing the major stakeholders to the case-study R&D projects to identify potential blockages to sustainable land management, attitudes and perceptions relevant to sustainable land management, constraints to taking action consistent with R&D outputs, and information networks (ie. map the AKIS).
- Stage 2—*technical reference groups* to review R&D outputs (products), confirm the universality or otherwise of the application of the scientific knowledge or principles to other regions, and advise on technology packaging.
- Stage 3—*relevance audit* (mid-term) of the case-study R&D projects, principally through a workshop of a wide

range of key specialists and interest groups to review the ongoing relevance and refine the approach of each project and to validate their applicability to regions beyond those under study.

- Stage 4—*focus groups* to examine and validate any emergent methodologies and to support technology packaging and promotion strategies.

With the exception of the third stage, the individual interventions were not new and are consistent with traditional market research and technology development practice. Novelty arose through their application to an agricultural R&D setting, and the fact that they were to be integrated with an aim to promoting an improved relevance and outcomes.

The mid-term relevance audit workshop probably remains the least-well understood and the most controversial of the suite of interventions. This applies with respect to both the case-study R&D teams and the various peers and stakeholders to whom the concept was exposed at various times during the life of the project. The logic for this intervention is, however, fairly straightforward. Given that sustainable land management R&D projects tend to be long and complex, it was conceivable that the issues that originally gave rise to a project or the prevailing physical or financial environment might change sufficiently during the life of the project to render the project obsolete or off target, thereby reducing the potential for useful R&D outcomes. The workshop was to provide an opportunity for the major stakeholders to detect and deal with this. A secondary objective was to expand the stakeholder network (AKIS) and potential ownership of the R&D outputs, and to detect possible spin-offs to other regions.

The preceding details of the interventions are recognised to be little more than descriptions of their general intent and a proposal for future action. The specific procedures and the actual mechanisms by which the interventions would align the case-study R&D outputs with stakeholder interests to produce effective outcomes (ie. wide-scale adoption of improved land resource management practices) were never clearly articulated. Neither were the specific methods or agencies by which their efficacy and cost-effectiveness would be evaluated addressed at the time of the planning and implementation of the project. There was simply a strong conviction on the part of the project promoters that, if the interventions were applied, the desired outcomes would necessarily follow. In hindsight, this position was incorrect, as further discussed in Section B.4.2.1 and B.5.1.

B.3.3 An evolutionary history of the original proposal

Conceptualisation and planning for the project that was ultimately established as CTC2 commenced well before a two-page proposal for it was submitted to IWRRDC in October 1991. That the project had a fairly complex history, had a significant bearing on its ultimate operational performance (section B.5.1).

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The proposal to formally pursue a major technology transfer initiative for R&D projects focused on sustainable grazing land management began to evolve in 1990. The GLASS project leaders played major roles in promoting the project through the various stages that culminated in a contract being signed with LWRRDC in July 1993. While a number of factors lay behind the decision to initiate the project, the results of a 'scientific audit'⁴ of the GLASS project conducted in October 1990 were crucial. To that time the GLASS project leaders had been reviewing the issue of poor adoption of R&D outputs and the challenge this posed for their project, leading to serious consideration as to how this might be resolved.⁵ Prior experience with other land-resource-based projects and some consultation with extension specialists in DPI and the University of Queensland (UQ) had created real doubt on the merit of pursuing traditional *ex-post* strategies which separated the R&D and extension roles.

The draft and final audit reports (November 1990 and March 1991) raised two issues that spurred a formal attempt to get something effective 'on the ground' as quickly as possible. Firstly, the GLASS project, which was seen within CSIRO as a important example of the design, planning and conduct of future pasture-based R&D, was acknowledged as a 'landmark project' (sic) for which an extension of funding through a renewed contract was warranted. The scientific merit of most of the experiments and the overall ecological approach were seen to potentially make a major contribution to understanding and arresting land degradation problems. Secondly, the reports were highly critical of the proposed technology transfer approach and recommended that planning for an 'effective' technology transfer strategy be given high priority. The consultants, and the then newly-appointed management team overseeing the MRC North Australia Program (NAP2) to which the GLASS project was attached, favoured the traditional linear transfer of technology model with the extension role being passed from the R&D team to recognised extension or marketing professionals. The final report specifically recommended that '*CSIRO should now be consulting with specialists in extension (particularly DPI and private consultants) and reaching consensus for implementing a joint technology transfer program... this should not be seen as being solely or even primarily the responsibility of CSIRO*'. The report also recommended an improved information flow and collaboration between CSIRO, DPI and MRC, via the negotiation of a '*more explicit program of meetings and information sharing and dissemination, with an extra budget, to implement better information flow and ensure effective technology transfer during the latter half of the project*'. Finally, the consultants also recommended that CSIRO and MRC renegotiate the GLASS

contract with a view to extending its funding by an additional 3 years and to ensure more attention to networking and technology transfer.

GLASS had always been seen as a long-term project (ie. 10 years duration) and funding had initially been sought on this basis. However, under the prevailing funding arrangements with MRC it was contracted for a 4-year period (due to end on 30 June 1992), with no formal guarantee of follow-on funding. Therefore, the GLASS project managers, while sceptical about the recommended technology transfer strategy and informally arguing for more integrative approaches, were keen to comply to the extent that this helped to secure the additional funding recommended for the project experiments. The audit report conclusions on technology transfer and the desire to extend the contracted life of GLASS had two separate effects that together led to the design and planning of a major project that was a forebear of CTC2.

Firstly, there was an increased sense of urgency on the part of the GLASS managers to devise a technology transfer strategy that was acceptable to the NAP2 managers in order to promote a speedy initiation of negotiations for extending of the project contract. The project leaders were also willing to explore the suggestion of greater networking with DPI on technology transfer, but not necessarily within the context of a linear transfer model. Secondly, consistent with the CSIRO view endorsed by the audit that GLASS was a pioneering (landmark) project, the project managers were seeking to be 'innovative' in all areas of its design and execution, including technology transfer. Before the audit most emphasis had been placed on the so-called hard scientific experiments, although the inclusion of an agricultural economist in the project team in 1990 was seen by CSIRO as an innovative step in moving towards increasing the 'relevance' of the R&D outputs (MacLeod and Van Beek 1993). A significant challenge was seen by the project managers to match up a landmark project centred largely on the biological sciences with an equally innovative project centred on the social sciences—an area in which CSIRO recognised that it had no longstanding tradition and limited expertise.

At this time, there was growing pressure from both the R&D-funding agencies and within CSIRO for project managers to take a more pro-active stand on technology transfer for their projects. Therefore, the need to devise an effective technology transfer strategy to extend the GLASS project contract was consistent with a general requirement to do this anyway. The absence of a prior history and culture in the extension field and of overheads tied up in specialist extension staff, was not seen as a problem. Rather, it was seen to be providing an opportunity to 'break the mould' of a flawed past practice. It also provided scope to seek afresh an optimal approach based on 'best-practice' in extension methodology, even to the extent that this might be theoretical in nature. Much of the landscape orientation of the GLASS experiments was novel and previously untested in the field. Therefore, a lack of practical prior application of any extension approach

⁴ The audit was commissioned by MRC and conducted by Research Management International, Sydney.

⁵ A matrix of communication methods targeting different stakeholder groups was constructed and included in the extension plan submitted to the audit consultants.

was also considered to represent an opportunity to break new ground rather than act as a barrier. To this end, the GLASS project managers sought to identify and make contact with the relevant experts in agricultural extension to discuss approaches to extension and potential methodologies, and to seek out potential collaborators.

B.3.3.1 Application to MRC

Following the release of the draft audit report in October 1990, a series of meetings was held in early November 1990 between the GLASS managers and a UQ academic with considerable experience in agricultural extension, to discuss possible technology transfer strategies for GLASS, to establish a collaborative network, and to develop an effective plan. There was substantial pressure to complete this process quickly as the MRC call for R&D grants for 1991–92 closed at the end of that month. At that time, the project leaders believed that any additional funding for GLASS that might follow from the audit recommendation to augment the project scope and extend the contracted project life would be absorbed by proposed modifications to the existing experiments. However, the audit endorsement of GLASS as a landmark project and the firm recommendation of the need to develop a strong technology transfer strategy centred on an extended network, gave credence to the view that an innovative R&D proposal could be successful in the 1991–92 call. The decision to seek funding for a ‘separate’ R&D project centred on technology transfer was further influenced by a view that the NAP2 program of which GLASS was a component had only a limited pool of funds, from which GLASS had already obtained its ‘share’. The MRC was then placing some emphasis on technology transfer within the guidelines for new project applications, and it was identified as a priority area for the socio-economic category of projects. Because there was no generally acknowledged model for effectively promoting R&D outputs in the sustainable resource field it seemed legitimate to research the process, rather than to simply seek funding for an extension campaign.

To a lesser extent, the decision to take a research approach was also influenced by the success with which support had originally been won for GLASS itself, particularly against relatively widespread opposition due its departure with conventional agronomic practice. A parallel was evident which supported a view that if it could be successfully done once, why not a second time? The challenge of the scientific audit and its subsequent endorsement of the GLASS approach was a strong catalyst for this viewpoint. Moreover, a benefit-cost analysis conducted for the audit (MacLeod 1993) identified the scope for large industry benefits from enhanced adoption, which was seen to require a successful break from past experience. The concept of ‘outcome vision’ played an important role in this as the GLASS project leaders had a clear vision that GLASS could make a significant difference to sustainable land management and, importantly, were genuinely determined to do so.

Therefore, once an expression of interest had been confirmed from the UQ specialist to pursue a collaborative R&D-based technology transfer project attached to GLASS, the November meetings quickly became focused on developing a testable plan and finalising a submission within a little over one and a half weeks. In this time, an R&D coalition had to be established, R&D concepts and plans defined and articulated, milestones established, budgets detailed and costed, agreements negotiated to participate and co-operate between the relevant managerial staff within the coalition agencies, and the proposal signed off by the collaborative agencies’ chief officers⁶. This was achieved and an application submitted on behalf of CSIRO and UQ.

During this phase, the DPI had not been formally approached and identified as a research partner in the project. However, it was assumed that DPI extension staff would participate in some of the proposed interventions. The individual GLASS team members were not significantly involved in the planning and had little detailed understanding of the proposed project and how it would specifically involve them. It had generally been assumed that most of the team members would not take an ‘active’ role in the proposed interventions. Members who might be involved were consulted and were amenable to participation, to the extent that it was consistent with work they were planning to do⁷.

The objectives of the proposed project were:

1. To identify socio-economic and biophysical factors affecting adoption, by beef producers in the tropics and sub-tropics, of two different products of research, viz:
 - (a) a ‘commercial’ innovation embedded in a machine (eg. BandSeeding); and
 - (b) a more complex ‘environmental’ package of practices and innovations (eg. sustainable pasture management).
2. To identify regional or enterprise differences in these factors (within 12 months).
3. To design, develop and test an effective technology transfer strategy for the two innovation types (BandSeeding and pasture management) in sub-regions for implementation by research and advisory agencies.
4. To annually monitor adoption rates and changes in attitudes of beef producers to the two innovations.

The research questions and proposed methodology were heavily influenced by research conducted earlier by Pampel and Van Es (1977) and Chamala *et al* (1982) that differentiated between the potential adoption performance

⁶ MRC had not adopted the present two stage application arrangement.

⁷ This mainly applied to one individual who had developed the BandSeeder which was used for the GLASS experiments and was actively canvassing MRC and NSCP (LWRRDC) to fund a major demonstration effort for the machine.

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of so-called 'commercial' innovations and 'environmental' innovations. The former were seen, *a priori*, to be relatively straightforward and (arguably) suited to existing extension practice based on linear models of technology. Environmental innovations, which were assumed to include sustainable land resource-based projects such as GLASS, were seen to be more complex and to have generally poor adoption histories. However, it was assumed that both types of innovation faced biophysical and socio-economic adoption barriers. It was further assumed that such barriers would differ both between the two types of innovations and within the population of target enterprises according to individual circumstances, which included personal belief factors and regional influences. These would need to be understood, and once strategies based on these insights were developed, their impact could be assessed.

The proposed R&D methodology was:

1. Identification of homogeneous groupings of beef enterprises within the tropical and sub-tropical grazing lands, based on biophysical and socio-economic factors. Some previous experience suggested that there might be 4 or 5 distinct groupings based on agro-climatic factors, physical resource bases, and predominant enterprises (eg. breeding/finishing).
2. Study existing production systems and information networks, individual styles of management, and attitudes towards adoption of improved pastures and alternative management practices within each group. This involved an extensive postal survey, with any significant insights followed up by rapid rural appraisal (RRA) and local consensus data (LCD) workshops in the identified sub-regions.
3. Develop economic profiles of representative enterprises and production systems for each group, and conduct benefit–cost analyses for different scenarios involving adoption of the innovations for the representative enterprises in each group. The underlying rationale was that a new R&D-based innovation would be adopted only if it met at least the following criteria:
 - (a) a perceived need to adopt the innovation;
 - (b) an actual desire to adopt the innovation; and
 - (c) the means and ability to adopt the innovation⁸.
4. Select a group of beef producers within each group who have adopted the technologies (early innovators), to monitor their performance and to test and refine the technologies. The aim was to find 2–3 co-operating landholders from each of the representative groups to field test the BandSeeder and pasture management technologies under commercial conditions (eg. 30–40 hectares). This aspect was consistent with another audit report suggestion that testing of the GLASS 'technology' be extended to larger-scale commercial situations⁹. In the first instance early adopters would be selected or, if none were available in a given sub-region, access would be opened to a CSIRO-owned BandSeeder. The testing program would also generate a progressive build-up of information that could be incorporated into technology transfer packages appropriate to each group.
5. Monitor the rate and pattern of adoption of the technology within the sub-regions, with particular emphasis placed on adjoining enterprises, and the attitudes of adopters and non-adopters of the technology. Essentially the rate of 'infection' was to be measured by concentrating on 5–6 neighbours who would be periodically canvassed for their attitudes towards adoption and non-adoption of the two technologies.
6. Design, test and develop effective technology transfer systems for each sub-group. It was felt that an action-based system of R&D, modified to suit regional needs and attitudes, would be more likely to have the greatest chance of ensuring successful adoption of complex technologies. The insights and ownership obtained from the combination of postal survey, RRA, LCD workshops and case studies of the co-operating and neighbouring properties would be such as to have the basis of an effective technology transfer strategy already in place. Unlike many existing extension systems that were seen to be based on trial and error, the strategies would be based on purposively selected information obtained from the regional trial results, fine-tuning of the technologies, and recognition of the appropriate pattern of knowledge dissemination. Regional extension agencies (both public and private) would be invited to become involved in refining the technology package. This process would raise both the potential for successful adoption and an acceleration in the rate of adoption, thereby significantly raising the pay-off to the investment in GLASS.
7. Finally, a benefit–cost analysis of the proposed project would be completed. The rationale for this was that the project was seen to be a new initiative for R&D evaluation. Its conduct and findings could assist in promoting the technologies being trialed and perhaps other technologies from similar R&D initiatives. Therefore, it was desirable to obtain a rigorous economic assessment of its ultimate impact. It would also provide an ex-post test of the validity of the ex-ante assessment used to justify GLASS for the scientific audit.

⁸ This criterion is commonly overlooked by R&D providing agencies, as is the fact that non-adoption may be a rational decision.

⁹ It was also consistent with a view that the GLASS project was built around the existence of clearly definable technologies.

The four-year budget for the proposal was approximately \$600,000¹⁰, a significant proportion of which was absorbed by the full salary of a technical assistant position and salary contribution to the principal investigators.

Following submission of the project proposal to MRC in November 1990, further meetings were held to review the proposal and consider some informal feedback from MRC and other parties who had reviewed it. DPI, whose interest in participation in the 'extension' component had been sought initially by telephone, followed up with a copy of the proposal, was represented at these meetings by the Manager of Farming Systems Group, a Senior Extension Specialist and a Communication Manager. DPI was concerned that it apparently had no formal involvement in the research component of the project. This was considered desirable to meet MRC's demand for inter-agency co-operation in projects it was funding and to shore up support from within DPI at both management and operational levels. In January 1991, MRC was sent a modified proposal which formally included the DPI as an active 'research' partner. Before these meetings, the people involved had not actually worked together on a project and knew little or nothing of each others' research and extension experience or interest.

Initially, a technical assistant was to be appointed to support the principal investigators. Instead, a specialist extension researcher from DPI would be seconded to CSIRO. This individual would work actively on the research component of the project and formally liaise with the DPI extension network during the extension strategy design and testing stages. It was argued that this would increase the sense of 'ownership' of the project by DPI regional extension staff, thereby further promoting the chance of a successful outcome. At this time DPI involvement was also internally negotiated with the incumbent managers. The DPI involvement through additional travel and operating expenses raised the projected cost by approximately \$350,000.

Despite some encouraging feedback from MRC, and the project's merit being actively canvassed with the NAP2 managers during meetings to review the final audit recommendations and to renegotiate the GLASS contract, the application was rejected. Explicit reasons for rejecting the proposal were never given, but from informal feedback and a single-page check-sheet returned with the application, the following points appear to have influenced the decision:

1. The MRC assessment criteria ranked projects according to scientific and technical aspects, industry considerations, and other MRC considerations, which are then used to determine a final assessment and recommendation.

With the exception of 'adequacy of understanding of issues and literature review' and 'perception of

¹⁰ By way of contrast, the 4 year allocation from MRC that was finally agreed to under the re-negotiated contract for GLASS itself was \$700K.

personnel competency', the project was judged deficient on the first criterion. Objectives were not seen to be 'unambiguous, quantifiable or time-bound'. The design, methodology or milestones were not seen to be appropriate. Project costs were judged to be unreasonable, and the 'probability of the project succeeding in reaching the stated objectives on time, and within budget' was low.

On the second criterion, the assessment of 'relevance of the issues, benefits if solved, and applicability of results' was judged as being realistic. The likelihood of the project having a 'significant impact if the R&D was successful' was also judged as high. However, the assessment of the commercialisation (technology transfer) process was judged to be unrealistic.

On the third criteria, the 'achievement record of the principal investigators and their organisation(s)' was judged adequate and the target was deemed suitable for MRC funding. However, the project was judged to unnecessarily 'duplicate past, current, or planned R&D', although the relevant tense was not specified.

2. Informal advice from a member of the NAP2 management committee was that the application was screened by an employee of a prominent beef industry association, who said they could not understand what it was about and could see no immediate financial benefit to individual beef producers. The NAP2 management committee had previously commissioned a survey of beef producers in northern Australia and felt that the surveys included in the proposal would simply duplicate this work.¹¹
3. The NAP2 management committee was newly appointed and wanted to change the way that R&D projects were managed. This included promoting a more commercially-orientated approach to technology transfer. The NAP2 Program Manager particularly favoured a specialised marketing emphasis whereby R&D products would be promoted by a 'product champion' on the basis of defined financial benefits. Future project selection would be dominated by farmer-first principles through a selection process involving Technology Transfer Advisory Groups (TTAG) made up of beef producers, consultants and MRC personnel. Producer input to matters of the sustainable resource management was to be further elicited through a major LCD initiative being promoted by DPI in central and northern Queensland (Clarke and Coffey 1993).¹²

¹¹ This viewpoint was disputed on the grounds that the scope of the NAP2-sponsored survey was of a very general nature, whereas the technology transfer proposal was seeking to specifically target issues relating to barriers to adoption of very specific types of technologies.

¹² When the GLASS contract was renegotiated the project came under NAP2's sub-program for sustainable pasture R&D which included the LCD project as the main technology transfer initiative.

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The response of the project 'champions' to the rejection of the application and their interpretation of the underlying reasons was that both MRC and the NAP2 managers had missed the point of what was being attempted. Moreover, they were promoting a model of technology transfer that was unacceptable to the GLASS project. The GLASS managers still faced the problem of needing to develop a technology transfer strategy and, as the project leaders had anticipated, additional funding for this was not provided when the contract was renegotiated with MRC.

The rejected proposal was reviewed with an aim to either seeking alternative means of support or implementing a smaller project funded and staffed from within existing project or agency resources. The central role of the extensive producer survey was reconsidered, acknowledging that the MRC viewpoint on duplication had merit. The survey would be either curtailed or eliminated from a future proposal. It was also acknowledged that the budget had been greatly inflated by UQ's insistence that it cover a substantial proportion of their salary and on-costs, and the need to fully fund the salary and on-costs for the DPI specialist extension officer. Attempts were made to rationalise the LCD-based interventions included in the proposal and the LCD project being promoted by NAP2, to see if the separate activities could be reduced or integrated. However, the MRC-supported proposal covered the broad area of beef production and land management and was judged to be too remote to be directly useful for GLASS. Moreover, the project leaders did not want to pass total control for technology transfer to another party, or to dilute the contribution of GLASS towards sustainable land management with that of other projects with which it had limited affinity. It was decided to take no immediate action until the GLASS project team had reconsidered its position on a technology transfer strategy. Nevertheless, the project managers were not prepared to fall in with the NAP2 plan, as they understood it.

B.3.3.2 Application to LWRRDC

In October 1991, LWRRDC called for project grant applications for 1992–93. Preference was to be given to projects that would "*lead to results enhancing the better management, sustainable use and conservation of land, water and vegetation resources*". A formally identified program area was "*social and economic management systems*", and the suggestion was made that "*proposals which take an integrated approach to the management of natural resources and involve a range of disciplines, and which have outcomes that can be applied readily by resource managers*", would be favoured. Unlike the previous MRC application procedure, the LWRRDC system called only for a two-page preliminary application to be submitted by 1 November 1992.

The GLASS managers saw the LWRRDC call as an ideal opportunity to reconsider the unsuccessful application to MRC, and to seek support from potentially a more sympathetic party. There was a strong conviction that both GLASS and the technology transfer project were seeking outcomes that were consistent with LWRRDC objectives.

The DPI officers who had been associated with the MRC proposal were informally contacted to reconfirm interest in DPI involvement in a collaborative technology transfer research initiative for the GLASS project. The UQ, which had been a major partner to the earlier proposal, was not approached about the new proposal and no formal role was foreseen for the academic staff member who was to have had a major input to that project. This decision, which unfortunately led to a good deal of subsequent ill-feeling, was taken for several reasons. Foremost was the view that the survey-orientated approach favoured by the UQ researcher which was central to the original proposal, was not appropriate to the aims of the revised project. The DPI extension specialist and his colleagues were keen to test a number of group-based interventions that were consistent with an emerging extension systems approach to action learning methods¹⁵. Secondly, UQ staff involvement in the original project had been understood by the GLASS managers to be strictly conditional on substantial support for salaries. This was considered to be unlikely to improve with a revised proposal and taken to be a major source of failure for the previous proposal. Finally, it was understood that the affected staff member would be overseas on study leave for a significant part of the project's life if it went ahead. In hindsight, the decision clearly alienated a potentially important stakeholder to the research.

Several meetings were held in October 1991 between the GLASS project managers and the DPI extension specialist to confirm DPI interest in jointly applying to LWRRDC for a research grant. The original proposal was reviewed in detail and a number of significant modifications were proposed that fundamentally altered the character of the project and the power relationships of the partners, while also retaining a number of features that were consistent with the objectives of the original proposal. The changes also sought to reduce the projected cost.

Between the time of submitting the MRC proposal and the time of planning the LWRRDC proposal, a dialogue had been maintained between the GLASS managers and the DPI extension specialist, through which an increasing emphasis had been placed on systems-based participatory research and extension methods. The nature of the technology transfer problem for sustainable land resource orientated R&D was further considered and many aspects of the original proposal questioned. These were generally seen as being excessively reliant on the premises of a linear model of technology transfer or less relevant to identifying which R&D issues should be addressed in the first instance. The earlier proposal also presupposed that the technologies or outputs from the R&D were well known and readily identifiable, whereas this was not entirely consistent with experiences of conducting such R&D, including GLASS.

¹⁵ A major role of the extension research specialist was to promote the introduction of extension systems methodologies within DPI.

A modified proposal was drafted that took account of the premises listed in Section B.2 surrounding the potential failure of an R&D project to successfully lead to beneficial outcomes, and of 'learning' from the failed MRC application. The new objectives were¹⁴:

1. to identify and test perceptions held by potential end-users of, and their reactions to, complex land-management technologies and to provide feedback to R&D providers.
2. to understand both the biophysical and socio-economic factors that might promote or hinder the rapid integration by potential end-users of sophisticated R&D-based technologies into complex sustainable land management systems.
3. to identify and, where possible, quantify differences between adopters and non-adopters of simple and complex innovations involving grazing land management.
4. to devise an effective technology transfer and communication framework to (i) improve adoption of complex land management innovations, and (ii) adjust further R&D work to the needs of resource managers.
5. to identify the relevance of the findings to other resource management R&D projects and extend them accordingly. While focused on the sub-tropical and tropical grazing lands of Queensland, the findings would have national relevance.

The objectives were more concise than those of the proposal submitted to MRC and focused more directly on the 'complex' end of the technology spectrum. A specific intention to devise an operating framework (objective 4) for application by R&D project managers also dominated the objectives. This intention to develop a 'model' for practice substantially differed to the proposal to 'tailor-make' packages of strategies according to localised circumstances that was contained in the earlier proposal.

The objective relating to 'national relevance' was to be achieved by applying the 'model' to two case-study R&D projects in different agro-physical regions that were ostensibly addressing the same land resource management issues in different ways. The decision to operate with two case-studies that were separated by considerable distance rather than the GLASS project alone was based on three considerations. Firstly and most pragmatically, it was assumed that support was more likely to be obtained if the project covered more than one region. While the case-studies were located within the same State, basic industry and vegetation community, the biophysical and socio-economic differences between them were sufficient to justify a claim for a 'national' outlook. Secondly, replication of the results was important for a PhD study proposed for the project officer.

¹⁴ as stated on the two page application submitted to IWRRDC in October 1991.

This would not be feasible with a single case-study project¹⁵. Thirdly, CSIRO management was seeking to change the conduct of R&D and technology transfer activities in the north Queensland region, which were seen as having been inadequate for addressing the emerging issues surrounding sustainable grazing land management and resource degradation. The experience, to then, with the GLASS project and the interest its proposed new approach to technology transfer was generating, led to the CSIRO Program Manager deciding to involve the R&D staff of the Davies Laboratory in Townsville in the proposed project.

From the outset, including the second case-study raised many problems for CTC2 (Section B.5.1), in large part because the agreement to participate was not directly negotiated by the individuals who would be directly involved in the execution of either CTC2 or the case-study project. Like many aspects of the planning and conduct of CTC2, the negotiation process was largely informal and not well documented, thereby creating uncertainty with respect to individual obligations and responsibilities. A second factor was the changing structure and scope of the targeted project. At the time that CTC2 was first proposed, the second case-study was to be largely conducted by CSIRO staff with some input from DPI. This was a similar structure to that of the GLASS project. As negotiations with MRC evolved, the final structure took the form of a larger coalition of CSIRO, DPI and Department of Lands research and extension staff, and this arrangement was not particularly stable. Some of the potential partners to the R&D were not aware of the proposed existence of CTC2 or any implied obligation to co-operate. Moreover, a larger extension initiative based on LCD groups was included in the suite of sub-projects and this project had both substantial endorsement from MRC and DPI regional management and district staff. The formal CSIRO position was that it was proposing to integrate the technology transfer aspects of its experiments within CTC2. A stand-off emerged that, from the author's perspective, was never satisfactorily resolved.¹⁶

The perceived role of CTC2 in the conduct of the new R&D project was complicated by an unfortunate choice of the name given to the case-study R&D project in informal exchanges between some, but not all, of the affected parties¹⁷. Because case-study #1 (GLASS) had a clearly identifiable acronym, it seemed logical to also give the proposed second case-study an acronym. Unfortunately, when the proposal was being drafted this project was not sufficiently advanced to have a formal name or acronym, and by default it was called

¹⁵ Replication associated with this PhD project probably led to the decision to ultimately abandon the second case-study being deferred for longer than was warranted on the basis of practicality (Section B.5.1).

¹⁶ The situation was probably made even more confused by the early visit to Townsville and Charters Towers by the newly appointed project officer during which the proposed application to 'ECOSSAT' was reinforced, and a willingness to be 'part of the LCD project' expressed.

¹⁷ The name was used in the grant applications to IWRRDC which were eventually circulated to the case-study R&D staff and the NAP2 managers without clarification.

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'ECOSSAT' as it was then seen to be an 'extension' of an earlier project by that name. However, the ECOSSAT project was well known locally and was being wound up with extension having been done. Many of the individuals exposed to the CTC2 proposal took this to mean that the proposed project was to relate to formally extending the results of that work, rather than the new R&D initiative. This understanding would also be consistent with the traditional view and conduct of technology transfer within CSIRO and DPI where the extension activities are upgraded after the R&D has been largely completed. While the extent to which confusion was inadvertent or conveniently engineered on the part of many individuals is unclear, the end-result was a severe problem of variable expectations, obligation and commitment to CTC2 by individuals whose co-operation would be necessary for the project to succeed.

Other problems involved in running case-study #2, such as resourcing and time constraints, compounded by physical disability problems for CTC2 staff, were addressed in the annual Milestone Reports.

The revised methodology, particularly the integrated set of four interventions (Section B.3.2), represented a significant departure from that of the earlier proposal. With respect to a historical overview of the evolution and implementation of CTC2, the relevance audit intervention warrants some further mention. As noted (Section B.3.2), the audit had several roles, which were both poorly understood and controversial. One role was to allow a wide range of stakeholders to affirm the ongoing relevance of the project and, where appropriate, recommend changes. This role presented some major difficulties, particularly in light of the involvement of MRC in substantially funding both of the case-study R&D projects. The notion of 'empowering' other stakeholder groups to influence the direction of a project that was financially supported by one particularly powerful stakeholder group, and backed by a contract, was not likely to go unchallenged.¹⁸ While the introduction of multiple perspectives and community empowerment is consistent with much of the new technology transfer thrust, problems can arise for R&D-providing agencies when additional 'empowered' players are introduced into projects. Arena theory (Dunford 1992; Cunningham and Barawryh 1993), discussed in Sections C.3 and D.3 of this report provides considerable insight into these problems.

The three-year budget for the revised project was \$120K, considerably less than the \$900K sought in the earlier MRC grant application. The budget covered travel and operating expenses only. It was envisaged at the time, that a project

officer would be appointed from within CSIRO or DPI, their salary being met by whichever agency made the appointment.¹⁹

The two-page project grant application was rejected by LWRRDC for funding in its own right. However, it was suggested that the feasibility of co-operating with several other applicant projects within a commissioned program of R&D might be explored. A meeting to consider this proposal in December 1991 endorsed proceeding with a revised application on the suggested lines. The project champions reviewed the application and the underlying project design and attempted to firm up the specific activities and obligations of the partners, and further scale down the budget.

The decision to proceed with the application introduced three new factors that would eventually have an impact on the conduct and performance of CTC2. The first was that to proceed as part of a co-ordinated suite of projects meant taking on obligations beyond those specifically proposed for the project. These obligations included the need to meet a number of reporting and co-ordinated activity requirements, as well as pooling and co-interpreting data from a diverse set of projects conducted by individuals working outside the immediate target area of interest for CTC2. This was not a trivial task, as the project promoters were particularly conscious of the time constraint that already existed for execution of the planned interventions for case-study #1, which had been compounded through the late-stage replication involved with taking on a second case-study. Participation in the co-ordinated venture involved working with a Program Co-ordinator and an overview project to be conducted by the Communication Research Institute of Australia (CRIIA), which implied a partial transfer of power in decision-making on project execution from the principal investigators to the Program Co-ordinator. This transfer ultimately presented both problems and opportunities for the project managers.

The second factor, related to the first, was the need to further revise the proposed budget. As the project design and operating plan were revised to accommodate the proposed program structure the required budget increased, largely due to a revised agreement to part-fund the salary of the project officer to be seconded from DPI to CSIRO. This was consistent with a plan for one of the other projects in the suite (CTC3) and was specifically sought by the DPI partners to increase the attractiveness of both proposals (CTC2 and CTC3) to DPI senior managers. The proposed operating expenditure was also increased as the project design was altered and the tasks involved became clearer. However, there was an overriding pressure to reduce the total funding request for the suite of projects if the final program was to be feasible from the point of view of LWRRDC and the funding consortium

¹⁸ In fact, it did not go unchallenged, culminating in a meeting between the CTC2 team, LWRRDC representatives, MRC NAP2 management committee, and DTCP and DPI managers in March 1993. The meeting was ostensibly about overlaps between CTC2 and the NAP2-supported LCD project, but was presumably motivated by territorial concerns including stakeholder access rights to both GLASS and the case-study #2 project.

¹⁹ DPI participation was finally conditional on receiving funded-support for salaries of the order of \$60K for the projected three year project life.

that they were trying to establish. To accommodate this, the partial salary commitment to DPI was offset by CSIRO. Also, DPI agreed to absorb an increased proportion of the proposed operating expenditure. The final three-year budget request was \$180K, which in net terms was equivalent to the original request plus \$60K for the salary support. That this budget could not support significant progress on CTC2 became obvious early in the life of the project and was raised in the Milestone Report #1.

The third factor was the formalisation, subsequently in 1993, of a dual role for Associate Professor Art Shulman of CRIA as both a CTC2 co-researcher and supervising program manager.²⁰ Before the establishment of the program, Professor Shulman had been identified as a potential supervisor for the project officer who would be undertaking the project as part of doctoral studies at the University of Queensland. The dual role under the proposed program significantly changed the power relationship between the various team members and a fair degree of autonomy for the activities of the CTC2 team was surrendered. A major impact of the new relationship was on the proposed execution and evaluation of the interventions. The project promoters had no substantive specialist skills in communication research, and the project proposal had been couched in relatively abstract terms with respect to testing and evaluation of the interventions (Section B.4.2). This status both added to the confusion of the case-study R&D teams as to what was expected of them, and also meant that a considerable proportion of project management was subsequently devoted to defining and redefining what it was about and how it should proceed.²¹ While insights from the Program Manager, who was recognised as having the necessary research skills, proved to be most useful they also led to a major reappraisal of the feasibility of continuing to attempt to adhere to the project plan outlined in the original milestones and GANTT chart.

While the application was being revised, different individuals associated with the proposal were negotiating with various stakeholders, notably the case-study R&D teams, DPI district extension staff and senior DPI managers in the targeted regions. The latter negotiations were understood by CSIRO to have been undertaken by the senior extension specialist and/or the Manager of the Farming Systems Group.²² Negotiation and communication with the two case-study teams was largely undertaken by the CSIRO principal investigator (case-study #1) and the CSIRO Program Manager (case-study #2).²³ These discussions were not formally documented and

it is now apparent that few of the parties to the proposal had a clear understanding of the specific agreements that had been reached. A major restructuring of DPI was in process which led to a number of fundamental changes in the management hierarchy and command structure in both head office and the regional centres. This compounded any existing problems relating to recognition and acceptance of responsibility for meeting any expectations for staff involvement with CTC2. A substantial proportion of the early reconnaissance activities involved the CTC2 team visiting various CSIRO and DPI managers and field staff to clarify the project and to shore up a new structure of support (Section B.5.1).

A revised project proposal, including involvement as part of a co-ordinated program, was submitted to IWRRDC in February 1992. Advice was received from IWRRDC of the decision to fund the co-ordinated suite of projects in March 1992.

In April 1992 a notice was circulated within DPI calling for expressions of interest from individuals seeking secondment to CSIRO to act as project officer for CTC2. This was subject also to their willingness to undertake a course of study towards a PhD at UQ related directly to the project. The specific brief agreed to between the promoters was to select a mature individual with an extension background and high order skills in extension R&D, team management, liaison and communication, and scientific writing. The position was filled by a former DPI manager who appeared to be well-qualified and to possess a background appropriate to fulfilling the role.

At this stage, the CTC2 project team, which consisted of two Principal Investigators from CSIRO and DPI engaged on a part-time basis (20% and 10% time commitment) and the full-time Project Officer seconded from DPI, was deemed to have been assembled and project operations commenced.

B.4 Execution of the approach

B.4.1 Methods employed

This sub-section details some of the methods that were employed in the execution of the project activities.

B.4.1.1 Selection of participants

Consistent with the AKIS approach, there was an array of potential stakeholder groups identified for each of the case-study R&D projects. Some perceptions held by these different groups on issues relating to sustainable land resource

²⁰ Note: At the time that the Program commenced in 1992, the role of Prof Art Shulman (CRIA) was that of a co-ordinator for the various projects, including CTC2. His authority as a Program Manager did not come into place until 1993. Until then, program management responsibility was held by an officer of IWRRDC.

²¹ The required skills were not available within DPI or UQ, leading to a successful Milestone Report #1 (Appendix B) request for additional funding to CRIA to provide training for program members in communication R&D skills.

²² During the participant interview process for this review (Section C.4) it was revealed that this was incorrect and that few of the DPI regional managers were aware of the IWRRDC project proposal.

²³ Case-study #2 was then still largely a CSIRO initiative and the negotiations centred on CSIRO Davies Laboratory R&D staff.

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management and grazing land degradation had been canvassed before the project (MacLeod and Taylor 1995). Issues raised by this background research included:

- that different stakeholders held an array of perceptions concerning the sustainability of existing grazing practices, the extent to which these contributed to serious land degradation problems, and the causes;
- that while there were marked differences in perceptions between many stakeholder groups, there was substantial consistency in these perceptions within respective groups;
- that the temporal and spatial scales at which degradation processes occurred or should be studied differed between groups, especially scientists and beef producers;
- that both beef producers and scientists generally felt that land degradation problems could be overcome and that the information (technology) required to do this was held by a number of different groups, although R&D professionals and experienced beef producers were identified as key sources.

While an overriding aim was to promote successful R&D outcomes for the two case studies, a focus was also on influencing the behaviour and perceptions of the actual R&D staff rather than that of beef producers and/or other identified stakeholders to the R&D alone. That is, a structured and ongoing sequence of communication interventions was to be used to improve their understanding of system performance from different stakeholder perspectives, and the potential contribution of the integrated/synthesised outputs of the R&D to that performance. Therefore, as key stakeholders, the R&D teams themselves, were self-selected through their apparent willingness to participate. In the case of the GLASS project, willingness to participate was directly confirmed by the individual R&D team members. For the second case-study this was 'assumed' through the proxy vote of the relevant CSIRO Program Manager as the constitution of the actual team was unclear at the time of planning. Many of the actual case-study #2 team members would either have had little understanding of this commitment or inclination to be involved. As none of the proposed interventions, beyond the initial reconnaissance activities, was initiated for case-study #2²⁴ the remaining notes relate to case-study #1.

Other participants were selected on an 'opportunity/needs' basis involving: past association with the case-study R&D project or its constituent team; membership of the network of contacts of the CTC2 project staff (notably the Project Officer); and/or through indirect nomination from the previous two groups.

²⁴ The reasons for abandoning operational activities associated with this case-study were canvassed in both Milestone Reports #1 and #2. Details are also provided in Section C.5. of this report.

For the *focus groups*, beef producer participants were selected via a two-step process. In the first step, a group of DPI extension officers was approached on the basis of local area involvement and geographic convenience to be involved with the project and to act as a 'host' to one of the four producer-group focus meetings (Toogoolawah, Kingaroy, Binjour, Monto). Each officer was then asked to help draft a list of potential participants based on the following general criteria:

- likely to have a genuine interest in having an input into R&D;
- manage a reasonable size of operation (ie. excluded hobby farmers);
- include some participants who the extension officers would not normally contact, including individuals who do not belong to mainstream producer organisations (eg. Cattleman's Union or United Graziers Association); and
- some preference for 'management teams' (eg. husband and wives, fathers and sons).

Agribusiness and financier focus group participants (Murgon and Mundubbera) were selected from lists made by the Project Officer in conjunction with DPI extension officers from Kingaroy and Ipswich. The research scientist focus group participants (Brisbane) were nominated by the case-study R&D team at a meeting in Brisbane, and the extension officer focus group participants (Kingaroy) selected by the Project Officer on the basis of his knowledge of the DPI network.

Because the case-study R&D teams were a principal focus for the project, it was intended that the technical reference group should play a pivotal role in the total suite of interventions. Selection of the participants was carefully considered by the principal investigators. A three-stage process was finally adopted, through which the R&D team, having had the role of the group explained to them, agreed amongst themselves on the disciplines that should be included on the invitation list with a notional limit of approximately eight members. The case-study R&D team members then individually submitted names and perceived disciplinary strengths. These were reviewed in a combined session by the team and the principal investigators. A short list was then agreed to and invitations to join the group initially made by telephone contact in order of preference until the required numbers were filled. This was followed by a formal letter of invitation accompanied by a detailed explanation of the role, structure and proposed method of operation of the technical reference group and background material on the case-study R&D project. The basic criteria for selection were:

- acknowledged high-order experience and professional standing in a relevant discipline;

- familiarity with grazed ecosystems or management systems, preferably similar but not necessarily identical to that under study;
- experience or empathy for multi-disciplinary R&D projects
- located somewhere 'geographically convenient' to the case-study R&D project to reduce participation cost—Queensland or north-central NSW was preferred but the ultimate consideration was finding the best people for the task.

The proposed relevance audit, in light of serious delays encountered in initiating the various interventions, was abandoned in 1993. Selection of potential participant 'groups' (eg. agribusiness, conservationists, R&D professionals etc) had not been resolved by that time, and so the more specific selection process for identifying and engaging the participation of specific individuals had not been defined by the project team.

B.4.1.2 Defining the 'technology'

The 'technology' being developed and/or refined by the case-study R&D team would ordinarily be expected to be clearly defined and understood by the case-study R&D teams, if not the targeted direct end-users and, perhaps, other stakeholders. For the GLASS project this remains ill-defined (Section B.6). It has, however, been related to information concerning pasture system structure, response and performance under an array of prescribed management interventions applied within the context of beef cattle grazing a generally recognised vegetation/soil complex. Occasionally, and in the minds of some R&D team members and other stakeholders (eg. extension officers and cattle producers) the technology appeared to take a more specific and narrow form relating to the species and establishment technique used in a subset of the experiments (eg. legumes and BandSeeding). On one or more occasions the R&D team identified, within the context of brainstorming sessions, a list of so-called 'products' that might be considered part of the technology or experimental output. Lack of a well-defined technology or, more importantly, consensus within the R&D team and other stakeholders, contributed to the performance of both the case-study project and CTC2 (Sections B.5.1, B.6).

B.4.1.3 Modes of intervention/order of intervention

The general scope, ordering and connecting relationships between the proposed suite of interventions to be tested are presented in Figure 1. To the extent that some, but not all, activities did commence, this general ordering was pursued until the project was terminated in August 1994 (Section B.5.1). Of the proposed interventions, the reconnaissance activities, first focus group meetings, establishment of technical reference group and some semi-structured

interviews with key participants (R&D staff, R&D managers etc) were undertaken for case-study #1. Only the reconnaissance activities were completed for case-study #2.

B.4.1.4 Data collection techniques

The following types of data were collected for the various interventions:

- immediate*—for many of the exercises conducted by the CTC2 team, data were collected through 'face-to-face' interviewing on an individual or group basis (eg. reconnaissance, focus groups, etc). Flip charts (butcher's paper) and short point note-taking were commonly adopted to provide a basis on which 'data' could be reviewed almost immediately during and after the intervention.
- feedback*—wherever possible, participants to both the project and the individual interventions were provided with written feedback for verification, comment or to maintain interest and commitment to the process. This often took the form of summaries or transcripts prepared by the project officer on the basis of observers' notes or tape recordings of meetings, where this was previously negotiated and agreed to by the participants.
- transcription*—for many of the interventions proceedings were taped using microcassette recorders. These tapes were transcribed to typed hard-copy in most instances, and circulated amongst project team members and some selected participants outside the case-study R&D teams. While this occasionally proved to be useful for enriching the meeting notes and stimulating recall, it represented a heavy resource commitment for the project and may not have been particularly well-handled by the project managers.
- diaries/meetings*—team members kept diaries and took written notes during the majority of the interventions and informal meetings. These were frequently compared in debriefing sessions aimed to share and discuss individual observations and interpretations. Common themes of the meetings were 'what did you hear?' and 'what did you see?'. That is, data were sourced from personal observations and discussion within the team.
- archival material*—much archival material relating to the first case-study project (GLASS) was collected from individual R&D team members, the official records held by the project leaders and CSIRO Communications Activities Section. The project officer attempted to review much of this material but with little positive outcome. The material included the project application, contracts, minutes of meetings, audit submissions and public relations material covering aspects of grazing land management sourced to the case-study project.

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- f. *semi-structured interviews*—a number of these were conducted by various team members, notably the project officer before and after the various interventions. The notes were circulated to the management team.

B.4.1.5 Data processing

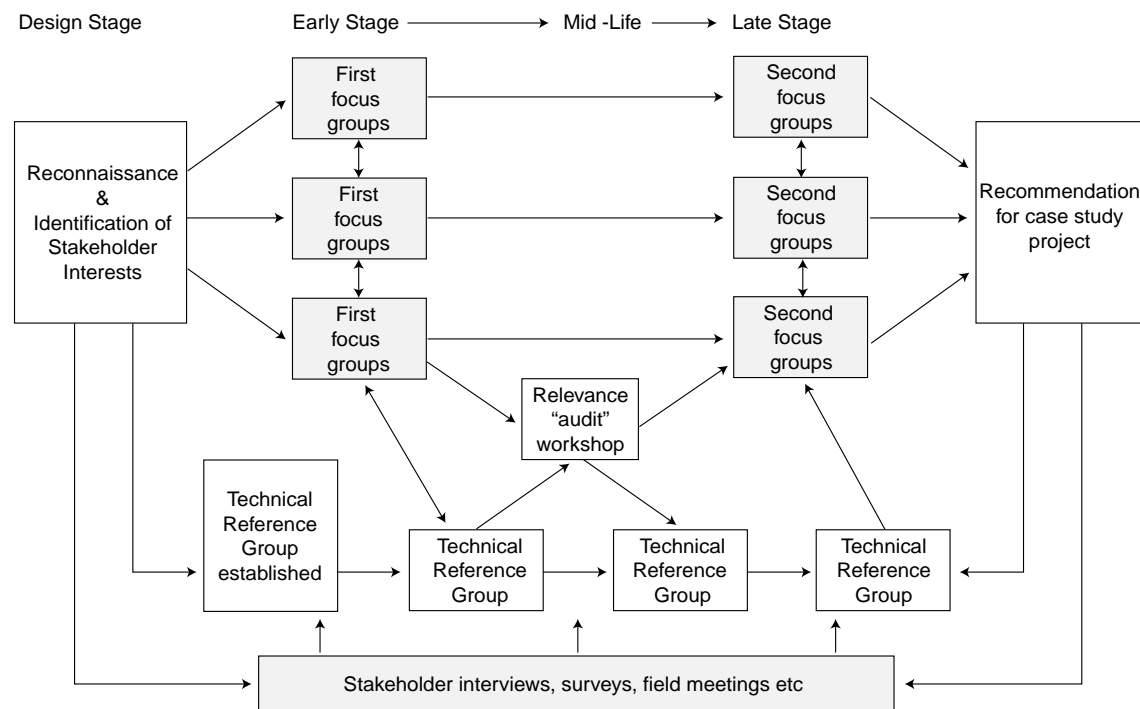
This aspect of the operation of CTC2 was, in hindsight, not handled as well as it might have been. The team was overloaded with raw data from the sources outlined in section B.4.1.4, but very few data were processed into a form (ie. information) that was amenable to easy review and interpretation. This was especially noted by the case-study R&D team members and CTC2 managers who claimed to be preoccupied with a range of other commitments (Section C.4). This has been referred to by one individual as a case of using the 'photocopier' rather than 'brains'. A common theme recorded in interviews with various participants was that there was an overload of information, much of which may have been interesting in part but hard to handle in the whole. Data were not seen to have been summarised sufficiently succinctly and clearly for operational use during the earlier stages of the project.

B.4.1.6 Data reduction

As noted in Section B.4.1.5 there was very little data reduction. Some material was summarised by the project officer as 'key points' from several of the interventions (eg. focus group meetings) which some case-study R&D team members found to be useful (Section C.4). However, there was a counter view expressed by some team members and the principal investigators that the summaries were often unduly biased by the perceptions and motives of the project officer. That is, they did not fully reflect a balanced synopsis of what had actually been discussed at some of the meetings.

Poor progress in this particular area was highlighted in the two annual Milestone Reports (Appendix B) and assistance sought for resources to support the acquisition of specialist skills through training or secondment. The Program Manager agreed to part fill this gap and, in the process, was instrumental in identifying the need to more comprehensively collect and analyse baseline data for both case-study R&D projects (Section B.5.2).

Figure 1. The general scope, ordering and connecting relationships between the interventions to be tested



B.4.1.7 Feedback

Feedback of information to the project managers, case study team members, intervention participants and other stakeholders occurred at several levels. The main level was through direct correspondence in the form of letters accompanied by summaries and transcripts. These occasionally included survey forms that sought to capture further comments or verification. Some seminars were held at the CSIRO Cunningham Laboratory in which aspects of the project and some of the information obtained from the interventions were reviewed. However, this was not necessarily tailored to the time constraints and personal level of commitment or interest of the various individuals to whom the material was directed. In that sense, everyone was treated as an 'equal'.

B.4.1.8 Management aspects

It is generally conceded by most individuals exposed to CTC2 that the management was deficient. This is discussed in Section C.4.

Management responsibility lay in the hands of three individuals drawn from two agencies (CSIRO and DPI) acting in different roles with different notional commitments of time to the project. The principal investigator role was shared by two individuals on the basis of a 20% and 10% time commitment and the project officer on a 100% commitment. The project officer was also enrolled as a full-time PhD candidate at the University of Queensland. The principal investigators saw their role mainly as overseers and directors with a responsibility for directing the general thrust of the project; act as conduits between CTC2 and the two case-study teams and the parent agencies; and to help interpret the results. The project officer was given a large degree of autonomy for running the day-to-day aspects of the project and, as a PhD candidate, collecting, analysing and interpreting the data.

The project was part of a wider IWRRDC-sponsored program (Section B.3.3.2). As such, project management was also influenced by the activities of the various program initiatives and the Program Manager who held the dual role of supervising the project officer's PhD studies. The project and program had to report annually to a Resource Management Committee representing the interests of the parent R&D agencies and the consortium of funding agencies who were financing the program.

B.4.2 Evaluation of the model/ interventions

Evaluation procedures for the project in general, and the separate communication interventions in particular, were not clearly specified in the original project application. In fact, the need to identify and implement effective evaluation procedures never happened even though it was recognised by the principal investigators and the Program Manager as a problem requiring urgent solution.

During its first year of operation, an approach emerged which was essentially based on three separate thrusts. Firstly, 'testimonial' (ie. self-report) evidence was elicited from participants to the various interventions and other affected or interested parties concerning their perceptions of the value or effectiveness of the CTC2 model and its constituent interventions. This was to be captured through the use of 'entrance' and 'exit' polling of the relevant individuals at the beginning and end of the overall project and throughout its life as the various interventions were implemented. The information to be sought and analysed largely related to whether or not they felt (from their own perspective) that the exercise had been 'worth while' and/or if it might have been approached in other ways.

A second thrust was to document how the interventions were actually impacting, by observing the behaviour of the R&D teams in their interactions with each other and stakeholders, and the forms and content of messages being transmitted to and from the teams and stakeholders.

The third thrust was to keep track of the rate and pattern of adoption of the R&D 'outputs' throughout the life of the project. Much time was spent discussing possible methods and querying their practicality and validity, but little was actually achieved, before the intervention of the Program Manager in late 1992. However, while this intervention was specifically sought by the team and supported by the Resource Management Committee, it was not sufficient to develop a set of useable evaluation procedures. Rather, it tended to further highlight the deficiency. A root cause of this lack of coherent action was the limited prior experience of the CTC2 team members in basic communication research procedures.

Early in the life of the project, serious questions were raised as to what baselines performance should be measured against. This was fundamental to resolving the equally important issue of measuring whether or not the project activities were performing successfully. Fundamental questions as to what the project was really supposed to achieve and how this would be effected began to be raised. There were also questions as to the objectives of the two case-study R&D projects. To a fair degree the project team and Program Manager were initially 'naive' in taking as given that within the case-study projects there were clear sets of 'products' or 'technologies' that the R&D teams could describe (Section C.6). The wording and approaches taken in both the CTC2 and case-study project applications suggested this. For example, CTC2 set a significant part of its aims in terms of achieving better technology transfer outcomes for the case-study projects, implying increased levels of adoption of their R&D outputs without actually pre-specifying what these might be.

Therefore, a major task for resolving the evaluation issue was to obtain clear statements from the CTC2 and case-study R&D teams of what their projects were trying to achieve, and the industry and institutional context within which this was being attempted. Once this task was completed it would be

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feasible to categorise the 'products' as a key construct and establish valid baselines around them. However, while the project applications were written in terms of 'products', some of the language also related to the R&D process driving 'outcomes'. In this case, establishing baselines was also considered to include a need to ask questions such as 'Who were the processes and products for?' and 'How will the R&D specifically benefit these stakeholders?'. For example, if the R&D was to add to an available knowledge base concerning sustainable land resource management, then it would be necessary to identify the present knowledge base and the way that stakeholders might access it. That is, how do the stakeholders view the 'technology', use it or get more information about it etc. Time was spent in the early operational (reconnaissance) phase searching for information to support the establishment of baselines consistent with these questions. As noted in the earlier section (Section B.1) detailing the project objectives, an underlying premise of the CTC2 model was that the knowledge bases would change as a result of interaction between the case-study R&D team members and other stakeholders. This might be seen in shifts in what the R&D personnel and the stakeholders were 'saying' and 'doing' with respect to the technology generation and transfer process. However, during the reconnaissance phase and throughout much of the operational life of the project, it was apparent to the project leaders and Program Manager that the identity of the targeted R&D 'products' was unclear to both the CTC2 team and the case-study R&D teams. This finding promoted a shifting emphasis in the evaluation task and the operational logic of some of the interventions, notably the focus groups and technical reference groups. This re-orientation is detailed in Section B.4.

The changing emphasis on 'outcomes' and processes expanded the scope of both what should be measured and for whom the measurements should apply. That is, the evaluation context was expanded to consider evaluation of the products and processes by other stakeholders (eg. other scientists) beyond the more traditional ones such as beef cattle producers. In evaluating the effectiveness of the focus group intervention, consideration might now be given to examining the ways that the case-study R&D team members were conceptualising the role that their experiments would play in contributing to the projected products and outcomes. Shifts might be observed in what individual team members would be saying about their work and its potential contribution as input to other disciplinary experiments or interpretation of data, or the collective project outcome. For example, in preparing the 'common story' for case-study #1 (Section B.5.2) it was anticipated that individual team members might be seen to shift from focusing on single themes based on their disciplinary interests to a more integrated depiction if the process led to a changed understanding of what other members were actually doing. Interest was also placed on checking whether such a phenomenon, if it was observed, was permanent or part of a

switch to a changing pattern in the way individuals were presenting information and, if possible, what they believed. Related aspects included assessing the extent to which they might begin to change the shape and scope of the individual experiments or overall trial and the extent to which individuals might seek to tie their work in with others. Evidence for such shifts might be found in the manner in which data were collected, managed and analysed, in personal testimony from interviews and in formal presentations such as milestone reports, seminars, field day presentations and themes, and research publications.

Therefore, under the guidance of the Program Manager, the evaluation focus was moved from a search for confirming testimonials of the extent that stakeholders deemed an intervention or interaction to have been either useful or a failure. The new focus was on the extent of conformity with the stated project objectives of increasing R&D relevance, and on changes in the way that individual R&D team members and other stakeholders conceptualised the problem context and operated. As a first step, the project officer and one of the principal investigators attempted to apply a basic content analysis to various data sources, and undertook training from the Program Manager to accomplish this task (Vance and Van Beek 1994). The aim was to capture major themes that would reveal where various people were positioned at any moment and to test the extent to which these themes changed over time with respect to the different interventions and a general increase in the level of interaction between team members and various stakeholders. Emphasis was to be placed both on shifts in what individuals might be articulating as representing their research approach and what they were seen to be actually doing. Emphasis was also to be placed on eliciting comments from stakeholders on their views on the research issues and the R&D project over time. To this end, the project team devoted a considerable amount of time reviewing archival material, records of interviews with R&D team members and other stakeholders collected during the reconnaissance surveys and transcripts from the focus group meetings. A critical review was made of what the stated objectives of the R&D were, categorising major concepts, identifying statements about the major concepts, and searching for shifts in these statements.

Because of restrictions inherent in the research design, the proposed and evolving evaluation approach could not address the important issue of whether changes in R&D performance could be achieved in more efficient or cost-effective ways. The project was testing only a single model with an integrated suite of interventions, so evaluation took the form of a 'before/after' approach as opposed to testing and comparing alternative models. As such, there was no 'control' model or intervention. There was an implicit assumption made that, without the model and the individual interventions, progress towards achieving an outcome for each of the case-study R&D projects would follow much the same type of path as other land resource projects that had

been conducted in the past. However, that baseline performance was not specifically identified or measured.

In part to address some of these issues it was considered useful to have the model applied to two similarly focused case-study R&D projects running in overlapping times under similar climatic circumstances with similar sets of stakeholders, but which also had reached different stages of development and initiation. On the basis of experience with a given intervention in one case-study, these could be modified and tested for increased efficiency and cost-effectiveness on the other case-study.²⁵

B.5 Results

Results for the project are presented from two specific viewpoints. Firstly, whether the project successfully adhered to its original execution plan as set out in the GANTT chart and milestones included in the contract documents. This might be considered as covering the *operational performance* of the project team. The second viewpoint relates to the impact of the individual interventions and their combined application on the case-study R&D projects and their quest for improved technology transfer. This would cover the *process performance* of the interventions. These are separately considered in the following two sub-sections.

B.5.1 Operational performance

The project experienced a number of operational difficulties from the time of its being proposed in October 1991 through to August 1994 when CSIRO advised the Resource Management Committee of its decision to terminate the project. Despite a significant commitment of time and resources, only a small subset of the interventions was actually applied. As noted before, most of these were confined to case-study #1. However, only the focus group meetings were implemented and firm results of this intervention have not been formally presented to the R&D team to date. Given the loss of project staff that has occurred since 1994 in both CTC2 and case-study #1, it is not anticipated that such a presentation will eventuate. For case-study #2, no single intervention was implemented beyond the early reconnaissance exercise in 1992.

On this basis, it is conceded that CTC2 was poorly managed and executed in an operational sense. The majority of the proposed interventions were not applied and, those that were, have provided limited insights for immediately improving the technology transfer practices of the two targeted case-study projects. However, while it would be easy, particularly in hindsight, to write CTC2 off as a 'failed' exercise, this would be short-sighted. Much positive learning did emerge from the experience both for the CTC2 team and the case-study

R&D teams. Considerable effort was invested in seeking to understand what did and did not work with the project and to move on to better models and methods for communication and technology transfer. In this sense, the actual 'process' of the engagement with the communication project should be seen to be as important as the 'product' (Section B.5.2).

The remaining principal investigator and the case-study R&D teams have endeavoured to make this an 'intelligent' failure (Argyris 1977, 1994; Sitkin 1992). This is explored in Sections C.3 and C.6, but the operational performance problems that were encountered included:

- a. lack of a clear methodology, including evaluation methods and assessment of baselines;
- b. lack of a unified management structure;
- c. lack of decentralised power to effect change in response to unforeseen adverse developments;
- d. poor pre-initiation management of ownership and resourcing;
- e. use of an untested and excessively rigid design;
- f. insufficient resources relative to the scope of the project;
- g. overconfidence in the ability of the case-study R&D projects to proceed according to their operational plans;
- h. excessively 'tight coupling'²⁶ (Perrow 1984) of many CTC2 activities to those envisaged for the case-study R&D projects.

From the viewpoints of communication efficacy and cost-effectiveness the operational value of the CTC2 communication model as proposed remains genuinely doubtful. However, a substantive modification is proposed (Section D) that aims to overcome many of these problems.

B.5.2 Process performance

As noted in Section B.4.1, only the reconnaissance exercise, focus group meetings, and establishment of the technical reference group were initiated for case-study #1 and only the reconnaissance exercise was conducted for case-study #2. For both case studies, a small range of semi-formal activities that largely related to meetings with team members and other stakeholders was also conducted. A common purpose of these activities was to follow up on issues raised in the more formal interventions or to provide information to the case-study R&D teams and/or relevant agency managers on proposed future project activities or feedback on previous activities.

B.5.2.1 Reconnaissance/establishment of baselines

The eventual role, power and resource commitment associated with this activity was considerably underrated at

²⁵ This was not actually achieved in the light of a decision taken in March 1994 not to proceed with applying the interventions with case-study #2.

²⁶ *Coupling* can refer to the strength, directness and complexity of causal relationships among parts of a system (e.g. McGrath 1991).

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the time CTC2 was being developed and initiated. The activity was originally proposed to be a relatively straightforward and 'one-off' exercise. It was foreseen essentially to represent a familiarisation exercise to allow the CTC2 team to get to know the case studies and their implementing teams better, gain a better understanding of the regional and industrial context for the case-study projects, identify key stakeholders and potential collaborators, collect relevant baseline material and, importantly, clarify the specific 'technologies' and their potential fit within local grazing systems. The activity was scheduled to account for approximately two weeks of field travel in each of the target regions in 1992.

However, this intervention, and a series of other activities that arose from its findings, eventually consumed a significant proportion of project commitment that extended well into 1993 and, to a lesser degree, early 1994. The reasons for this extended effort and some key findings included the following:

- a. the CTC2 project team had limited prior experience in conducting qualitative research in general and communication research in particular. The need for establishing effective baselines for such research, and the effort and skills required, were seriously underestimated. Extra resources were sought, including project staff training²⁷, to address this deficiency. In planning for CTC2 there had been no clear distinction drawn between the resource and effort commitment required to 'research' the communication process, as opposed to 'conducting' the communication process itself. The skill base of the project team was more appropriate to the latter task.
- b. the relative geographic isolation of the project team from the two case-study R&D sites presented more serious access problems than were originally foreseen. While allowance was made for the need for some repeat visitation by individual team members, contingencies to cover non-availability of certain key stakeholders or members of the case-study R&D teams at critical data capture times were inadequate. This problem applied more to case-study #2 where the rate of repeat visitation to complete specific data gathering tasks was much higher than anticipated. This problem was also compounded by the 'transitional' nature of the case-study #2 project whose scope and ultimate team composition was still in the process of being resolved well after the first reconnaissance visits were conducted in September 1992. In that sense, the reconnaissance was as much aimed at clarifying which 'project' was under study as to what its 'objectives' were²⁸.
- c. administrative procedures for the conduct of the project in terms of agency staff collaboration and resourcing

²⁷ Funding for this was provided by LWRRDC to the Program Manager in 1994 and the training provided under the auspices of the Communication Research Institute of Australia.

had not been adequately negotiated before project initiation. Agency managers, particularly from DPI, operating at the regional and project level, were not aware of any prior commitment or obligation to participate in CTC2 and had no sense of a requirement to subsequently do so. This arose for four major reasons. Firstly, support in principle for DPI commitment to CTC2 had been negotiated within the Director General's office rather than directly with the relevant regional and sectoral managers. Secondly, regional and sectoral management negotiation for joint CSIRO–DPI involvement in communication research had been conducted within the context of an earlier proposal (Section C.5) rather than specifically for CTC2. Thirdly, a major restructuring was proceeding within the DPI management structure that gave rise to a different set of managers holding key positions to those who had initially supported a joint communication initiative. Finally, the DPI was formally negotiating with MRC to implement a major 'in-house' technology transfer project centred on local consensus data (LCD) gathering exercises which was to involve a significant commitment of available R,D&E staff and resources. Several exercises were conducted in an attempt to obtain and shore-up support for CTC2 within the regional and sectoral management hierarchy of DPI, with limited success.

- d. a basic assumption had been made that the R&D staff attached to the case-study projects would basically share a 'common' view of the objectives of their projects and individually were aware of the potential contribution of their experiments and activities to meeting those objectives. That is, while a key premise of CTC2 was that effective communication within R,D&E projects teams was an important aspect of promoting successful technology transfer, an assumption was made that the individual viewpoints on performance and outcomes were at least internally consistent. This proved to be an excessively 'optimistic' position with respect to the case-study teams. The reconnaissance interventions identified substantially divergent viewpoints concerning the projected objectives and outcomes of the projects, key focus of individual experiments, roles and expectations of other team members, appropriate scales for data synthesis, responsibility for synthesising data, identity and real interest of stakeholders, structure and performance of local grazing systems, and activities of other R,D&E providers. Fundamental to this was a limited ability to clearly and consistently articulate the precise nature and performance of the project 'technology'. A significant effort was required, in conjunction with the

²⁸ Continuing confusion as to the project boundaries for case-study #2, combined with conflicting interests in technology transfer management with another project, was a contributing factor to the CTC2 team deciding to defer further action in northern Queensland and to maintain a general dialogue with the case-study #2 project managers.

R&D project managers, to address this issue which was further highlighted within the context of the focus group intervention (next sub-section).

The need to anticipate and manage for these developments was a key 'learning' of the intervention. In establishing both CTC2 and the underlying case-study projects, certain assumptions were made about the ability or willingness of people to perform particular tasks or accept certain responsibilities. Similarly, the resourcing task associated with different activities was underestimated.

B.5.2.2 Focus group intervention

The focus group meetings held for case-study #1 were the only part of CTC2's planned integrated suite that was actually completed, although these were held approximately six months after the proposed date. Nevertheless, much of the delay can be attributed to several of the factors noted within the preceding sub-section as having extended the scope and duration of the reconnaissance intervention.

The focus groups were initially intended to review, from the perspectives of a number of different stakeholder groups, relatively broad issues relating to sustainable land management practices and potential barriers to their adoption, attitudes towards sustainable land management and land degradation issues, relevance of the GLASS project, barriers to taking management actions consistent with the likely outputs of the project. Consistent with the AKIS approach being adopted, they were also intended to help identify sources of information flows and media preferences. In this sense they were probably not intended to be as tightly focused on a limited array of issues, or aspects of an issue, as the method is more conventionally applied in market research (eg. Stewart and Shamdasani 1990).

However, in actual application the reverse applied and, consistent with 'market research', the groups concentrated heavily on the GLASS project, its individual experiments and its potential relevance or otherwise to their particular situation. There were two main reasons for this. Firstly, the format for conducting a group session called for a single team member to present a condensed version of what the project was about and how it was seen to 'fit' within the context of the industry and other stakeholders. The need to prepare a condensed version of what the project encompassed was seen to present a good opportunity for the R&D managers to both highlight the apparent lack of common vision and synthesis of understanding within the group and to address it. A significant amount of time involving several workshops and group meetings was spent on this task. This was acknowledged by the GLASS team to have been both challenging and worth while both in terms of 'getting their story together' and in 'raising their commitment to identifying and valuing stakeholders perspectives' and 'seriously responding to the technology transfer challenge'.²⁹ The second reason for focusing on GLASS as it was instituted, as

opposed to broader issues, lay in its status as a major project that was already under way and for which a sizeable investment in skill, time and resources had already been committed and for which the design was reasonably inflexible.³⁰

There were eight focus group meetings held during February–March 1993. These comprised four meetings of beef producers and one meeting each of land resource management R&D professionals, regional and district extension officers, agribusiness representatives (seed and grain, livestock, meat processing and machinery sales), and financial agency representatives (trading banks, hire purchase, leasing and financial counsellors). The producer groups were drawn and grouped from what were regarded as distinct districts within the target region. The remaining groups were drawn from across the region and met as single groups.

Feedback from the meetings was varied but could be grouped within several common themes. For the producer group meetings, positive feedback tended to fall within very general acknowledgment categories, while negative feedback was typically related to fairly specific technical issues. For example, common compliments related to the opportunity to 'meet with R&D staff on reasonably equal terms and to have their point of view heard', 'appreciation that other producers had similar concerns and problems', 'appreciation of being told what is being done by way of R&D' etc. Adverse views included suggestions that 'it had taken a long time to get around to communicating with producers', 'GLASS would find little that was not known or could be profitably used', 'had the wrong cattle' (breed/type), 'had not found any really useful plants' (cheap/trouble-free/ highly productive), 'took insufficient account of the cost of different treatments', 'too focused on pastures and not enough attention to animal production issues', 'was not integrated within the whole property context', 'paid insufficient attention to specifying the impact on the dollar bottom-line', had 'little to say about timber regrowth' which was almost universally identified as 'the dominant land degradation issue' in the region, and 'did not apply to my property' because of the singular focus on 'black speargrass' (the species vs the region)³¹. Some participants expressed doubts as to 'whether their input would really lead to significant change in the R&D project'. On the basis of utterances, legume species were probably seen more by producers to represent a 'core technology' of GLASS as opposed to legume or pasture establishment 'methods'.

²⁹ These testimonials are based on *verbal*, taped recorded, and written feedback to the author at the time of the focus group planning meetings.

³⁰ To this extent the focus groups carried some of the role independently attributed to the *relevance audit workshop* intervention - that of confirming its ongoing relevance. The fact that it was held 'mid-life' also strengthens the comparison.

³¹ Generalised feedback taken from summaries of the tape-recordings of the meetings.

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The agribusiness group generally acknowledged the 'scientific merit of the R&D approach' and 'saw value in someone taking the issues on board'. However, two divergent themes also emerged. Firstly, while the GLASS team saw the 'system' as being 'complex' it was not placing its expected outcomes within the greater complexity of the 'whole business enterprise'. The 'dollar bottom line' was critical and this was influenced by many agencies and forces beyond those being addressed by the R&D. Recognition of the 'whole production and marketing chain' and its constituent players was important for sustainable systems and effective technology transfer. The second theme, however, was one of avoiding 'excessive complexity' and the need to simplify messages from the R&D into one or two marketable points. The sector's need was for simple technical answers to basic problems which could be readily pitched in terms of impact on bottom-line 'profitability'. Feedback from the financiers was generally similar with, perhaps, more emphasis placed on the value of the R&D as background information to assist them to make commercial judgments concerning credit applications for land development options.

The extension officer group raised a number of themes similar to those aired at the producer meetings. For example, there was a general agreement that a dialogue between R&D and extension staff was productive and the opportunity to learn more of what GLASS was about was valuable. However, many participants felt that the dialogue was overdue and some queried whether their views would/could really effect the future conduct of the project. Other themes included the 'excessive emphasis on pastures' as opposed to 'animal production and marketing', 'insufficient attempt to place the R&D and its initial problem setting' within a whole enterprise context, a questioning of whether the project would really find out 'anything that was not already relatively well-known', and the 'need to be able to communicate the results in terms of dollar value bottom line performance'. This group also placed some emphasis on perceived lack of operational performance and poor cost-effectiveness of the BandSeeder which was used to sow the legume component of the GLASS experiments. For some participants, BandSeeding was taken to be the 'core technology' under test.

The R&D professional group pursued several themes ranging from specific experimental procedures through to broad philosophies on the role of R&D in promoting social change essential for sustainable management of natural resources. More than the other groups, the R&D group focused on the sub-experiments and the applicability of methods and/or preliminary findings to the problem setting and other geo-climatic regions.³² The validity of taking a multi-disciplinary approach to addressing sustainable land use issues was endorsed, although some disagreement was evident over the adequacy of the disciplines represented within the GLASS team as it was then constituted. A lack of input from system modellers was seen to be a serious deficiency, for example in applying project-sourced

knowledge to other regions. Also, some participants were concerned that GLASS neglected market and human systems, and was too focused on physical systems to have a significant policy impact. However, other participants felt that attempting to venture beyond the physical domain into broader social systems, such as including economics, which GLASS had done (MacLeod and Van Beek 1993), would necessarily overextend the team and jeopardise its ability to come up with anything 'scientifically useful'. All of the participants 'enjoyed' the opportunity to discuss both the project and general issues.

All of the groups generally and enthusiastically endorsed the value of participating in the focus group meetings and encouraged R&D teams to consider their adoption in future projects. Some minor adjustments to the approach used were suggested, but there was little substantive criticism of the focus group approach per se.³³

The GLASS team response to the focus group intervention was also fairly positive, though they did find it relatively time consuming. The effort required to produce the 'GLASS story' was recognised as being worth while and the process was seen as having been useful in terms of highlighting the need to synthesise the individual experimental outputs and for clarifying the role of the different team members in this process. It was also seen to increase the level of 'ownership' or 'commitment' of individual team members to the projected 'outcome' of the project. Two separate influences may have underlain this trend.

Firstly, before this task, responsibility for championing the project and communicating its objectives and potential outcomes to stakeholders (notably funding bodies) had largely been seen to lie with the project leaders. Apart from the project leaders, few of the team members had a concrete view on who would actually initiate data synthesis and be responsible for its completion. Project milestone reports to that time had concentrated on the results of the individual experiments, with no evidence of integration. Material that transcended several disciplinary areas was almost exclusively confined to climatic data. Secondly, almost immediately before the start of CTC2, the GLASS project contract had been renegotiated with the MRC with a revised set of objectives (Section B.3.3.1). These new objectives more heavily focused the projected 'outcomes' on the development of a 'state and transition' model (Westoby *et al.* 1989) which was then proving attractive to the funding agency. A number of the team members, when encouraged to tie the GLASS story around the revised objectives and more specifically the state and transition model, resisted on the basis that they believed that these were only used by the leaders to win the contract extension while the original objectives still applied to their individual experiments. The

³² An obvious parallel with the projected role of the *technical reference group* should be noted.

³³ This general affirmation of the value of the *focus group* intervention was still evident in interviews with a sub-set of participants conducted in 1995 (Section C.4).

process of negotiating the content of the unified focus group presentation and the allocation of responsibility for its delivery to different meetings appeared to break down this resistance and led to a greater interest in both the revised objectives and the state and transition approach.

The team response to the eight focus group meetings was also generally positive, with universal acknowledgment of the value of experiencing a first-hand exchange of general project information, including its rationale, with different stakeholders. Before the meetings most exchanges with beef producers and some of the other stakeholder groups generally involved either presenting selected experimental results to groups at field days or, to a lesser extent, addressing specific technical questions on a 1:1 basis, often by telephone. Individual team members rarely found themselves in a position of having to explain or justify first-hand the broad logic of their work and, in particular, how it might provide benefits to 'stakeholders'. This was either not previously considered or was assumed to be the responsibility of others, usually the project leaders or Program Managers. In several instances, team members thought that the CTC2 team would, more or less, take on this role (Section C.4). The need for the team to prepare the GLASS story rather than the CTC2 team partly clarified the respective responsibilities.

A consistent criticism from most of the GLASS team was the project officer's ban on the team raising new information or responding with further information other than that relating to questions of clarification from participants. Coupled with the time limit of 20 minutes placed on the presentation covering a complex set of related experiments, this led to concern that misconceptions arose that should have been addressed. That is, there was a genuine belief that some of the negative feedback, particularly from the beef producer groups, concerning the scope of the project and relevance to other regions would have been overcome with some simple responses and/or more time in the initial presentation. Moreover, some team members felt that an additional extension effort would now be necessary to redress these problems. However, the 'no right of reply' rule was actually rated as one of the most positive features of the process by the majority of producer participants who expressed an aversion to 'being talked down to by scientists'. That is, they believed that the process encouraged questioning and shifted the power relationships in the producer:researcher and researcher:extension officer dialogue to a more democratic balance. This view was also supported by a significant number of participants of the other stakeholder focus groups, particularly the extension officers and agribusiness groups.

The GLASS team held a two-day debriefing meeting at CSIRO Narayen Research Station in May 1993. A number of issues that were raised, particularly by the producer groups, were acknowledged as requiring serious attention by the team. These included such things as the dominating concern about timber control as a key management problem, as

opposed to pasture and soil decline; the view that the adaptability and value of the legumes under test were not being seen within an appropriate geo-climatic context; excessive emphasis on legumes and BandSeeding in many stakeholders' perceptions on the scope of GLASS; poor placement of experimental results within whole enterprise or dollar bottom-line terms; and perceived irrelevance of GLASS to producers who did not have black speargrass pastures. Also, there was a universal acceptance that increased dialogue with stakeholders, particularly producers, was worth while, although the apparent time needed to do so was of concern to most of the team. To this end, an invitation was made to the producer participants to engage in future joint dialogue with the GLASS team, either through organised visits to the 'Glenwood' field site or site inspections in the local districts. A two-day field exercise was subsequently organised in the South Burnett region which involved the GLASS team travelling with producer participants of one of the focus group meetings (Kingaroy) to a number of heterogeneous sites and inspecting phenomena of management concern that were raised during the focus group meeting (eg. timber regrowth, hard-setting soils, tree decline, legume establishment failure, etc). Again, the GLASS team responded positively to this exercise and placed considerable value on the exchange, although it was evident at various times during the exercise that the individual team members were still focusing heavily on specialist disciplinary insights with lesser emphasis on a systemic approach to problem resolution. It was also apparent from the dialogue between individual team members and producers that the team still did not share a 'unified' vision of the project objectives. The practical response to both the focus group feedback and the field meeting, however, was more to modify the messages coming from GLASS (ie. qualify their scope) than to modify the R&D approach, with the exception that a series of exclosures was introduced to mimic the impact of different spelling strategies following the breaking of the drought.

One projected outcome of the GLASS project, identified in the focus group presentations, was to provide input to the Property Management Planning (PMP) workshops being run by the DPI³⁴. This was endorsed as a possibility by several of the focus group meetings including the extension officer focus group, many of the participants of which are active in PMP exercises. To extend this outcome, the GLASS team was involved in further meetings with the regional PMP managers and module designers and in a two-day workshop with PMP staff and local producers to obtain a better understanding of PMP and to identify what contribution could be made to future activities. The reaction to this participation was again one of general endorsement for contributing to PMP and confirmation of the value of direct interaction with stakeholders, but the number of meetings planned and the amount of time involved became contentious. As it turned

³⁴ PMP is a national initiative sponsored by the National Landcare Program and co-ordinated in Queensland by DPI.

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out, because of the worsening drought in 1993, the meetings did not eventuate.

From the perspectives of the GLASS project leaders and Program Manager, the process of developing the GLASS presentation, the focus group feedback, and interactions between team members and producers during the field meeting, highlighted how little progress had been made towards instilling a common project viewpoint. It also created a sense of urgency to synthesise the experimental findings. Further steps were taken to address this issue, including pressure on team members to integrate their individual experimental findings within the 1992–93 milestone report to MRC, explaining their implications for improved property management. Several team members participated in a two-day workshop on state and transition modelling in September 1993 which developed a draft model for GLASS. The model was further refined during the project's AGM in March 1994, which coincided with a two-day 'knowledge integration' workshop co-ordinated by an international consultant.³⁵ Increased emphasis was placed on integrating the experimental data in the 1993–94 milestone report to MRC. Despite some progress, both the GLASS project leaders and CSIRO senior management were not convinced that the process was cost-effective and were increasingly committed to scaling down the commitment of resources to future activities flowing from the original focus group intervention.

The following, in summary, are some key findings from the focus group intervention:

- a. many R&D professionals have limited direct contact with the stakeholders to their work. A good deal of the negotiation of R&D objectives and resourcing of projects with stakeholders takes place at a higher level than their immediate domain of influence. That is, both in the level of management at which negotiation occurs and the level of abstraction of the terms in which project 'outputs' are projected to provide 'outcomes' to stakeholders. For example, project leaders and Program Managers usually negotiate with representatives of stakeholders (eg. R&D funding agencies) on behalf of R&D teams. Individual scientists and technicians rarely, if ever, negotiate directly with individual 'end-users'. Moreover, individual R&D team members usually negotiate with their managers, and their performance is assessed, in terms of narrow experimental objectives rather than broader project or industry objectives.

The focus groups gave the individual R&D team members an opportunity to meet directly with individual stakeholders and to negotiate their work at a more integrative level. In this sense, they were attempting to

negotiate on the basis of real outcomes. The GLASS team and the stakeholders represented in the focus groups clearly valued the new opportunity provided by the intervention and its associated follow-on activities, although the time it took was of concern.

- b. the focus group intervention for GLASS helped to identify and highlight that there was limited foresight and commitment to integrating the disciplinary knowledge captured within the individual experiments. Another problem highlighted was the potential mismatch between the projected project 'outputs' and industry circumstances. The intervention provided an opportunity for the R&D team to accept 'ownership' of these problems. It also provided a vehicle through which the managers could consciously seek to redress the problems.
- c. the cost-effectiveness of the intervention, particularly in terms of the time it took, was of concern, both to the R&D team members and the R&D managers. In part, this was caused by a conflict between time allocated to experimental work and writing up results, and a commitment to better targeting R&D and extending R&D results. The strategic plans of the R&D agencies are increasingly calling for the latter, while the institutional reward systems are heavily biased towards the former.
- d. while the intervention was popular and had an impact on the direction of the GLASS data synthesis and communication strategies, it had no real impact on the design and structure of the project. Apart from a small experiment on post-drought spelling, the individual experiments remained essentially unchanged after the focus groups. Later changes arose purely from seasonal developments and matters of resource availability. To be effective, the intervention would probably need to be conducted at the pre-design stage, as was originally intended for the CTC2 framework and the proposed application to case-study #2.
- e. while some of the post-focus group activities were seen as useful, concerns were held by some CTC2 team members and the R&D project leaders that they were potentially leading to an unwarranted 'escalation of commitment' to non-core interventions (Section C.4). Given the delays being experienced in sticking to the original intervention schedule, there was concern that the non-core activities would further exacerbate these problems.

Therefore, while the focus group intervention was seen to provide value by promoting the original aims of an R&D project, it did not necessarily lead to significant change in those aims or the subsequent conduct of the project. Moreover, a significant part of the beneficial effect (ie. team building and data synthesis) was not linked to the original aims for the intervention. Perhaps the same beneficial effect

³⁵ Janice Jiggins (Agricultural University, Wageningen) was retained by CSIRO for 3 months to work with the CTC2 and GLASS project teams, as well as other DTCP projects including CTC1 and CTC3.

could have been obtained through more direct management measures, such as team building or role negotiation sessions, though a number of conventional team-building exercises that had been conducted before the start of CTC2 had limited lasting impact. This partly explained the intent of the CSIRO managers in extending the CTC2 model to the second case-study project. Nevertheless, each of the subset of individuals interviewed after the termination of CTC2 (Section C.4) said they saw value in the intervention and were generally willing to become involved in similar activities in the future.

B.5.2.3. Technical reference group intervention

The technical reference group was to have played a particularly important role within the CTC2 model, providing both a stimulus and check to the technical interpretation of the experimental findings and their generalisation to other locations. A panel of individuals with recognised high-level scientific and technical skills would meet from time to time with the R&D team over the life of the case-study project to discuss progress with the experiments and challenge or support the interpretation of the findings as they evolved. Depending on the disciplinary skill base of the group, it might also provide access to skills that were not represented in the R&D team or could not be justified on a full time basis. In the immediate context of GLASS, and the difficulties then being experienced in synthesising the experimental data, the project leaders also saw considerable potential in the technical reference group acting as a catalyst for greater efforts in this area.

For various reasons, the technical reference group, though supported by the GLASS team, was never able to meet during the life of the project.

B.6 Major ‘learnings’ from Phase I of CTC2

Most R&D must, by definition, deal with the unexpected. Although aspects of the project did not proceed smoothly, there were many valuable insights from CTC2. For convenience, these might be categorised as being positive or negative, though this distinction might belie the positive learning associated with both types of findings. Indeed, the idea that real value can be accorded to insights from less successful outcomes is promoted as a fundamental learning from the experiences of CTC2. These insights are presented in summary form here, and in more detail elsewhere in the report.

(1) Beef producers positively value ‘negative’ information

The traditional focus of both R&D reporting and extension has been the communication of ‘positive’ information. That is, results from experiments that are seen to have ‘worked’

in the sense of being statistically significant. The prevailing culture of R,D&E is not one that supports the reporting of equivocal results or of failures to achieve a desired result, nor does it generally reward such outcomes. However, beef producers and other stakeholders claim to find value in both types of findings (Section B.5.2.2). They place definite value on knowing what did not work and, perhaps more important, the reasons for the ‘failure’. Negative or disappointing outcomes are a hazard of their ‘real’ world and decision domains, and to know that something which they might be considering implementing does not work (or has a wider outcome distribution than foreseen) can be important to their activities. Therefore, full or open disclosure can provide potentially useful information to support their risk management strategies and/or modify their operating approaches. It would seem desirable that future communication or technology transfer initiatives be geared to providing both types of message, though for this to occur will require substantial shifts in the institutional and cultural arrangements normally associated with R,D&E conduct and management.

(2) R,D&E managers may also value ‘negative’ information

The previous finding may also apply to the management of R,D&E projects and programs. In fact, there is a growing body of anecdotal and empirical evidence that organisational performance can be improved substantially by placing positive weight on experiencing and interrogating sub-optimal performance. This evidence, related to the concept of ‘small loss learning’ and ‘intelligent failure’ is reviewed in later sections of the report (Section C.3). However, during interviews of several R,D&E managers as part of the project review (Section C.4), and in canvassing the ‘intelligent failure’ concept with our peers, it was evident that there was real support for such an approach. Exposure to the CTC2 experience has led to substantive changes in the way that future R,D&E projects are being planned and executed within CSIRO at least.

(3) External stakeholder involvement can improve R,D&E performance

An overriding aim of CTC2 was to promote better R,D&E practice through ‘meaningful’ communication between R,D&E personnel and external stakeholders. Purposive communication interventions which more clearly revealed the needs of stakeholders and the potential place of R&D outputs within their management and decision-making contexts were seen to positively promote this ideal. CTC2 has confirmed that external stakeholder involvement can lead to R,D&E that is better focused on the needs of primary stakeholders. In the context of one of the underlying case study R&D projects (GLASS), CTC2 did provide strong and clear insights to the relevant project and Program Managers on various aspects of the R&D design that were or were not

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valuable to a range of stakeholders and why. In a particularly strong sense this interaction also gave a clear message to consider 'ceasing doing certain things that the project teams were currently doing or were proposing to do'.

- (4) *Open communication with stakeholders can increase their appreciation of the risks and uncertainties associated with science*

Associated with learning (1), but perhaps more broadly applicable, is the reality that, in the conduct of science and R&D, there are many uncertainties and risks associated with outcomes. Science is not about providing certainty or secure outcomes. However, there seems to be a widespread impression within the community that such certainty is both desirable, and possible to achieve. While much extension and science communication focuses on positive results, the reality remains that R&D more often than not is confronted with confirmation of null hypotheses or previously unforeseen outcomes. When stakeholders were exposed (eg. through focus groups and site meetings) to both the positive and downside aspects of the case study R&D experiments and the uncertainty associated with interpretation of the results and what was done in deriving them they also obtained a better appreciation of 'science' and what it can realistically be expected to deliver.

- (5) *We were able to more clearly identify and conceptualise barriers to R,D&E in a different and more integrative way*

Technology transfer failure is frequently summed up in terms of the existence of so-called 'barriers to adoption'. At the most simplistic level, such failure is a communication problem through which otherwise worthwhile R&D outputs have not been placed in sufficiently clear and attractive terms for would be end-users to take advantage of them. That is, there is a blockage (barrier) in the assumed conduit between the R&D endeavour and the stakeholders. This is often blamed

on faulty extension and identified as an 'extension failure' and the perceived solution is more and/or better extension. Another view, however, might focus on a serious non-alignment of R&D and stakeholder contexts, lending more weight to the notion of 'R&D failure', though faulty extension may also still apply. However, the appropriate avenue for addressing this problem will depend on the actual source of the non-alignment. For example, limited capacity of farmers to afford a new technology due to a market downturn would be seen more as a 'credit' problem than a 'research' problem. On the other hand, R&D which is targeting an irrelevant issue would be better redirected to something that was relevant to stakeholders. CTC2 sought to identify and address both types of problem. However, while both 'R&D' and 'extension' problems were identified as potential impediments to ultimate adoption performance, the structure of these problems was revealed to be more pervasive and complex than assumed before the start of the project.

- (6) *Evaluation methods have to be appropriate to the intended aims of the project. When these aims are consistent with an emerging focus of 'outcome-orientation,' the evaluation criteria more traditionally applied to 'output' performance are no longer appropriate.*

Unless R,D&E projects commence with clearly stated evaluation criteria that are 'outcome-orientated' it will be difficult to do good communication research. This is particularly important for the episodic nature of R,D&E with the need and opportunity for making observations on system and project performance over periods of time. *Output*-orientated evaluation tends to treat technology transfer and R&D success more as a 'one-off' event. An *outcome*-orientation promotes a more pro-active process of engagement with stakeholders than is usually applied to an *output*-orientation which tends to be characterised as passive information collecting and evaluation.

Section C

Review phase (Phase 2)

This section reports on a critical review of the project design, management and performance, and other activities undertaken after August 1994 when the operational phase was terminated.

C.1 Rationale for a review of CTC2

C.1.1 Informal review activities

By about the first third of the projected life of CTC2 (12–14 months) it was evident to the principal investigators and the Program Manager that the project was not performing to expectation and that it was, without significant remedial intervention, at risk of failing. Beyond the immediate issues associated with the management and operational performance of CTC2 there were parallel concerns raised over the design, direction and performance of the case-study #1 project (GLASS) and serious questions raised as to how effective a communication project could ultimately be with this particular case-study. At the same time, further progress with the second case-study was doubtful without access to a much larger set of resources and increased management and workload for both the CTC2 team and the R&D stakeholders.

As the project moved into the middle period of its life these performance and structural problems became even more evident, and the need to address them as significant research learnings were more acute. That is, it was quite clear to the project managers that beyond the conduct of CTC2 there were major problems with both case-studies that were likely to impact on the eventual technology transfer or outcome performance of those projects.

Around this time consideration was given to these issues in more structured terms, drawing on expertise and the literature on organisational management, project management and risk-related decision theory. This led to a second thrust of activities which centred on identifying and addressing project design and performance weaknesses with an aim to getting better R,D&E (MacLeod and Shulman 1993). This approach is central to the notion of 'intelligent' failure through which positive learning is achieved from interrogating both successful and unsuccessful experimental outcomes. Elements of the various models considered useful to this process are detailed in Section C.3.

C.1.2 Formal review activities

In the concluding section of Milestone Report No. 2, it was acknowledged that the project, despite some successes (including those detailed in Section B.5.1) towards meeting the milestones re-negotiated in February 1994, was still being dogged by a number of unresolved problems. These related to personnel, resource commitment and scheduling problems. The last issue was further exacerbated by the formal decision taken by CSIRO senior management in July 1994 to halve the number of staff committed to the GLASS project by late 1994 and to terminate the project in 1996, rather than seeking to extend the contract with MRC for a further four years. With no active involvement projected for case-study #2 in 1994–95, the changed status of case-study #1 made continued commitment to the CTC2 model an unworkable proposition. It was suggested that it would be appropriate at that time to take stock of the project, its performance and prospects and consider the feasibility of whether to further modify it or to terminate it.

The CSIRO position as advised to the Resource Management Committee was that it remained committed to the original objectives of CTC2—defining, and delivering from, effective technology transfer models. To this end it was prepared to continue to support technology transfer R&D. However, on the basis of what it had learnt from the CTC2 project and its underlying theoretical model, it was not convinced that it necessarily represented the approach that would be pursued with future R&D projects.³⁶

CSIRO also recommended that the continued operation of CTC2 be restricted to analysing the data that had been collected, to the extent that this was feasible given a proposed withdrawal of DPI staff on 30 June 1994. CSIRO also proposed that the remaining principal investigator and Program Manager conduct an assessment of the weaknesses and strengths of the CTC2 model and/or alternative models that might offer scope for more cost-effective solutions to technology transfer problems. A formal report, including a proposal for future review and research initiatives, was to be completed by 31 October 1994. This recommendation was accepted by the Resource Management Committee and a review of the history of CTC2 accompanied by a proposal for more intensively reviewing the project was completed and submitted in early November 1994.

The remainder of this section relates to the review. Initial emphasis is given to potential models or frameworks that were considered appropriate to considering project performance, identifying problem areas and potential avenues for improvement, and optimising the value of potential learning for R&D managers from the CTC2 experience. Other

³⁶ CSIRO also took the view that, despite the IWRRDC-supported commitment of additional resources for training of project staff, significant progress in data coding and analysis for the interventions that had been completed to June 1994 was unlikely.

material is also presented that was derived during the review, including that from interviews with some participants in the CTC2 interventions (Section C.4).

C.2 Evaluation

A prototype three-dimensional framework for evaluation of the design and operational performance of both CTC2 and the case-study projects has been developed by the principal investigator with assistance from the Program Manager. This framework is being refined and a suggestion for extending this work is carried in the conclusions to this report. Case evidence has also been collected at first-hand from the experiences of the CTC2 managers and the case-study R&D teams. This case material has also been supported by data collected through a series of semi-structured interviews with a sub-set of stakeholders who had either been exposed to the CTC2 model or had some role in the process leading up to its initiation in 1992 (Section C.4).

The semi-structured interviews, which sought information of a more fundamental nature concerning the performance of CTC2, represented a different process of engaging with stakeholders to that envisaged at the time the project was designed and initiated. It also widened the scope of the stakeholders with whom a technology transfer project might traditionally have been expected to engage. The process centred on two separate themes, the first of which was more consistent with the original project objectives.

The first theme was that of further identifying or understanding 'barriers to achieving outcomes', although this now was more focused on R&D design and management than on technology transfer processes alone. Information was sought from stakeholders on possible ways to overcome barriers to effectively addressing issues and delivering outcomes. However, a major barrier appeared to be various complex linkages of project elements (referred to as DEPOSE elements in Section C.3) and problems with inter-agency collaborative alliances (MacLeod and Shulman 1994; MacLeod *et al.* 1995) and so a second theme directly sought to address these linkages and alliance issues.

The second theme particularly considered the issue of managing R,D&E projects when performance has been sub-optimal, and also recognised the reality that teams would want to engage with the same sets of stakeholders in the future. This approach sought to manage the communication of project 'failure' with different stakeholders in a manner consistent with an ideal of learning equally from what does not work. We emphasise that the concept of 'intelligent' failure is almost alien to the traditional R&D culture and so a further process of evaluation has been proposed (Section E.) to capture the success or otherwise of the approach. This involves, as a study separate from CTC2, a series of workshops with R&D managers and other stakeholders at which the evaluation framework is presented along with learnings from

CTC2 and the case-study R&D projects. During the workshop series participants will be encouraged to seek ways to overcome problems identified for the case projects (CTC2 and the two case-studies) and to apply the model and learnings to other R&D projects.

C.3 Theoretical basis for reviewing project performance

In conducting both the project performance and management review, a number of useful insights were obtained from the organisational management and engineering literature. The following sub-sections canvass some models and theories that provide valuable elements for constructing a framework with which to assess the performance of a project and to identify weak areas for possible redress.

C.3.1 System complexity and 'normal failure'

Both the summary of the evolution of CTC2 (Section B.3.3) and the review of the operational performance of CTC2 (Section B.5.1) identify a number of actions or developments that were seen to contribute to, or compound, the poor overall performance of the project. Some significant problems and developments that arose within the two associated case-study R&D projects have also been identified and presented in a later section (Section C.5). These were noted as learnings in Section B.6 of this report. An important point to be made is that these were intricately interwoven with some important developments internal to the design, management and execution of CTC2. In fact, it may be recognised that both the case-study projects and CTC2 are both 'complex' projects and, by nature of the design and proposed intervention processes, 'tightly coupled'.

The notion of technological complexity and systems coupling leading to unpredictable, but logically anticipated, system performance problems has been raised by Perrow (1982, 1984) in the context of high risk technologies (eg. nuclear power generation, computer facilitated airport control). The concept of coupling specifically relates to connections between and within various system elements which Perrow has designated as the DEPOSE elements. These include design (D), equipment (E), procedures (P), operators (O), supplies and materials (S), and the environment (E), as depicted in Figure 2. System performance problems are not necessarily the result of sub-optimal performance in any of the individual elements, and commonly occur through problems involving combinations (coupling) of the elements. Moreover, while the root performance problems attributed to an individual element may be relatively minor, the combined or coupled effect can be relatively serious. Perrow (1982) suggested that poorly identified element linkages are a common source of unforeseen failure

in many operating systems, including those specifically designed to warn of, or prevent, system failures. In this sense, such 'failures' were described as 'normal accidents' because they are unconsciously built into system designs. Their occurrence, while potentially disastrous, should not be viewed as 'abnormal'. Uncertainty relating to system performance is compounded when the complexity of a given system masks the nature and extent of element coupling, particularly when the systems are dynamic and the extent of coupling is progressive or intermittent.

The DEPOSE elements and the dual concepts of 'simple' versus 'complex' system designs and 'loose' versus 'tight' element coupling are logical components for a framework for reviewing the design and performance of CTC2. Within the experience of CTC2, with the possible exception of E (equipment) and S (supplies and materials),³⁷ it is easy to identify a number of examples of performance problems associated with the various elements and their linkages within CTC2 and the two case-study R&D projects. However, while the Perrow model is useful for learning from examples of complex system failures, and such learning can be useful for enhancing diagnostic skills in assessing project design, it remains essentially incomplete for laying down prescriptions for better design and management systems in the future; that is, the prescriptions are more implicit than explicit. Nevertheless, while the Perrow model has been formally detailed within the context of relatively bounded systems that are under 'control' of a relatively few stakeholders (eg. a defined air space, a single manufacturing process, a given R&D project), it has provided considerable insight for CTC2 for which the two case-study R&D projects were less bounded and had many potential stakeholders.

C.3.2 Project stage or life-cycle

The literature on project management in agro-environmental R&D and technology transfer is surprisingly thin. However, a consistent theme of project execution centres on various stages of a project or a typical project life-cycle. Project planning and execution are usually assumed to follow a number of well-understood sequential steps whose ordering is relatively fixed. Such a sequence is depicted in Figure 3 which includes: conceptualisation, planning, initiation, execution and control, termination, and (possibly) review. Rational project management procedures and negotiated milestones, as depicted in GANTT chart task lines, are usually based on a view of the world similar to this. Therefore, the stages in a project's life cycle are another dimension that may usefully be applied to a framework for reviewing the performance of a project. The operational performance of CTC2 in terms of contracted milestones was reviewed in this sense in Section B.5.1.

³⁷ Inadequate resources (funding) was raised as a 'supplies and materials' issue at various times within the life of the project as a barrier to progress with some of the interventions, especially for case-study #2.

However, using a linear staged-execution model for assessing project performance has severe limitations. Much observed project management practice may be better described by decision-making and management processes that are non-sequential and iterative. For example, the 'garbage can' model of organisational decision-making (Martin 1982), while focusing on the interaction of the DEPOSE elements within the context of project life stages, assumes that R&D management can take many forms. For example, the model process elements—theoretical problems, research participants, methods selection, and R&D outcomes—may be linked together in loose or tight association depending on time and context. The entry point to the R&D process need not be confined to the problem identification stage but could occur at any of the stages. There are many possible pathways, including departure from the sequence and no return to the initial theoretical schedule (which did occur for CTC2 when certain interventions were scrapped), or the content of the solution may be partially 'known' before the R&D starts. This, in turn, influences the approach taken and resources committed.³⁸ An important consideration raised by the 'garbage can' model approach is the recognition of the 'pull' of existing R&D infrastructure on future R&D planning and initiation. In this important sense it is naive to assume that many R&D initiatives genuinely commence with a 'clean slate' or open mind on the appropriate researchable problem and approach (Section D.3.4). While the 'garbage can' model does not really describe a desirable process for the conduct of R&D, it may provide more accurate insight into what actually happens than models based on assumptions of rationality in R,D&E conduct. Therefore, it may be a useful descriptive model for explaining some of the process underlying the linkages that lead to potential system failures (Sections C.3.1, D.3.4).

C.3.3 Escalation of commitment

Some of the more spectacular examples of system or project failures (eg. Hubble space telescope, Sydney Opera House, F111 fighter-bomber) show a history of expanded commitment of resources and effort in the face of emerging performance difficulties. While there is a very limited formal literature on this phenomenon within an organisational or project management context, the available models are potentially more prescriptive than the models described in the preceding subsections. For example, the 'escalation of commitment' model of Ross and Staw (1993) can be used to place the system element linkages of the Perrow (Section C.3.1) and Martin (Section C.3.2) models within the context of previous decisions and events (both internal and external to a project) to explain how an organisation or project management team can become locked into a 'failing' system or project, well beyond the time

³⁸ The rewritten objectives of February 1994 partly 'reflect' the activity had occurred to that point as much as the activity actually reflecting the objectives

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and extent to which it would have been rational to pull out or follow a different course of action. The model attributes potential escalation of commitment to the interplay of five sets of forces over time, including:

- a. project determinants—objective aspects such as remedial costs, perceived economic pay-off, salvage values of equipment, causes of setbacks etc.
- b. psychological determinants—reinforcement traps such as ditching previously ‘rewarded’ activities, personal motivations such as ambition, fear of failure, biases in interpreting information etc.
- c. social determinants—interpersonal processes such as fear of offending others, seeking to justify losing projects to potentially hostile audiences (managers, R&D fund providers), cultural norms favouring strong stable leadership etc.
- d. organisational determinants—including issues such as the degree of political support for a project, reward structure, level of economic and technical ‘side-bets’ incurred by the organisation with respect to the project (eg. seconding staff, specialised training, equipment purchases), or extent to which other projects are seen to rely on it (coupling).

Figure 2. DEPOSE elements. Source: Perrow (1984)

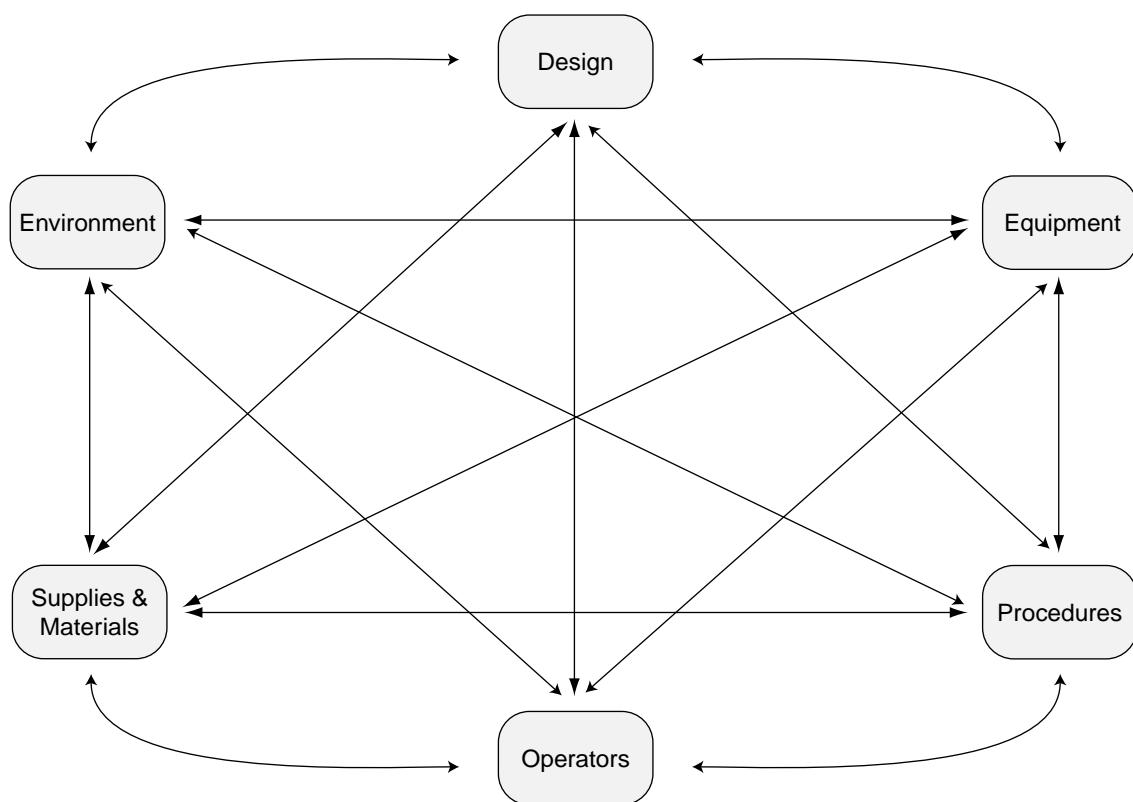
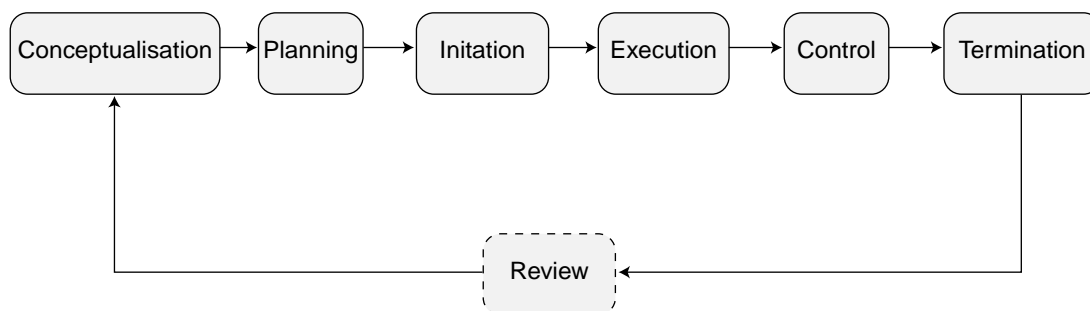


Figure 3. Stages of project execution



- e. context—the overall environment within which the activity is taking place. For example, political forces and developments occurring elsewhere (eg. actions of potential competitors etc.).

The model also suggests a temporal ordering of these influences in many escalation scenarios. For example, project variables may be most important at the early stages of an escalation episode, psychological and social variables may dominate in the middle stages, and both organisational and project considerations may become most influential at the late or ending stage.

This five-force framework provides a third potential dimension for categorising developments and factors underlying performance and management problems within R,D&E projects. It also points to the desirability of taking a multi-level approach to resolving problems of escalating commitment if and when they are identified. For example, providing additional time, resources, or the opportunity to rework a project's design and procedures may be insufficient, if problems occurring at the other levels (eg. psychological, cultural, organisational) have not been addressed. The escalation of commitment model also highlights the importance of understanding the organisational context within which a problem or system failure has occurred.

Not all escalations of commitment need be sub-optimal and circumstances can arise when escalation of commitment or delayed action is warranted. For example, the concept of 'retained options' (Bowman and Hurry 1993) recognises the positive economic and managerial value of deferring decisions and maintaining open options. That is, a deferred decision may be quite rational, particularly in uncertain (complex) decision situations where the option may increase in value as additional information becomes available. Therefore, while deferring action may be consistent with escalating commitment in some situations, so too might be the taking of precipitate action which locks project managers into particular courses from which escape is difficult or expensive. To the extent that deferred decisions on major aspects of project management, including design specification and field scheduling, might reduce the incidence of tight element and process coupling it may also reduce the scope for premature system failure. The appropriate timing and triggers for decision deferment need to be better understood within a R&D project management context (Section E.2).

C.3.4 Intelligent failure

'Controlled chaos' (Quinn 1985) and 'small loss' learning theory (Sitkin 1992) are central to the concept of 'intelligent' failure.

The 'controlled chaos' approach to learning advocates managed risk taking and entrepreneurship to mimic some of the serendipity underlying many significant breakthroughs in industrial innovation and research. It is argued, for example, that the rigidity of many management systems

constrains the creativity and chance element of innovation and, therefore, the potential outcomes of R&D. Thus, formal planning and control mechanisms (eg. TQM, GANTT, SMART milestones etc) that may seem to be useful for reducing certain project management risks, may equally increase the risk of stifling environmental factors that promote innovation. However, consistent with the escalation of commitment model, while it is acknowledged to be important for R&D teams to be allowed to keep some options open, it is also important to know when to shut down unpromising projects and to support others (Section E.2).

'Small loss' learning involves consciously incorporating the scope for 'intelligent' failure within organisational structures (including reward systems). The underlying theory, confirmed in part by the beef producer focus group participants (Section B.6), is that learning through failed experimentation is as powerful as that from successful experimentation. In fact, if complacency from repeated exposure to successful outcomes is considered it may be more powerful. Therefore, apparently rational decision procedures which focus on maximising successful outcomes may actually promote risk-averse strategies that provide short-term stability and gains at the expense of greater gain over the longer-term. That is, R&D organisations are more likely to generate a larger output of worthwhile innovations through risk-seeking exploratory strategies that are relatively unconstrained by a fear of failure. Moreover, small loss learning is argued to promote more rapid learning if mistakes are not repeated and the underlying reasons for failed outcomes are clearly analysed, understood and disseminated (Sections E.2, E.3).

C.3.5 'Double-loop' learning

The concept of 'double-loop' or 'strategic organisational learning' has been developed by Argyris (1977, 1994) to explain the inability of many organisations to autonomously uncover errors or inefficiencies in their structures and procedures, and to face up to unpleasant truths. This argued inability to self-critically review performance severely restricts the potential of affected organisations to genuinely learn from shortcomings in system and project performance (Section E.2). As such, the theory makes a logical contribution to the concept of 'intelligent' failure. However, the process underlying the 'double-loop' learning model is substantially different to the 'controlled chaos' and 'small-loss' learning models.

The central argument of the model is that much of the performance learning within organisations is 'single-loop', and may identify and, possibly, correct some (short-term) problems. Single-loop learning is directed to addressing the question of how best to achieve a particular objective. However, this process is rarely accompanied by a serious evaluation of the underlying and more fundamental (long-term) structural or process-related causes. That is, a more complete diagnosis would proceed around a higher-order loop and address some fundamentally tougher questions;

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such as should the present goal(s) have been pursued by the organisation in the first place, and other questions embedded in organisational culture and the behaviour of responsible individuals within that culture.³⁹ One significant reason for the reluctance of managers to engage in the second loop of 'double-loop' learning is that this type of open strategic inquiry is both potentially embarrassing and threatening. Moreover, Argyris (1977) argues that there are strong psychological, social, cultural and organisational forces in place within organisations and the general community which act to prevent such inquiry. These forces appear to be similar to those underlying the escalation of commitment model of Ross and Staw (Section C.3.3).

Argyris (1994) has identified a paradox for project and organisational managers who may seek to implement rational efforts to understand and overcome the types of problems that are seen to require a shift to a 'double-loop' learning process. These practices are argued to actually inhibit the learning and communication required to effect the transition because they are either centred in 'single-loop' processes (eg. TQM, best practice) or disempower the personnel that are meant to be empowered by the practices (eg. management by 'walking around', 'hands-on' management). A fundamental requirement for 'double-loop' learning is, it is argued, a complete paradigm shift in which staff take an active role not only in describing the faults of others or the system, but also in drawing out the truth of their own behaviour, motivation and role in system performance shortcomings (Section E.2).

A major barrier to the transition to 'double-loop' learning, noted by Argyris (1994), is not so much that individuals are unwilling to honestly be critical of others and to critically self-appraise if asked, but rather they are rarely invited to do so. The review process for CTC2 (Section C.4) was one step in the suggested paradigm shift for CSIRO and the individuals whose views were canvassed on the project were both willing and forthright in expressing their opinions. Moreover, they welcomed the opportunity to do so and endorsed a suggestion that such reviews be incorporated within 'normal' project management procedures (Section E.2).

C.3.6 Networks and stakeholder alliances

There has been a growing emphasis within R,D&E design, conduct and management on the role of networking, including both multi-agency or multi-disciplinary networks, and the wider engagement of stakeholder groups within formal project management structures (eg. Stuth et al. 1991; Jiggins 1993). A central assumption behind this trend is that such networking is beneficial to project or system performance (Section D.3). However, MacLeod and Shulman (1994) and MacLeod et al. (1995) have queried the universal

truth of this assumption and argue that identification of the forms and organisational structures for which networking is genuinely value adding is a proposition requiring serious research. Two separate and distinct concepts, 'dynamic networks' (Miles and Snow 1986) and 'arena theory' (Schattschneider 1960; Dunford 1992) have been highlighted as bearing a direct relationship to the issue of the impact of multiple partners or multiple stakeholders on project performance.

'Dynamic networks' describes a form of networking that is strongly emerging in some service and high technology industries, both as a cause and effect of the extremely competitive and uncertain environment that has faced these industries from the late 1980s. These networks typically represent formal or informal staff or function sharing arrangements that are generally temporary and targeted. They seek to avoid more formal organisational structures typified by joint ventures and contracted service provision. Within the context of agro-environmental R&D project management, the development of such networks is becoming increasingly evident, especially in response to pressure on R&D agencies from both internal (eg. corporate management) and external sources (eg. R&D-funding agencies) to integrate their work more closely with other competing agencies and stakeholder groups. The dynamism of these networks flows from their being essentially 'marriages of convenience', and while they can potentially offer many positive benefits (Moss Kantor 1994) including economies of scope and cost-sharing, they also carry the potential for extensive downside risks. The latter include, for example, problems of hidden personal and corporate agendas, lack of genuine performance accountability and managerial control, incongruent organisational priorities, and unforeseen temporal commitment of staff and resources from the partner agencies (MacLeod and Shulman 1993).

'Arena theory' (Section D.3.2), while still evolving (Schattschneider 1960; Dunford 1992; Cunningham and Barawryh 1993), can be used to depict the activities of R&D project staff and other stakeholders and their interaction within the analogous context of a competitive arena.⁴⁰ That is, the project and its operational environment resemble a contest played according to certain explicit and implicit 'rules' of engagement. As more stakeholders enter the arena and are allowed to participate in the contest (ie. are empowered) these rules may change in a manner that is beneficial, neutral, or antagonistic to the interests of the project objectives and/or some or all of the interests of the existing contestants. This process can, foreseeably, be managed and manipulated by some or all of the stakeholders leading, perhaps, to increased likelihood of 'success' or 'failure' of the project (MacLeod et al. 1995). However, in the case of multiple

³⁹ A similar concept known as 'helicopter-thinking' refers to management focusing on local detail (tactical focus) on one level, while also taking a more open (strategic focus) view of the issues within a broader organisational or environmental context.

⁴⁰ The arena is context dependent. For example, for some issues a given R&D project may represent an arena in its own right or belong to a larger arena.

stakeholders, particularly when multiple agencies are conducting the R,D&E, the project outcome may be judged quite differently by the different parties involved.

C.3.7 The 'hidden hand'—'unintelligent' failure

The preceding theoretical models are used to underpin the notion of positively learning from poor project performance outcomes—'intelligent' failure. A major emphasis of the models (eg. the Perrow system accident model), is that poor performance may be traced to unforeseen problems associated with project design, operation, management or the environment. However, it would also be appropriate to give some consideration to the issue of foreseeable problems that can also give rise to poor project performance and sub-optimal R,D&E outcomes.

In reality, many causes of poor project performance are engineered into a significant number of projects from the start and would, on careful reflection, become evident to the project planners and project team members. A reason that they get past the planning stage is simply that most project planners and promoters do not, cannot, or will not see them. There are various reasons for this, including increasing pressure to obtain funding, tight time limits for project development, group delusion, and so on. This failing has rather succinctly been described by Uphoff (unpublished) as the 'hidden hand' phenomenon.⁴¹ The process sees many project managers semi-intentionally ignoring the more obvious problems associated with a proposal and after project initiation, finding themselves committed to allocating a significant proportion of time and other scarce resources to addressing or rectifying the shortcomings. The 'hidden hand' is seen to be a powerful foil against the careful and detailed planning and organisation that is usually assumed to occur within R,D&E organisations.

In hindsight, the 'hidden hand' was strong during the gestation and operational phase of CTC2. This is evident in the historical account (Section B.3.3) and the review of operational performance (Section B.5.1). There is not much that can be said about this phenomenon other than to suggest that the 'rules of engagement' in proposing R&D projects, and the associated reward system that encourages over-promising on potential outcomes, be addressed and that managers devote more time and attention to detail. Nevertheless, recognising and responding to the 'hidden hand' phenomenon is a potentially valuable learning experience within the context of 'intelligent' failure.

⁴¹ Prof. Norman Uphoff, University of Colorado, made passing reference to the 'hidden hand' phenomenon within an unpublished presentation to the 37th Meeting of the International Society of System Sciences, University of Western Sydney, Hawkesbury Campus, 6 July 1993.

C.4 Stakeholder interviews

In early 1995, a series of semi-structured interviews was held with a sub-sample of individuals who had been exposed to the CTC2 project at some stage during its life. These included members of the CTC2 project team (1),⁴² case-study #1 R&D team (4), CSIRO managers (2), DPI branch and regional managers (2), and district extension staff (4). Attempts were made on several occasions to interview members of the case-study #2 R&D team and other individuals associated with both that project and CTC2. Unfortunately, circumstances conspired against these efforts⁴³, and the full scope of interviews proposed was not completed.⁴⁴

General points that were raised by each of the groups or key individuals are presented in the following sub-sections.

3.4.1 Case-study #1 R&D team members

1. All of the R&D team members had a general idea of what CTC2 was trying to achieve, and generally supported the project and their involvement in it. Their motives for this support varied considerably. For example, in some cases CTC2 was seen as a useful vehicle for promoting their work and relieved them of responsibility for taking individual action towards technology transfer. In other cases, co-operation was seen to be supporting the wishes of the project leaders or assisting CTC2 members to obtain data for their postgraduate studies.
2. There was an almost universal lack of understanding of the detail of CTC2, including the rationale for specific interventions and their inter-relationships with each other and the case-study project. In fact, most of those interviewed when shown a diagram of the proposed relationships (Figure 1) suggested that it was the first time they had actually been able to make the connection and queried why this had not been circulated earlier (it had).
3. Even in cases when the rationale for an intervention was well-understood, its relationship to the suite was not. In some cases, a 'clear understanding' was expressed which differed from that of the CTC2 promoters. Some of this arose from variation in messages emanating from different members of the CTC2 team.

⁴² Numbers in brackets represent the number of individuals who were interviewed.

⁴³ For example, the severe drought situation prevailing in the Charters Towers region was requiring a major commitment of time and resources for DPI staff attached to the Grazing Lands Management Unit, and a scheduled visit of key regional managers was aborted at the last minute due to a minimum notice abattoir closure in Townsville.

⁴⁴ Fulfilment of this task is still planned in association with detailed case-study work being jointly-conducted by the principal investigator and Program Manager.

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4. There was general confusion as to whether a given intervention or spin-off activity was part of the CTC2 'research', a case-study 'extension' exercise, or part of a 'PhD experiment'. Commitment to engagement varied according to perception. Related to this was concern at apparent escalation of commitment of time to CTC2 activities, in terms of an apparent expansion of expected commitment to activities that were accepted to be part of the CTC2 framework and to activities that were seen to be 'spin-offs' or 'new leads'.
5. The roles of the CTC2 team members and the Program Manager were not well understood. Some members raised concern at not being sure of the 'hat' an individual was wearing when information was given or sought concerning CTC2 and case-study project communication activities. The role of the project officer, in particular, was not clear. This was seen to range from a 'hands-on' extension officer working with little autonomy under the direct control of the two principal investigators or the case-study project leaders, through to the CTC2 'champion' driving all of the processes under the benign guidance of the remaining team members.
6. Few of the team could recall clearly when they first heard of the project, although most identified the period immediately following the MRC audit (Section B.3.3.1) as the main exposure to the proposal to take on a major initiative. All generally felt that they had been offered little opportunity for input to the planning and implementation process, but to the extent that communication or technology transfer was seen as an 'add-on' to normal R&D activities, and a separate team was on board to pursue this, it did not unduly concern them until the time commitment issue began to take hold (ie. around the time of the focus group meetings).
7. All of the team members felt that the focus group meetings had been a useful and interesting experience and welcomed the opportunity to interact with different stakeholders. However, most did not feel that the format was suitable for getting across a message as 'complex' as that/those being addressed by their research, and the process may have led to misunderstandings in certain stakeholders, notably the beef producers and agribusiness groups. None of the team members felt that the interventions had been successful in changing any of the experiments or the overall R&D approach. This was largely put down to the lack of synchrony between the starting date of CTC2 and the case-study (GLASS) which had begun 4 years earlier. In fact, one interviewee was so concerned that change may be required and expected by stakeholders that his participation was largely motivated to ensuring that it did not affect his individual experiments. Most conceded that if the timing of the focus groups had been in accordance with that proposed for general application it might be useful for defining R&D issues and establishing better R&D projects.
8. Notwithstanding some confusion over the role of the individual interventions, the role of the technical reference group was endorsed. All of those interviewed regretted that this particular intervention had not been able to proceed and endorsed its inclusion in a revised model.
9. By mid 1993 (after the focus group meetings) most members of the team were aware of growing friction within the CTC2 team and an apparent disillusionment among some team members with progress, direction and research competency. This compounded some of the concern over direction and commitment noted before.
10. Feedback from the project and, in particular, written material circulated by the project officer was received with mixed feelings by all team members. While some team members found some of the material (eg. focus group meeting summaries) to be useful or perhaps just interesting, there was thought to be too much of it and most went unread. Preference was given to oral feedback during project meetings. In some instances, team members were concerned that the interpretation by the project officer of some of the material from the reconnaissance surveys and focus groups meetings either did not match their perceptions of what was discussed or was unduly biased towards an 'anti-R&D' and 'pro-extension' viewpoint.
11. Some teams felt that some of the material highlighted as 'findings' by the CTC2 team was 'irrelevant' to the terms of reference of the case-study project. A concern was expressed that the project officer was seeking to set up further exercises and commitments to stakeholders carrying an obligation for the R&D team to address them. For example, tree-clearing and timber regrowth and sowing pastures into hard-setting soils were identified as priority issues for beef producers that were not covered by the GLASS experiments, the suggestion being that the project should be widened to cover these issues or attention be diverted away from existing experiments to them. The case-study team argued that, while these were important issues in some regions, they remained outside the main scope of the project which had been clearly explained to both the CTC2 team and to the focus groups. That is, effort to pursue these issues was not seen to be 'value-adding' to the existing experimental work. Therefore, the extent to which the project could actually influence R&D directions and the extent to which this was a reasonable expectation remains unclear, at least from the perspective of the R&D team members.
12. Exposure to the project had changed the R&D team members' views on many issues surrounding both technology transfer and R&D risk management. The nature of the task associated with trying to shift from an output to an outcome orientation was better appreciated although its redress was not clear. Some team members

felt that the engagement of a full-time extension specialist for all large R&D projects was warranted. The Perrow DEPOSE model and the notion of tight coupling of elements and events were cited as particularly useful concepts for R&D planning and management, as was the concept of 'intelligent failure'. In the latter regard, the debriefing on their experience with CTC2 was enthusiastically endorsed and suggested as a mandatory procedure for all future R&D projects.

13. One interviewee, who had subsequently left the R&D agency to work for a private agribusiness firm, was particularly supportive of the focus group approach and was now using it with his commercial clients and colleagues. His new experiences in the private sector had led to him to query the approach and operational methods employed by public R&D agencies for communication and technology transfer. He now saw the secondment of a dedicated extension officer (project officer) to large R&D teams working in 'complex' areas as essential. However, he also felt that the gulf between private and public commercialisation practice was so large, the former being more intensive, that a model such as CTC2 would still be unlikely to deliver significant outcomes. A long history of a lack of serious commitment to maintaining communication and development programs after the R&D 'terminated' was pinpointed as a flaw which was still evident in the CTC2 design and not well addressed in funding proposals put to the mainstream funding bodies (eg. MRC).
14. All of the team members agreed that if they were asked to participate in a future exercise they would be willing to do so. However, they would be much more critical of the process and demanding of knowing the 'what, where, when, how long, and why'. Their perception of the competency and track record of the communication or extension research staff would be a key determinant in deciding whether or not to proceed.

3.4.2 Extension officers with exposure to CTC2 interventions

1. The extension officers, like the R&D team members were not familiar with the overall framework being applied within CTC2, or of some of the specific interventions. When shown the flow diagram (ie. Figure 1) they also expressed a view that it seemed to 'make sense' and queried why the figure had not been used during the early exposure sessions. Most felt that the project officer was unclear as to what was involved, but was new to the project at the time and would presumably 'come up to speed' as it got going. The universal view seemed to be that their engagement was initially conditional on experience with a given intervention and future engagement would depend on a personal evaluation of the 'outcome'. That is, none of the extension officers

was prepared to unconditionally commit to participating in all of the interventions up front.

2. Most of this group had an exposure limited to contact during the reconnaissance phase and all were involved with the establishment and conduct of at least one beef producer focus group meeting and participated in the extension officer focus group meeting. It was universally acknowledged that the focus group meetings had been 'useful' and the extension officers would be prepared or were planning to use this device in the future as part of their district work. There was some serious prior reservation on the extent to which the focus groups could actually have an impact on the R&D direction and conduct given that the project was well established at the time the meetings were run. Subsequent lack of change to individual experiments other than termination of a few on technical reasons or the drought was cited as affirmation for this view.
3. None of the extension officer interviewees was aware of any directive from regional or central management to support participation in CTC2 or assist with its interventions. Most became aware of it during a meeting at Brian Pastures Research Station in 1992, or through informal contact with the CTC2 team during their reconnaissance surveys. There was no budget allocation specifically dedicated to supporting CTC2. The decision to participate was largely on the basis of a view that GLASS might have something useful to support their general work on pasture management and through prior work and social relationships with the project officer who had been based in the region for many years. The fact that the project officer was attempting to use the project to obtain a PhD either increased or decreased the support they were willing to show to CTC2. Nevertheless, without the personal empathy for the project officer, most felt that they would have needed a lot more convincing. A couple made the comment that they had wondered how the project would go in the north (case-study #2) where the project officer was not generally as well known and were, therefore, not surprised that it had not advanced as well as for case-study #1.
4. Feedback was generally considered to be excessive and not in a form that was immediately useful to them. It was, however, conceded that the transcripts from the focus group meetings that each had organised was useful for 'jogging their memories' and contained some useful general leads for their normal work. By late 1993 most feedback had ceased other than an occasional personal telephone call from the project officer.
5. All reported some positive feedback from focus meeting participants and the occasional query of future activities associated with CTC2. However, these ceased within about 2–6 months and some of the lack of subsequent interest was attributed to the worsening drought.

6. Several interviewees felt that the physical isolation of the R&D team from the region for which the R&D was targeted remained a substantial barrier to any technology transfer initiative. True participation in the R&D was seen to require more frequent contact and a degree of empathy for local context than had been evident with past R&D by CSIRO in the region. While the CTC2 proposal was a step in the right direction, it was still not seen to be sufficient to overcome the distance problem.

3.4.3 Case-study #1 project leaders⁴⁵ and other CSIRO managers

Many of the points noted for the R&D team members were common to this group. The following relates to the R&D management implications.

1. The confused role of CTC2 as a substantive research project versus an operational extension program was prominent in responses. Common to the R&D team members, the project leaders often had trouble determining whether a particular exercise was a general extension activity of part of an experiment and, therefore, what the expected outcome would be or the appropriate level of commitment to give to it. Strongly related to this was an apparent confusion of roles of the various CTC2 team members, particularly that of the project officer and seemingly different explanations for the rationale for various interventions, if not the entire project. In fact, the 'real agenda' of the project officer was unclear and of concern.
2. An escalation of commitment of team time and resources to certain activities of unclear purpose and outcome was a major concern. The case-study R&D project faced a number of critical performance problems. Some of these were particularly related to staff time management and research performance, which were seen to be compounded by some CTC2 initiatives rather than resolved by them. On the other hand, many of the 'extra-curricular' interventions (eg. district property inspections, PMP workshops) were seen to have some potentially valuable features that would support the project. Drawing the line was difficult and there was a feeling that the project officer was drawing the team and the project leaders into commitments that had not been fully negotiated or 'signed-off' with them.
3. As an 'extension' exercise many of the CTC2 activities were accepted as being of an appropriate standard and generally seen to offer some value (the commitment issue raised in the preceding point notwithstanding). However, the 'research' aspect of CTC2 was a major concern, particularly to the present project leader, CSIRO Program Manager, and LWRRDC Program Manager. A strong feeling was expressed that the project officer was simply 'not up to the job' of conducting such research, a position that was seen to become even less tenable due to deteriorating health problems. Moreover, as the project was proceeding, its basic approach, management and evaluation was considered to be 'substandard' as judged against the norms of 'good' R&D practice. Nevertheless, how this might be redressed was unclear, as control and management of the CTC2 team and the terms on which the project officer was engaged were never formally negotiated. The research role of the project officer as opposed to his extension role was further clouded by the unclear status of his PhD studies including the actual topic and the extent to which this might either support or detract from both the CTC2 and case-study R&D objectives. For example, much of the latter part of 1993 and early 1994 seemed to have been spent working on PhD-related material with little apparent effort allocated to either CTC2 interventions or extension activities associated with the case-study R&D project.
4. Management responsibility, performance and accountability for the seconded project officer were unclear. Having identified a serious personnel management problem, the case-study project leaders were not sure of what to do. The project officer was not directly linked to the CSIRO project leaders through the CSIRO PPE process, and the line of management authority and performance accountability within DPI was unclear. It was generally assumed that the second principal investigator from DPI might be partly responsible. However, as there was no formal agreement for the secondment per se there was also no formal performance compliance mechanism. Moreover, as the health problems of the project officer became increasing more debilitating there was a feeling that it would be 'wrong' to challenge the performance and/or demand improvement. By mid-1994 it was universally conceded that the situation was beyond recovery and that termination of the secondment was the only feasible option, although the appropriate means of doing this was unclear given lack of a formal agreement in the first place.
5. There a strong view that little formal 'learning' was coming from the operational phase of CTC2. That is, while aspects of the interventions were considered useful, the project was not delivering useful management prescriptions (eg. timely and effective feedback) or proceeding towards generating useful 'outcomes' for the case-study project. Moreover, the cost-effectiveness of what had been done was challenged. A key outcome was that the focus group preparation had confirmed the extent to which the case-study R&D team was not unified and was seen to be a useful 'team-building' instrument. However, there was also a feeling that much of the limited cohesion was already apparent and that alternatives to

⁴⁵ Note: the author was both a CTC2 team member and joint-project leader of case-study #1, sharing this role with three other individuals during the life of the case-study project.

team-building were available and may have been more efficient. From their perspective, the lack of unity was less apparent to the individual team members than to the project leaders or more senior managers.

6. The 'learning' offered from exposure to the review process of which the interview was part was acknowledged. For example, the DEPOSE model and notion of failure being promoted through tight coupling of project elements and complex designs was valued and has been used as a guide for planning future R&D. The 'intelligent failure' and 'escalation of commitment' models were also identified as playing a key role in the managers' thinking on project risk management and design of future work. In fact, the informal discussions of the escalation of commitment model and exposure to the relevant literature (eg. Ross and Staw 1993) were instrumental in supporting the decision to terminate CTC2 in July 1994. The risks associated with establishing and managing R&D networks and the pitfalls inherent with open-ended commitment to 'participatory' R,D&E have also been identified as a 'learning' of the review process. There was a general consensus that the leaders would prefer to have direct control over future technology transfer strategies rather than delegate this to some other party.
7. The importance and value of engaging stakeholders in R,D&E was acknowledged and it was conceded that future research should be structured to accommodate this. It was agreed, nevertheless, that this would be difficult to achieve.
8. The interviewees who had been involved with the early planning and implementation of CTC2 agreed that its management had been poor and that if it were possible to begin anew then much a tighter planning, management and performance protocol would be demanded. Secondment of staff from other agencies would require formal agreements and clear duty statements.

3.4.4 DPI managers

Note: the interviewees included the Branch Group Manager and a Regional Manager to which the DPI component of CTC2 was notionally 'accountable'. The former was interviewed at the start of planning in 1991 and the latter at the time of termination in 1994. The Branch Manager was a co-supervisor of the project officer's PhD studies.

1. The evolution of CTC2 (as described in Section B.3.3) came about at a time of considerable upheaval within DPI. As it eventuated the project did not have a natural home or 'champion' within DPI. Between the time that the original proposal to MRC was submitted and the CTC2 proposal accepted by IWRRDC most of the managers who had some familiarity with the proposal had changed roles or retired. While the involvement of DPI staff had been negotiated at the regional/district level for the MRC

proposal, it was conditional on success of that application and the funding it implied. When the MRC bid was rejected the previous commitment also lapsed. When the revised IWRRDC proposal was submitted, approval in principal for DPI involvement appears to have been obtained at the level of the Director-General's Office and not negotiated with the regional managers who ultimately set priorities and allocate resources to operational projects. Competing projects (eg. the LCD initiative for northern and central Queensland) would have had the requisite regional and local endorsement.

2. The short notice given to DPI at the time the MRC proposal was drafted, and the active DPI involvement it implied, were resented by the DPI central and regional management hierarchy. In fact, early DPI contact was more fact finding than a reflection of interest or potential commitment. Moreover, there was a perception that the southern case-study project, which was driving the application, did not involve significant input of DPI staff and was a competitor to another DPI project that had failed to attract funding at that stage. There was, therefore, a general reluctance on the part of district staff to join the work.
3. The Group Manager left DPI shortly after the MRC proposal was submitted and was not involved with the revision of the proposal to IWRRDC but had incorrectly understood that it had the same general thrust as the original submitted to MRC. That is, an action research project within which promising leads for participation by stakeholders that could improve the technology transfer for the case-study R&D project would be pursued by the project officer using whatever interventions were seen to be appropriate. In discussing the project with the project officer and agreeing to co-supervise his PhD thesis, it was assumed that this view of the CTC2 structure was correct. The project officer had never really elaborated on the specific structure of the CTC2 model and the intent to test it as a 'fixed' design. In this light, the project officer had frequently been encouraged to try 'different' things and the lack of synchrony with the original CTC2 model had gone unnoticed. The project officer was seen to be someone who would very likely set and follow his own agenda which would be appropriate for the action research model that was believed to be involved. Replication via a second-case study was not part of the original design and was not seen to be operationally feasible.
4. The decision by CSIRO to terminate the informal secondment and in this process no longer part-fund the project officer's salary was a stimulus for finding a 'home' for the ongoing work associated with the PhD thesis and analysing and writing up the existing data (eg. focus groups). Before this there was no formal reporting or performance linkage with CTC2 and the status of the project officer was that of someone on full-time study

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leave. The regional program to which the work was attached in 1994 initially considered applying some of the interventions (eg. focus groups) to other projects but eventually decided not to proceed. The initial decision had been largely based on providing replication for the PhD study, which was seen to be lost when case-study #2 did not proceed, but was not pursued as the viability of the work was judged to be doubtful.

3.4.5 CTC2 Principal Investigator

Note: this relates to only one of the Principal Investigators. The other Principal Investigator conducted the review interview.

1. There was a strong sense of conviction that the CTC2 model and project initiative was a 'good' one whose progress had been impeded by a number of developments not least its management structure and staff competency, and some underlying problems associated with the two case-study R&D projects. These centred on synchrony of timing between the case-studies and CTC2, case-study R&D team cohesion, the drought and failure of certain key experiments (eg. GPS tracking equipment) and clarity of definition of the 'technologies' the project was to work with. If the opportunity arose again, the model would be promoted with few changes other than to ensure clear management guidelines and secondment of competent and motivated project staff.
2. Much of the delay in implementing some of the interventions was seen to arise from the need to resolve more fundamental problems within the case-study projects. For example, the group presentation for case-study #1 took considerably more time and effort than would be expected for a more cohesive R&D team which had a better grip on what it was trying to achieve. While this increased effort was valuable to the case-study and a real 'outcome' for CTC2, it was not foreseen as it was considered to have been unnecessary for a better constituted team.
3. Problems associated with replicating the CTC2 model via case-study #2 were seen to be the result of ulterior motives: firstly, on the part of the CSIRO senior managers wanting to change the way that case-study #2 was to be implemented and managed given a poor track record of extension for previous R&D in that region; and secondly, on the part of the Program Manager to support the project officer's PhD studies and to extend the influence of the program. Involvement with the second case study was unwarranted and should have been dropped once the problems that were to emerge became obvious.
4. The time allocation of the Principal Investigators (respectively 10% and 20%) to CTC2 was hopelessly inadequate, but the initial allocation had been based on the perceived research and administrative competency

of the project officer which, in hindsight, was not warranted.

5. Trying to keep the project officer on track on project objectives and specific interventions had been extremely frustrating. It was evident from about one-third of the way into the project that the project officer was working to another agenda. This involved an open-ended approach to engaging stakeholders and projects beyond the case-studies, and despite repeated attempts to explain the requirements for CTC2, he would not be shifted. Towards the beginning of 1994 enlightenment came as to what CTC2 could really achieve, by which time it was too late to catch up and termination was warranted. There was no formal performance or reporting mechanism to support getting the project officer on track.
6. The technical reference group was seen to represent the 'lynch pin' for all of the interventions. If it could have been initiated earlier it may well have been a vehicle for salvaging the suite of interventions once the decision had been taken to not proceed with case-study #2.
7. In reviewing the performance of CTC2 there had been an excessive emphasis on 'failure', whereas the model itself had not been proven to have failed. The notion of 'intelligent' failure was seen to too easily mask success in identifying weaknesses and the Perrow DEPOSE model too easily construed to suggest that all complex systems will eventually fail. A preferred evaluation model was one that focused on objectives, process and products. The objectives were seen to remain sound and the products, as were achieved under the circumstances, were worthwhile. However, the process included management which was, ultimately, shown to be deficient and a key area for improving future applications of the model.

C.5 Some important developments within the case-study R&D projects

The reviews detailed in the preceding sub-sections centred on individuals and events that were directly and immediately related to the technology-transfer component of CTC2. However, the project was designed to interact with two specific R&D projects, which influenced its performance. Indeed, CTC2 evolved largely from initiatives taken within one of the R&D projects (GLASS), and the appearance of a second case-study created a number of operational difficulties for it. While detailing much of the interaction is beyond the immediate scope of this report it is useful to summarise some of the developments in the case-study projects that had a significant impact on CTC2:

1. Both case-study projects were, throughout the life of CTC2, severely affected by a worsening drought, leading in both instances to repeated destocking and restocking

decisions and delayed starts for certain aspect of the experiments. This had a generally negative impact on the willingness of the teams to be actively involved in CTC2 interventions, particularly case-study #2.

2. There were significant changes in leadership and research direction in both projects during their association with CTC2. Substantial personnel changes also occurred to greater or lesser extent for the two projects. For case-study #1, this largely applied to leadership, which changed four times within two years, while for case-study #2 the final staff complement and project leadership were still being 'negotiated' at the time of termination.
3. Both projects were substantially funded by MRC and 'co-ordinated' by the NAP2 management committee, which held strong views on the form technology transfer should take. To safeguard this funding, particularly while it was still being negotiated, the project managers were cautious in terms of balancing their relationship with CTC2 and NAP2.
4. The level of commitment to technology transfer in general, and the CTC2 approach in particular, was not known with certainty, and appears to have varied considerably between individuals within individual case-study projects and between the two case-study projects. For example, the GLASS project leaders were probably more committed to technology transfer and the CTC2 model than the other team members, but both more so than the case-study #2 managers and team.
5. There was active opposition to CTC2 within DPI at both operational and management levels, particularly in the northern and central regions. This is partly explained by the NAP2 support for the LCD workshops that were to operate through the DPI regional extension network at the time CTC2 was being implemented.
6. It was often not possible to clearly define or articulate the specific technologies that the case-study projects were supposed to be developing and, ultimately, 'transferring'. Even where this was spelled out by the project leaders, it was not always evident that the individual (disciplinary) team members agreed with the interpretations.⁴⁶
7. Parts of the design of one of the case-study projects (GLASS) were faulty, making it even more difficult to define the specific technological outputs. This particularly applied in cases where the technology was interpreted by either team members or stakeholders to be embodied in equipment developed for, or used within, the experiments. For example, many stakeholders saw the BandSeeder as a central element of 'technology' for

GLASS rather than the grazing regimes imposed on the legume pastures.⁴⁷ Repeated failures of the legume sowings carried the implication of the central technology failing. Also, for GLASS the GPS-based 'cowfinder' was a central piece of equipment whose development was subject to repeated setbacks, leading to its ultimate abandonment. This has created confusion as to whether the measuring device or the measurement was the key piece of technology.

8. A number of facets of the GLASS experiments exhibited problems associated with tight coupling of design elements and escalation of commitment that ultimately weakened the ability of the project to deliver its projected outputs. These, along with personnel performance issues, greatly influenced the CSIRO decision to end the project early. For example, the project was studying the effects of different grazing regimes on both native pastures and legume-augmented native pastures, with the latter pasture type comprising almost two-thirds of the treatment paddocks. The drought severely affected the establishment of the legume-augmented pastures, requiring prolonged periods of half stocking and eventually two separate legume sowings, as the experiments were designed on the basis of applying pressure to fully established pastures over the projected life of the trial.

A second major thrust of GLASS was to determine animal grazing patterns and preferences in large-scale treatment paddocks, information that supported its claim to relative "uniqueness" and was near critical to linking the animal and pasture systems in a meaningful sense. The proposed route to capturing this information started from computer-assisted ground-based triangulation technology and, following several setbacks with both the hardware and software associated with that system, eventually led to preference being given to a relatively sophisticated GPS-based remote sensing system. After three years and many failed attempts to resolve technical problems with the GPS system, it was abandoned along with any serious chance of capturing the preference data that were the ultimate target of this aspect of the trial.
9. R&D staff allocated to the case-study teams were not necessarily selected on the basis of their disciplinary track record or ability to work co-operatively and effectively within a multi-disciplinary team environment addressing complex issues. In the case of GLASS, several team members were on notice for their overall research and technical performance for much of the life of the project. For these individuals, distractions attributed to participating in CTC2 interventions carried an additional penalty and were a source of challenge for the project.

⁴⁶ It is recognised that the CTC2 interventions are intended to assist with this process.

⁴⁷ Interview responses from three DPI extension officers (Section C.4) supported the view that GLASS was centrally focused on 'proving' the BandSeeder as a viable technology for establishing legume pastures.

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The listing is not exhaustive and is used to illustrate the point that the case studies themselves, like most R,D&E in 'complex' fields, were not free of problems or 'failures' that were independent of the existence of CTC2.

Many of these developments combined to cause serious delays and abandonment in the planned timing of different experiments or expectations of interpretable data. The delays, in turn, created serious problems with respect to the implementation of the proposed CTC2 interventions. For example, the severely worsening drought in the northern region placed great pressure on local DPI extension staff to concentrate exclusively on drought management and financial counselling activities, thereby delaying the planned commencement date of the case-study #2 experiments. A delay in the start of the focus group intervention was sought, which carried further implications for the timing of the proposed technical reference group and relevance audit interventions. In the southern region, while seasons were initially more favourable, there was a delay of approximately six months in holding the focus group meetings. The worsening drought compounded the effect of the delay, increasing the difficulty of initiating the follow-up interventions, and leading to a decision in March 1994 to abandon the proposed relevance audit and to defer the technical reference group meeting.

The point being made is that the fate of a given intervention and the overall performance of the project was not exclusively determined by developments within the CTC2 project's domain of influence. These were also heavily influenced by developments within the case-study projects. That is, there was ample evidence of tight coupling and complex interrelationships at work between the respective projects that impacted on the ultimate performance (Sections B.5.1, B.5.2).

C.6 Major 'learnings' from Phase 2 of CTC2

- (1) *Escalation of commitment is a powerful phenomenon that can reinforce unwarranted allocation of resources to particular research and extension activities. Moreover, factors contributing to unwarranted escalation can be identified and addressed.*

Escalation of commitment to disadvantageous options is not well documented within organisations, including that relevant to R,D&E management. Personal, project, cultural and institutional factors that may reinforce a given escalation have been identified within both CTC2 and the case study R&D projects. The main impacts of such factors are seen to be twofold. Firstly, they can operate to place a project or communication endeavour within an escalation spiral leading to a higher probability of achieving a 'failure' outcome. Secondly, these same factors will tend to reinforce the effects

of past events to hinder recovery from such a spiral once it is under way. However, knowledge of both the factors and the processes through which they work can provide insights to R,D&E managers to prevent or escape from them (Sections E.2, E.3).

- (2) *'Complexity,' which is assumed to be a key feature of both sustainable land resource use problems and R,D&E endeavours to address them, is itself a 'complex' phenomenon whose poor articulation and understanding can compound research and communication failures.*

The traditional (eg. agronomic) R&D approach to complex situations is to impose tight control on experiments and generally to remove most of the sources of variation from consideration. This approach is deservedly criticised on the basis of creating outputs that are artefacts of the imposed design and are of little use in addressing real world resource management issues. More recent (eg. ecological) approaches are typically systems-based, employing a broader range of scientific disciplines and larger scales (eg. landscapes). They also may involve more elaborate management structures, including inter-agency alliances and networks. However, the real world complexity facing stakeholders may be largely the result of phenomena and events that are either unpredictable or uncontrollable and, therefore, their decision domain is focused heavily on managing consequences. The things that can be managed or controlled may actually be relatively straightforward. A problem that this poses for R,D&E is that, in attempting to address the assumed complexity of the problem context, unnecessarily complex designs and structures may be imposed. These will hinder, rather than assist, the task of addressing the so-called complex problem.

- (3) *Poor appreciation of the difference between human infrastructure and technical infrastructure can lead to R,D&E communication problems.*

Part related to the poor articulation of 'complexity' raised in (2), is the traditional preoccupation of much R&D on issues relating to natural (physical or biological) systems which might be defined as a technical infrastructure. This focus and its associated R&D approach or culture allows for the possibility of adhering to, or establishing, certain 'laws' (eg. laws of physics) and using these to dissect complexity in a fairly mechanistic way. However, resource use, decision-making, and communication deal principally with people who are negotiating a unique meaning within a given situation and so the focus moves to working within a human infrastructure. Issues such as indeterminacy of choice and human agency arise that are not readily amenable to reduction according to 'laws'. Their management requires, at a minimum, a 'rules' approach that is sensitive to the wide range of possible meanings that are selectively reinforced

within a particular situation. R,D&E skills and designs that are useful to addressing technical infrastructure issues are less useful for addressing human infrastructure issues. There is a tendency for practitioners of the more traditional scientific disciplines to act as if problems within the human infrastructure can be measured and resolved only through the application of deterministic methodologies (eg. survey sampling). The results of such methodologies can provide data for negotiating meanings and change. However, they do not in themselves create the change.

- (4) *Multidisciplinary R,D&E efforts are not in themselves sufficient to guarantee integrative outcomes for complex land resource management problems.*

Part related to (2), the use of teams of disciplinary specialists to capture and integrate the detail perceived within the structure of complex land management problems is becoming increasingly widespread. However, the incorporation of an array of specialist disciplines within a team or program structure will not automatically guarantee a convergence of perspectives on the underlying resource management issues, project aims and projected outcomes. In the case of both CTC2 and the associated case-study R&D projects it became evident early in the project that a clear and unified vision of project aims and outcomes was not held by the majority of team members or their managers. This clearly changed the structure and increased the communication effort required for effective 'technology transfer'. For example, internal communication tasks took on a larger role relative to the more traditionally identified external tasks. However, even where there are shared perspectives, or multiple ones are brought together, this alone is not sufficient to guarantee the emergence of successful project 'outputs' let alone 'outcomes'. Important team and agency management issues relating, for example, to performance accountability, responsibility and authority must also be addressed and resolved. These issues are particularly pertinent when inter-program and/or inter-agency team relationships underpin the R,D&E endeavour.

- (5) *'Complexity' and 'tight coupling' of project 'elements' can reduce the likelihood of achieving successful project 'outcomes'. In fact, such coupling can actually increase the probability of achieving a 'failure' outcome.*

Part related to (2), 'complexity', both knowingly or otherwise, engineered into project design or operating procedures can increase the likelihood of project outcomes failing to meet prior expectations and/or lead to the necessity for taking corrective contingency action at various stages within the life of a project. In many instances, an important dimension of the 'complexity' arises through linkages or 'coupling' between various project elements (R&D design, staff, skills, resources, procedures etc) and external factors (climate, competing projects etc). This coupling, particularly instances where it

is 'tight' in the sense that the elements act directly on one and other or are influenced by each other, can effect the extent to which project managers can exert independent control and/or foresee performance outcomes. The complexity and degree of coupling between project elements in both CTC2 and the associated case-study R&D projects was identified as having a major impact on both R&D and communication performance outcomes.

- (6) *Milestones tend to reinforce the 'assumed linearity' of R,D&E processes identified as a barrier to the implementation of effective technology transfer strategies. Moreover, rigid milestones can reinforce 'escalation of commitment' problems and further exacerbate poor performance outcomes.*

Milestones, while generally considered to be a positive aid to project management, can actually compound poor performance problems for some R,D&E projects. This is most likely to arise when such milestones tightly lock separate project elements (eg. DEPOSE) together and/or combine to reinforce the effects of sub-optimal or excessively rigid experimental or project design. As a general rule, milestones and related project management tools adhere to a 'linear' or 'parallel' orientation in task scheduling and performance. However, for many R,D&E projects, particularly those centred on participatory principles, such linearity is neither realistic nor warranted. Deviation from intended schedules is both common and desirable to ensure successful outcomes. Failing milestones, especially when supported by reward systems that demand strict or near-literal adherence to their achievement, can lead to subsequent increases in resource commitment and effort to cover 'deficiencies' or to reinforce decisions to adhere to task schedules and strategies that are no longer optimal. Under such circumstances, the spectre of escalation of commitment to less desirable options becomes more likely. Another issue related to the questionable value of tight milestones arises where these merely map what might be expected to be achieved, rather than necessarily providing a sound guide as to what might appropriately be done within the context and experiences of an active R,D&E project. With few exceptions, including CTC2 and the case-studies, project milestones are specified in 'output' rather than 'outcome' terms. As long as this holds, then project managers may as well not be too concerned about querying whether their work is leading to outcomes.

- (7) *The issue of 'tacking' extension and commercialisation strategies onto pre-designed R&D projects requires serious rethinking. These issues need to be addressed and resolved early in the project planning process.*

Consistent with a 'linear' view of the R,D&E process, technology transfer strategies often tend to be grafted onto

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R&D designs or added towards the end. The episodic nature of R&D performance and progress and the need to engage different stakeholders at various times with varying degrees of commitment, reduces the potential effectiveness of such strategies. Once engaged, stakeholder involvement has to be accommodated and managed which requires planning and commitment. External factors such as markets and climatic forces can sufficiently change the opportunity and potential impact of a given communication initiative to require modifications to plans, including abandonment or reinforcement. Insights into the effect and potential management of participation, especially within a context of episodic engagement between R,D&E staff and other stakeholders are provided through 'arena theory'. Arena theory recognises that the specific stakeholders who are engaged in negotiations with R,D&E providers, and the terms of that engagement, will actually change the probability of outcomes occurring in a particular form (Section D.3). The make-up of the participants in the arena and the power relationships between them influences the 'rules' under which the engagement is maintained.

- (8) *The existing State-based extension infrastructure, while staffed by some very good and committed personnel, is generally inadequate for conducting innovative and integrative technology transfer programs for sustainable land resource management R&D projects.*

There are insufficient numbers of skilled communication and extension staff located within the regions to support the level of commitment and effort required to successfully manage the communication requirements of large R,D&E projects or programs. Under present management structures the limited available staff cannot respond flexibly to the episodic nature of commitment required for effective R&D communication interventions. The same, moreover, could also be said of specialist R&D staff within CSIRO and DPI.

- (9) *The notion of 'replication' within participatory R,D&E endeavours is not well understood.*

Rather than simply 'duplicating' interventions to look for agreement, 'replication' may best take the form of applying or testing, in another situation, the principles that are thought to underlie a certain intervention or outcome. Episodes or cycles of involvement with different stakeholders across projects can provide opportunities to modify or reinforce the generalised application of a given intervention. Slavish adherence to the notion of duplicating each intervention

within the suite of case-studies proposed for CTC2 created many operational performance difficulties, especially with respect to the second case-study R&D project. There was a basic failure to recognise that the situations and agencies of different individuals involved in the respective case-studies varied over time. To seek to impose identical interventions rather than modify them according to the prevailing characteristics of the local context and prior learning lead to a loss in the power of the interventions to progress the project objectives.

- (10) *Entrenched norms within the institutional or organisational 'culture' of RD&E agencies remains a significant source of technology transfer failure.*

Despite increasing calls for agencies to take on a more outcome-orientated approach to their work and much agency rhetoric that suggests the calls are being responded to, the prevailing organisational culture (including R,D&E approaches and reward systems) appears to remain one that is consistent with the generation of traditional R,D&E 'outputs'. Attitudes towards the motives and contexts of stakeholders and the nature of the task required to make technology transfer practice genuinely effective appears at best to be 'naive' and the positive learning value placed by many stakeholders on 'negative' outcomes neither appreciated nor mimicked. A proposal for making progress towards overcoming this problem is presented at the conclusion of the report (Section E.).

- (11) *From the learnings obtained from exposure to CTC2, and further reflection on technology transfer issues for agro-environmental R&D, an integrative model for managing R,D&E within changing 'arenas' has been developed.*

The insights obtained from arena theory have been taken as a core from which a model for managing participatory R,D&E processes that reflects both the episodic nature of stakeholder engagement and the agency of individuals and networks (Section B.3.4) has been developed. This model promotes a positive movement towards a 'double loop' organisational learning process which encompasses valuable 'first loop' management practices and guidelines that are supported by recognition and use of escalation of commitment processes, appropriate levels of stakeholder engagement and its management, and intelligent failure learning opportunities. A series of proposals is made for further development and utilisation of this emergent model (Sections E.2, E.3).

Section D

Analysis and re-examination of the CTC2 model

In Sections B and C, detailed consideration has been given to the two substantive phases of CTC2, which have been separately designated as the operational and review phases. These reflect the main thrusts of activities undertaken by the project team over the three years, roughly co-inciding with the first and second halves of the project life. From both phases, and despite the many problems described, positive 'learnings' were reaped. These 'learnings' and the basis from which they were derived have been covered in detail in Sections B.6 and C.6.

This section takes a broad overview of what was discovered, re-examines the premises which underpinned the CTC2 model and draws some conclusions on its suitability for future application. On the way, the AKIS model which underpinned the CTC2 approach is briefly revisited. The value of insights from arena theory to augment both the AKIS approach and future research in the technology transfer and general project management fields is further examined.

D.1 General reflections

In many ways, CTC2 did not, and could not, perform to a level consistent with expectations. The way the team saw the operation of R,D&E processes working and the manner in which the interventions were arranged and their implementation scheduled was not realistic. Much was assumed about the nature of agro-environmental research problems (eg. complexity) and the way that multi-disciplinary R,D&E teams function (Section B.2). The basic assumption of R,D&E as a linear, sequential process was not challenged. Positive value was automatically attributed to collaborative arrangements between individual disciplines and agencies, and to participatory mechanisms through which 'empowered' stakeholders would co-operate to direct the R,D&E towards more integrative solutions. It became clear that these positions were relatively naive. We note, in our defence, that many R,D&E practitioners and funders seem to espouse similar viewpoints. Moreover, in cases where apparent research or extension failure was found, the mechanisms underlying the failures were often different or more complex than was envisaged before the event.

A basic premise of the thinking of R,D&E practitioners and funders on technology transfer failures seems to be that the desirable R&D outputs either fail to find a willing market, or that otherwise sound R&D outputs fail to meet the contextual needs of clients. In either case, the traditionally cited root cause is ineffective communication processes before and/or after the event. However, a key finding of the CTC2 experience is that an extension failure or a research

failure (or any combination of the two concepts) may have as its likely root cause a general failure in basic project design or management. Such failures may be manifested in an array of circumstances including, as two simple examples, excessively tight or unforeseen coupling of elements (eg. DEPOSE) or events; or unchecked escalation of commitment to actions, individuals or techniques that ultimately prove disadvantageous to outcome performance.

Another premise is that shared goodwill and communication between significant stakeholders and R&D providers will of necessity, and perhaps with some management, lead to genuinely integrative solutions to industry or wider problems. Our finding is that individuals and organisations have loyalties which cannot be assumed to be automatically subsumed to the higher ideal of loyalty to project objectives or mutually beneficial outcomes.

One further premise that should be reconsidered in the light of the CTC2 experience relates to the perception that agro-environmental R,D&E is carried on within the framework of a well-structured and ordered process commencing with problem recognition or definition through to delivery of useful and useable products. The orderliness assumed for this process, even when distinctive stages are recognised, can give rise to several equally unrealistic assumptions. For example, the nature of the management and reporting task is assumed to be well suited to forward planning according to relatively inflexible but otherwise SMART milestones, which now dominate the evaluation practice of most R&D providing and funding agencies. It also might suggest that stakeholder participation can be comfortably aligned with the R&D process with reasonable continuity of any arrangements that are implemented to achieve this. However, the reality of the R,D&E process, especially in an agro-environmental context, seems to be characterised more by a punctuated set of 'episodes' of activity, opportunity and commitment whose nature and timing are influenced by forces which are both internal and external to the project, and which might operate on a range of scales (eg. project specific through to global). This would call for an appropriate mix of proactive and reactive management interventions which are context specific. It would also suggest that the scope for and desirability of participatory engagement with different stakeholders might also be context dependent.

A final premise that warrants some serious re-appraisal relates to a view that the value of participation of additional and different stakeholders within the R,D&E process is necessarily integrative, or at least neutral. That is, the insights and interests of the different groups, when revealed and taken into consideration, will lead to R,D&E outcomes that are in the best interests of all of the participants. Conflicting views can be resolved and additional insights used to create a richer picture of the environment within which the R,D&E is seeking to promote useful 'outcomes'. Frequently allied to this viewpoint is a further moral-based view that the interests of all participant stakeholders should be accorded reasonable

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(if not equal) status throughout the life of the research projects and that participation should be neither conditional nor manipulated. We suggest that this ideal is partially misplaced. Negative or misplaced outcomes can arise in an unmanaged environment. Moreover, our view is that participation should be value-adding (MacLeod and Shulman 1994) and is best actively managed according to the situation at hand, in a manner consistent with the agreed goals of the participants and the problem setting that gave rise to the impetus to conduct the R&D in the first instance.

These issues are further addressed in the following sub-sections.

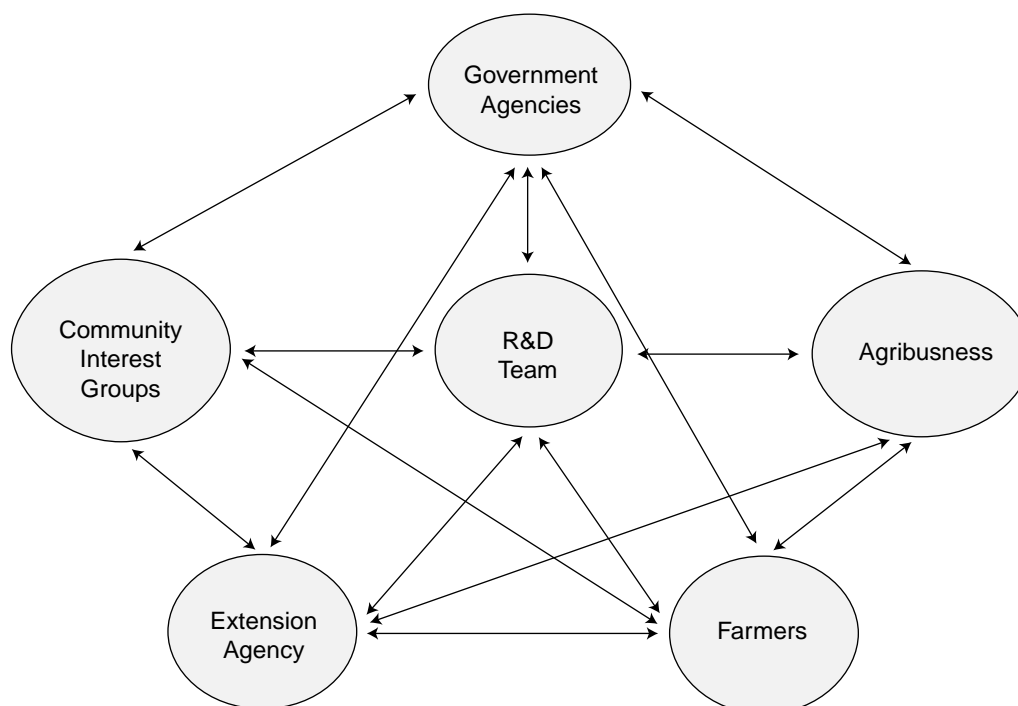
D.2 A reflection on the AKIS concept

In Section B.3.1 it was noted that, initially, the AKIS concept was favoured as an underpinning approach for CTC2. The AKIS model(s) specifically recognises the existence and importance of multiple stakeholders and patterns of information flow with respect to issues that are targeted by R,D&E efforts relating to sustainable land resource management (Figure 4). These models are believed to be well suited to the general thrust of participatory R,D&E goals which seek to bridge 'output-outcome' gaps by aligning stakeholder perspectives, promoting ownership and increasing R&D relevance (MacLeod and Van Beek 1993).

Under an AKIS approach an attempt is made to identify the major stakeholders, sources of knowledge and information flow patterns to a particular problem setting. This 'mapping' of the relevant AKIS and strategically tapping into it is claimed to have a number of strengths over more traditional directed communication strategies between R,D&E projects and individual stakeholders. These include: comprehensive coverage of many stakeholders; recognition of multiple sources of technical information in stakeholder search patterns; cost-effectiveness in delivery through co-ordinated efforts; source credibility; and so on. To a greater extent, these claimed advantages must be recognised as being quite valid and the insights obtained from 'mapping' the relevant AKIS recognised as being useful.

However, an apparent problem with using AKIS models would seem to lie more with their application and interpretation than their logic. For example, some AKIS model proponents implicitly assume that the pattern of communication and power relationships between stakeholders is static. That is, the AKIS is assumed to be stable and, once mapped, to be useful for the life of an R&D project or researchable issue. This assumption can lead to a failure to identify emergent properties that can arise from different patterns or modes of communication between stakeholders. However, relationships between and within stakeholder interest groups and information flow patterns are more likely to be dynamic and, as noted before, much R,D&E practice commonly involves 'episodes' of action. Concomitant with

Figure 4. Agricultural Knowledge Information System (AKIS) model of technology transfer



this is the potential for varying degrees of potential engagement with different stakeholders. Also, AKIS models largely deal with information or knowledge flows as opposed to power relationships, which seem more central to directing R,D&E and imparting 'ownership'. In this regard AKIS says little about identifying which stakeholders within the various identified groups should be given the most recognition or power (MacLeod et al. 1995).

D.3 Arena models and collaborative alliances

While acknowledging the potential value of AKIS models, we feel that more insight might be gained from such models if they were supported by the insights of arena theory (Section C.6). Arena models take as a starting position an assumption that power relationships and communication patterns between stakeholders are both dynamic and emergent properties of interactions between R,D&E personnel and other stakeholders.

D.3.1 Participation in R,D&E versus managed collaboration

In suggesting arena models for promoting technology transfer ideals, we are also touching on philosophical and pragmatic issues of querying the respective merits of 'participation' versus 'collaboration' in R,D&E. At the root of this question lie some fundamental beliefs in the democratic value or rights of affected parties to participate, as opposed to selective engagement within the context of collaborative alliances. On the basis of pragmatism, reinforced by our experiences with CTC2, we are inclined to favour proactively managed collaboration (MacLeod et al. 1995) rather than to endorse an open-ended commitment to participatory ideals for R,D&E. Moreover, many 'participatory' models fail to address some fundamental questions, such as:

- 'what is the participation to achieve, who is to be involved and to what extent?'
- 'what level of participation is actually envisaged?' For example, this could range from casual consultation through to complete involvement in day-to-day decision-making.
- 'will motivation and empowerment actually guarantee better resource management?'
- 'how are conflicting stakeholder interests to be reconciled?'
- 'what patterns of participation promote useful outcomes and improved land resource management?'

A key consideration in addressing these sorts of questions is to seek the most desirable form and extent of collaboration between R,D&E projects and stakeholders, rather than pursue a participatory approach per se. Arena models may be useful

for recognising, analysing and managing the dynamics of interactions between multiple stakeholders, with an aim to improving land resource management.

D.3.2 R,D&E as an arena concept

Central to the concept of arena models is that complex problems involving people can be analysed in terms of the diverse interests and resources of the participants (Dunford 1992). The interaction between R,D&E personnel and other stakeholders may be likened to a sphere of action, or arena. An arena of battle notionally involves both scope and stakeholders, and arena theory is based on the idea that the composition, pre-disposition and relative power of the different stakeholders will ultimately decide the outcome of an engagement.

The arena represents a series or network of relationships between participants and, in that sense, has obvious parallels to AKIS models. However, at any given time within the arena an individual is likely to be involved in several networks. For example, an R&D project leader may be part of the obvious network of his/her immediate team, the network of agency managers, a network of disciplinary peers, and/or other networks involving advisory groups and other clients. Separate arenas can form around specific issues with which participants become involved, and activities within those arenas can have a bearing on processes and outcomes of other arenas, including those of particular interest to R,D&E managers.

A simplified version of an Arena Model is shown in Figure 5. Participants are the individuals or groups (including also sub-groups or organisations) concerned with the issue under focus. For this variant of the model (after Cunningham and Barawryh 1993) three different sets of participants have been identified:

- a. contestants—those participants who have an active or direct stakeholding or dialogue in the contest (eg. the R&D team, farmers, extension team, and other special interest groups such as agribusiness etc).
- b. spectators—individuals or groups who have a potential influence on the outcome of a contest but who, as of yet, are either simply observing the contest (eg. general public) or are still deciding on whether or not to seek/demand an active role in the contest (eg. potential interest groups such as environmentalists, policymakers).
- c. commentators—are potential intermediaries who are close to but not engaged in the immediate action and who can influence relationships between the contestants and the spectators (eg. funding agencies, media, R,D&E agency management etc).

In addition to players, an arena model has objectives, rules of engagement (explicit and implicit), resources, strategies and tactics and, as a consequence, outcomes.

Commentators have a particularly important role in challenging objectives, and eliciting support for particular

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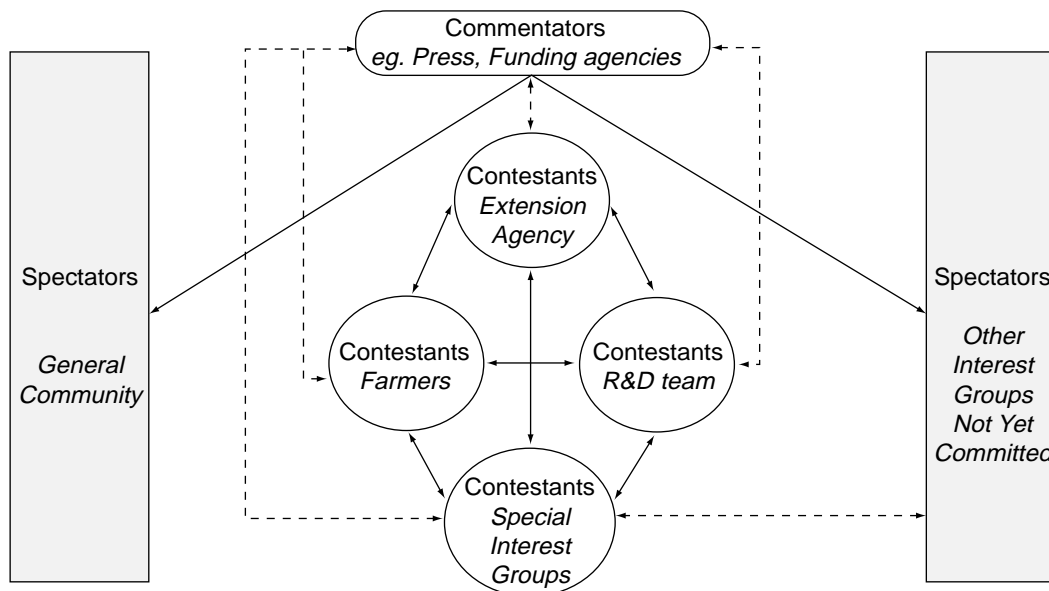
contestants, or the contest as a whole, in terms of resources and shifts in the rules of engagement. Additional resources and power can also be obtained by contestants through manipulation of commentators, inviting new contestants into the arena or direct appeal to the spectators.⁴⁸ Power can also be lost by any given contestant, for example, through passive or ineffective responses to other contestants' strategies or commentators' influences. An important consideration, often overlooked in participatory R,D&E models, is that the entry of additional contestants, invited or otherwise, will always change the distribution of power and rules of engagement. Whether this is desirable or not from the perspective of a given contestant depends on how the rules are changed and the goals of that contestant. A key point is that the ability to manoeuvre the conflict or issue into a desirable arena, thereby activating some potential stakeholders and minimising the influence of others, will shift control of the outcome. Therefore, within the context of AKIS models, when power relationships determine outcomes, it is not sufficient to identify networks of potential participants. Rather, it is also advisable to identify and contrast their power, objectives and available resources, and to devise tactics that are appropriate to meeting project objectives, which includes generating genuinely integrative outcomes.

If an arena model is specifically applied to the control of R,D&E endeavours, it is compelling to suggest that previous attempts to implement improvements in technology transfer may have failed to some extent, because either they (a) did not recognise the context of the arena with which they were involved, or (b) were unable to change the structure and performance of arenas.

Possible ways of changing arenas might include:

- the introduction of new contestants (as above). For example, marketing specialists or stakeholder representatives might be seconded to R&D teams.
- to change the locus of responsibility through legislative/regulatory requirements. For example, changing the terms under which industry levies or taxpayer contributions used to support R&D are allocated or used.
- the formation of new coalitions among contestants. For example, coalitions with other R,D&E agencies, agribusiness, marketing or extension groups etc.
- providing contestants (and the other participants) with new knowledge. For example, relevant data or information might be provided in more user-friendly or context-appropriate forms.

Figure 5. Arena model of technology transfer



⁴⁸ The interplay of these forces has been described by Pfeffer (1992), particularly within the context of purposively managing power relationships to the advantage of achieving a goal (outcome) consistent with that of a particular *contestant's* interest.

- e. following the prescriptive steps for managing power such as those detailed by Pfeffer (1992).⁴⁹

Before this theme of R,D&E processes conforming to the arena model concept is developed further, it is useful to revisit the scene from which CTC2 planning started: that is, the linear model of technology transfer and the ensuing development of participatory R,D&E models. From this departure point the episodic nature of the R,D&E process and the changing power relationships that ultimately determine R,D&E outcomes can be more readily contrasted.

D.3.3 Simple models of technology transfer revisited

A simple version of the linear model of transfer of technology is presented in Figure 6. It is basically a conduit model of communication in that information (and power relationships) are represented as a one-way flow (Shulman 1993). In this model there are two basic stages of interest, viz: (a) technology generation, and (b) technology transfer.

In the first stage of this stereotypical model, most of the key R&D issues (eg. problem identification and project design) are internally resolved and managed by the specialist R&D team and their agency managers. The R&D outputs are then 'released' to the stakeholders for adoption, usually via the medium of an specialist extension agency. The second stage is then assumed to involve a communication dialogue (or monologue) between the extension professionals and the stakeholders. Once this second stage process begins, and depending on the nature of the technology, the expertise and commitment of the extension agency staff and the receptivity of the stakeholders, a pattern of adoption will emerge that leads to an eventual R&D outcome.

In Figure 6 the stakeholders have been depicted as 'farmers', but could represent other stakeholders. The concept being promoted is that, under this fairly rigid model of

communication, the R&D specialists traditionally did not recognise multiple stakeholders. If they did, the process depicted would have largely run in parallel for each stakeholder group identified, rather than as an integrated process. Some feedback on the technology performance may occur between the stakeholders and the extension specialists, but this is largely fine-tuning or clarification. To the extent that this is so, the model would then more closely adhere to a transactional model of communication (Shulman 1993). Direct communication between stakeholders and the R&D team is not a feature of the technology generation or transfer stages.

The conduit and transactional models of technology transfer have been widely criticised on a range of grounds, not least of which is the selective filtering of information through restricted channels, limited scope for empowering stakeholders and failure to fully address the context within which the R,D&E output is to apply. These models have now largely been supplanted by various participatory models of R,D&E which seek to more fully engage (empower) the various parties to the process (Cox 1993; Jiggins 1993). One such model, which might be called a participatory technology development model, is presented in simplified terms in Figure 7. A significant departure from the previous model(s) is the more interactive communication between the researchers, extension specialists and stakeholders. Depending on the degree of participation envisaged, the various groups involved are expected to have an influence on identifying the R&D issues and designing the research project or program, generating the 'technology' and ensuring its conversion to an eventual outcome. The AKIS approach is quite consistent with this model.

As depicted, while the R&D specialists play a significant role in developing the outputs, the other partners also play a role. As the process develops through the technology generation and transfer stages (which are not clearly delineated) the relative roles may change and the extent of feedback or dialogue is much greater. An underlying assumption is made that the high degree of stakeholder involvement throughout the process should raise the scope for more widespread and rapid adoption, leading to more substantive outcomes from the R,D&E investment. In the figure, the non-agency stakeholders have been specifically identified as 'farmers'. This is deliberate and, although it need not be the case, is intended to highlight the fact that many promoters of participation in R,D&E commonly overlook the interests (and agendas) of other stakeholders. However, regardless of who is involved, a major criticism would seem to be that the process is still assumed to be linear (perhaps a forward-thrusting spiral) and the empowered participants will move towards a shared objective. In more democratic (naive) variants of the participatory technology development model, implicit assumptions can be made that all of the participants have equal rights or power in the engagement. The model does not necessarily highlight the possibility of multiple agendas or objectives which are themselves dynamic.

⁴⁹ Pfeffer (1992, p. 29) has described a process for using and managing power relationships in order to get things done in otherwise difficult or complex situations. This 'implementation' process involves the following steps:

1. Decide what your goals are, what you are trying to accomplish.
2. Diagnose patterns of dependence and interdependence; what individuals are influential and important in achieving your goal?
3. What are their points of view likely to be? How will they feel about what you are trying to do?
4. What are their power bases? Which of them is more influential in the decision?
5. What are your bases of power and influence? What bases of influence can you develop to give more control over the situation?
6. Which of the various strategies and tactics for exercising power seem most appropriate and are likely to be effective, given the situation you confront?
7. Based on the above, choose a course of action to get something done?

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Moreover, it rarely recognises the objectives and power of those parties with a stakeholding in the R,D&E issue who either have not been invited to participate or are given token membership in the first instance. When these various interests and power relationships are taken into account, the assumed progress towards a common goal, particularly one determined at the commencement of the R,D&E process is no longer assured. Why this might be so can be illustrated using the modified version of the arena model that was originally presented in Section D.3.2.

D.3.4 A punctuated arena model

We argued in Section C.6 that an important characteristic of most R,D&E endeavours is that their conduct is largely episodic. Why this is so, is not well understood and the claim is made more on the basis of experience and general observation than detailed empirical study.⁵⁰ However, the forces involved would seem to be both internal and external to the direct management of a given project.

Figure 6. A traditional model of R&D information exchange

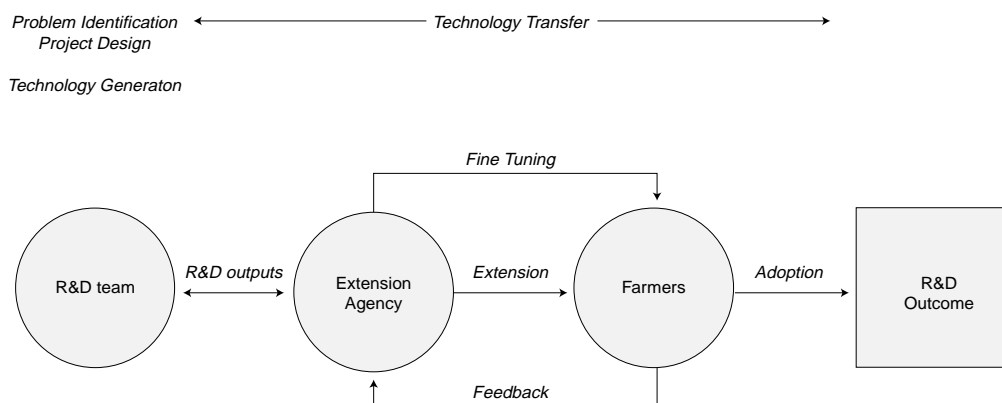
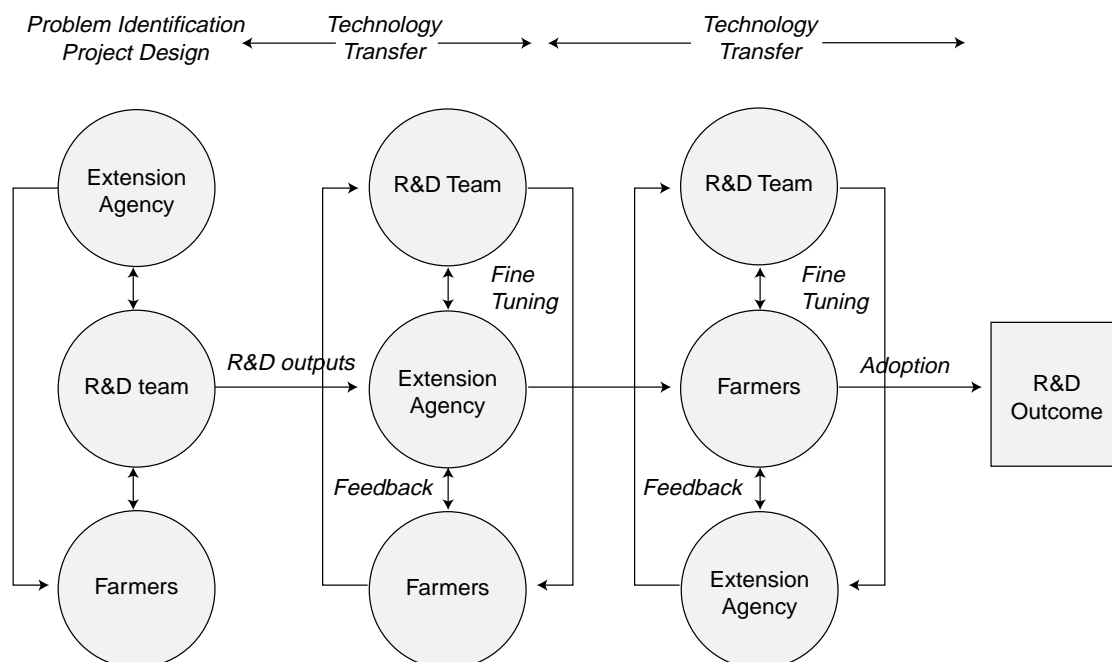


Figure 7. A participatory model of R&D information exchange



⁵⁰ Some useful empirical insights are now being provided by *punctuated equilibrium* models (eg. Gersick 1994).

Most, if not all, R,D&E projects are comprised of stages in which the focus of effort varies throughout the project's life (eg. Figure 3). The amount of effort committed and the personnel involved vary naturally throughout these stages. In a management sense, it would not be reasonable to expect that all parties would be equally involved in the day-to-day activities of the project, and some individuals or groups would be expected to have a greater or lesser interest or commitment during any one particular phase (episode). A second factor, promoting an episodic character is that, for many large or specialised projects, the staff complement will include certain individuals (or groups) who are simultaneously committed to several different projects (McGrath 1991). In this sense, their involvement is not just episodic in terms of task requirements, but also because of their other commitments. Unexpected, interesting and/or disappointing findings can call forth increased or decreased interest from various team members or external stakeholders, including those previously uncommitted to involvement with the R,D&E activities. Examples of external sources might include such factors as climatic effects (eg. drought, floods etc) that prevent certain experiments or demonstrations proceeding or being drawn to a successful conclusion. Loss of key personnel through promotion, transfer or staff cuts are other factors that easily come to mind. Finally, management reviews (inspired by 'double-loop' questioning, for example) which might result from the influence of either internal or external factors may lead to increased or decreased commitment of resources or support to a given project. Each of these was experienced, for example, with respect to the two case-study R&D projects.

This episodic character and the implied changes in relative power for different team members and other stakeholders suggests a further dynamic for arena models—a 'temporal' dimension. Rather than depicting an R,D&E issue as a single ongoing contest, it may be more appropriate to think in terms of a 'series' made up of constituent 'matches' with various feedback connections between them. Outcomes are then the aggregate effect of the outputs of each of the matches (episodes), and tactics can be revised according to progress between the various episodes. We have attempted to capture schematically in Figure 8 the process we envisage.

In Figure 8, the R,D&E for a particular project context is depicted as a series of interactions (arenas) between R,D&E personnel and various stakeholders through a loosely structured sequence of engagement episodes. In each episode, the various participants are assumed to interact after some 'negotiated' fashion and within the context of the R,D&E 'goal' as each participant or grouping perceives (or wishes) it to be. Various stages of the R,D&E process (eg. problem identification, design, technology generation, technology transfer etc) have not been specifically delineated, as these distinctions are no longer easily identified. Also, as argued below, there is no certain guarantee that the participants or the process will actually move through these different stages within the life of a project. The groupings in each episode

could be likened to an AKIS and could involve many participants acting in the three arena model roles (eg. contestants, spectators, and commentators). For convenience and consistency with the earlier communication models, only four groupings are shown; viz the R&D team (R), extension agents (E), farmers (F) and other stakeholders (O). The last-named group is used as a 'catch-all' grouping, which can embrace spectators and commentators (including previously uninvolved R, E and F groups) who in subsequent episodes become interested enough to participate. This engagement may be by invitation from existing participants or perceived self-interest. The size of the circles is intended to convey some sense of relative commitment or power of each group at each time.

At the start (episode 1) we have assumed that some projected outcome has been negotiated for the R,D&E endeavour between the various participants. For the want of a better term, it might be noted as the 'ex-ante objective' or 'ex-ante outcome'. There are many ways in which this ex-ante objective or outcome might be established.

For example, it might be negotiated between some or all of the parties (eg. using focus groups, search conferences, negotiation etc), commissioned by a funding-agency, or simply dictated by the R&D planners and promoters as is common R,D&E practice. Its main purpose for the present model is to state where the R,D&E process and presumably the R&D managers, their team and backers (eg. funding bodies) intended to proceed. In passing, it might be noted that the first episode need not involve a 'clean slate' start with a newly identified research problem. It might be, consistent with the 'garbage can' model (Section C.3.2), an extension of an older or concurrent R,D&E initiative or, as is also common with much existing R,D&E practice, built onto an existing infrastructure. As depicted, the relative commitment or power distribution initially favours the R&D team. This need not be universally true but recognises that much R,D&E is initially driven by 'champions' (commonly project leaders and Program Managers) from within the R&D-providing agencies.

As the life of the R,D&E endeavour unfolds, and both internal and external forces come to play, the project moves through a series of separate episodes. The actual number of episodes will vary from case to case depending on the context within which the episode-generating forces are acting. The model as illustrated simply attempts to convey the concept that the R,D&E process is episodic. Moreover, the distinction or boundaries between episodes need not be clear, but rather could represent 'punctuated' segments of an otherwise steadily evolving set of circumstances or relationships. In this sense, they might be similar to the 'state' concept incorporated within the new non-equilibrium (state and transition) models of vegetation change under grazing (eg. Westoby et al. 1989) in which some 'states' are determinate while others are essentially characteristic of significant patterns observed during major ongoing 'transitions' between such determinate

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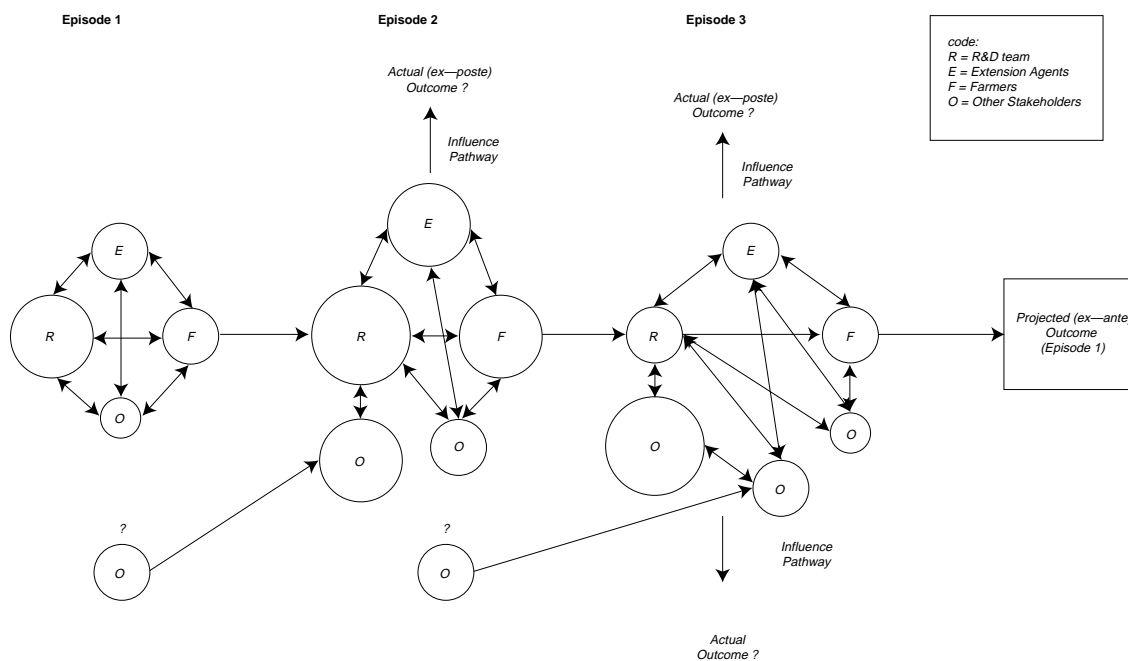
'states'. Depending on who is involved within each episode, and their commitment or power, the process may move towards the ex-ante goal or some 'negotiated' revision of that goal. The direct 'inception to realisation' path (ie. from ex-ante plan to ex-ante outcome) is commonly assumed to represent some sort of 'default' sequence in project management theory and practice. However, in the absence of purposive management, the process will possibly follow some path of 'least effort' or 'satisficing' agreement (McGrath 1991). In that case, the interaction between the different participants, including new participants, and the effect of previous actions (including escalations of commitment) and circumstances (eg. climate, organisational change) may be such that the process leads to substantial shifts away from the ex-ante goals in new directions towards other ex-post outcomes.

These changes, depicted as moving along 'influence pathways', may also involve further episodes with different configurations of participants and relative sharing of power depending on how the engagement is negotiated and managed and which forces operate on the process. The actual (ex-post) outcomes may or may not bear some relationship to the original (ex-ante) goal. They may also be considered to be acceptable, or otherwise, to some or all of the individual participants to the R,D&E process. The main point is simply that the ex-ante and ex-post outcomes can differ and that these differences might be viewed as a resulting from a combination of circumstances, power-relationships and context. If the actual outcome or direction (suggested by the relevant influence pathway) is not judged by a particular participant

to be desirable (from their perspective) then it may be possible to effect a return towards the desired target through some form of conscious management. Of course, all of the participants may well be attempting to do this and so their overall success will, ultimately, depend on their skill in manipulating the arena that is operating within a given episode, or in shifting it (thereby creating a new episode). An important consideration for publicly-funded R,D&E agencies seeking to address 'public good' issues such as sustainable land resource management is that the ex-ante goal and associated outcomes may remain socially-warranted targets. To achieve these outcomes will require vigilant and consistent management which, in turn, can be supported by a conscious shift to a greater willingness to engage in 'double-loop' questioning of both strategic and tactical project performance. Moreover, it should be apparent that simply 'empowering' various stakeholders to an R,D&E-focused problem is no guarantee that a socially integrative solution will actually emerge.

Finally, before returning to a specific review of the CTC2 interventions within the context of a punctuated arena model, an obvious deficiency of 'mapping' an AKIS in a static sense (Sections B.3.1, D.2) can be illustrated using Figure 8. Were one to 'map' the AKIS as it stood during any of the episodes depicted, even if the connections and relative power influences were correctly identified, this may give only a transient and, hence, misleading picture. The AKIS is dynamic, and as each episode unfolds within the life of the R,D&E process the 'map' and any insights it might provide can become increasingly inaccurate.

Figure 8. An arena model of information R&D exchange



D.4 The CTC2 model revisited

With the advantage of hindsight from the practical experience obtained in conducting the project, the subsequent review of its performance and the insights offered by the dynamic Punctuated Arena Model (Section D.3.4), it is possible to make some suggestions for modifying the approach taken with an aim to better meeting the original objectives. In doing this, we pursue two major arguments. The first is that in initiating the project we uncritically assumed that the model and its components would work. In taking that position we failed to clearly recognise the nature of the arena that the project and its constituent case-studies would be operating within. We also critically misunderstood the projected (ex-ante) outcome of the case-study R&D project with which the project had the strongest engagement (GLASS). The second argument is that the CTC2 model components, in themselves, were not necessarily inappropriate to the task. A major failing lay in the manner in which they were configured and it was proposed to undertake them, which was not appropriate. This is in the sense of both appropriateness with respect to the projected case-study R,D&E outcomes, as we understood them to be, and the developments that were occurring within the arena at the time the interventions were meant to be implemented. These are, of course, co-related as the arena has a major impact on the projected outcomes and their ongoing relevance to the R&D teams and the other stakeholders.

D.4.1 The arena

At the time that the CTC2 model was proposed, and at times during the life of the project when the various interventions were being attempted, we did recognise some aspects of the structure of the arenas within which both CTC2 and the case-studies were engaged and our respective performances within these arenas. For example, different stakeholders and some of their interests were recognised, including the potential for these to be in conflict. Competing projects (eg. the MRC-supported LCD) and interests (eg. NAP2) were also recognised and some major 'setbacks' that these caused were also recognised. Various distinct episodes of engagement in R&D activity and direction were recognised (eg. new project leaders, a major resowing of one case-study etc) along with their effects on project performance. However, it was only late in the life of CTC2 that we began to totally appreciate the scope of the relevant arenas or the full implications of their existence for both R,D&E management and likely outcomes. Were this revealed earlier, our approach to both the design and management of the project would have been much different. It would have been more specifically directed towards operation within an arena with shifting patterns of engagement, transient objectives and variable performance, including the effect of several major internal and external episode-generating forces. That is, while CTC2 as proposed saw itself as being a proactive initiative for effecting desirable change in technology

transfer practice, as it was implemented it became reactive to each unfolding development within the arena.

The CTC2 model approach was based on premises that included some complex relationships and problems for technology transfer management (Section B.2). However, in many instances these were not necessarily the relationships or factors that were to give rise to the major technology generation or transfer problems experienced by the two case studies. For example, while conflicting stakeholder interests and communication inefficiencies were identified as potential problems areas, it was assumed that these could be overcome through increased opportunities for participation and open exchange between the various parties. Underlying this was the view that the various stakeholders would want to move towards a common desired objective. This ignored the reality that the positions and interests may be entrenched or partitioned within other arenas of which CTC2 had little understanding or influence over. Potential escalation of commitment problems were not included within the original premises and these were, in hindsight, a major aspect of both CTC2 and the case studies. External forces over which the case-study projects had little control, such as the drought and a significant redeployment of staff and other resources within the respective parent R&D organisations, also had a major impact on the projects' ability to deliver their projected outcomes. These external factors are not typically factored into technology transfer failures. Therefore, a major deficiency of both the CTC2 model and the general R,D&E management of the case-studies was their failure to incorporate 'early warning signals' for such developments and/or contingency planning to overcome or lessen their impact. A greater failing was, perhaps, not recognising the importance of including provisions to promote or ensure a commitment to enhanced organisational learning. This particularly applies to the promotion of regular sessions of 'double-loop' strategic questioning of where the projects were heading and what they wanted or needed to achieve and the most appropriate means of doing so. Had this been done, there would have been more scope for recognising, and intelligently reacting to, such fundamental issues as a realisation that the proposed project outcomes or the way of attaining them (ie. manner and pathways) may no longer have been appropriate.

D.4.2 Uncoupling the interventions

In several sections (B.4.2, C.3.4, C.6), the ordering and tight coupling of the CTC2 interventions were highlighted as serious deficiencies of the proposed model being tested. However, in other sections (eg. B.5.2) it has been suggested that each of these interventions, in their own right, might have offered definite value for R,D&E managers seeking to improve the performance of their projects. That is, none of the model interventions was actually proven to be ineffective or unwarranted. However, because all of the interventions were not actually tested, this viewpoint is speculative.

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In hindsight, the various interventions might be better seen not so much in terms of a fixed (or interrelated) sequence of phases or activities but rather as a set of alternative kinds of activities that the R,D&E teams or their managers may elect to engage in according to circumstances. Although a given R,D&E endeavour may be designed to take advantage of all of the proposed interventions, it would not be necessary, or even necessarily desirable, to do so. There are many different time-activity paths that might be optimally pursued according to the specific circumstances being faced by the project managers (McGrath 1991). Ideally, the choice will involve the least resource-demanding and complex combination that the project goals, resources and circumstances warrant. This also allows for both the possibility of multi-possibility and equi-finality in approaches which is, according to the degree of purposive management pursued, consistent with many action-research ideals of allowing the agenda and thrust of the R,D&E to flow in the directions desired by both reality and stakeholder preference. It is also consistent with the reality of the punctuated arena (Figure 8) in which actual (ex-post) outcomes may diverge from the projected ex-ante outcome. The point being made here is that R,D&E managers often have legitimate agency (eg. vested on behalf of society) and may well seek to direct the path that their work and investment is following.

Consistent with the dynamic arena model, the individual interventions could have a role to play in moving R,D&E initiatives towards desirable technology transfer outcomes. On the other hand, they might not. A key factor that might ultimately influence this lies within the specific project and its participants' objectives, and the context within which the R,D&E is operating.

For example, the focus group intervention had a projected role (Section B.3.2) of opening a dialogue between the R&D team and other potential stakeholders (contestants within the arena), commenting on issues relevant to the R,D&E and/or seeking consensus on the projected outcomes. However, this intervention could also be consciously used to lay down the rules of engagement and direct any consensus on the projected outcomes if this is judged to be warranted. The idea that a focus group might be consciously managed or manipulated should not be taken with excessive alarm. It essentially recognises the reality that at some stage in any participatory R,D&E venture a decision has to be taken on who is to be selected as representative stakeholder participants and the basis on which their participation is invited.⁵¹ This choice and the underlying conditions, no matter how idealistically motivated or liberal, will inevitably influence the R,D&E direction that is ultimately pursued (ie. the influence pathway).

Other forms of engagement that involve different implicit or explicit powers of engagement for different stakeholders are possible. For example, as an alternative to focus groups or similar search-type conferences, the advisory committee that is a common feature of many R,D&E agencies and funding-agencies can also represent an opening forum for engagement by stakeholders. The power relationships involved with such alternative arrangements will vary with the group and its relationship to the R,D&E team, the parent agency or funding source. For example, while it would be natural to assume that an R&D team would take some notice of the recommendations of an agency advisory committee, it is more likely that an advisory group attached to a funding agency (eg. the MRC Technology Transfer Advisory Group—TTAG) would be taken more seriously. This would be the case even if the latter were notionally acting in a voluntary and independent role. It would not be unrealistic to assume that the proposed outcomes of the R,D&E and the actual influence pathways would vary according to which type of engagement was selected, even if these notionally drew on the same sets of stakeholder interests.

If for some reason it was determined that the ensuing influence or direction needed to be checked, then it would be feasible to invoke further interventions to redirect or otherwise manage the process. This might, for example, involve the relevance audit or technical reference group acting in their projected roles (Section B.3.2), or some other intervention including a direct invitation for other or different stakeholder representatives to become involved. In the case of the relevance audit, the fundamental approach and direction (ie. the particular influence pathway operating at that stage) is opened to 'wide' scrutiny by a potentially diverse array of stakeholder interests and may be changed. The technical reference group is notionally narrower in its focus, but could still conceptually act through its provision of technical advice to swing the R,D&E in another direction or hold it to the original path (ie. acting like one of the 'O' stakeholder groups entering the arena in Figure 8). By inference, the individuals associated with these interventions have interests, credibility and power which will come to bear on the arena processes. Moreover, they have to be selected and invited to engage with the R,D&E project and, like the case of the focus groups and other forms of advisory/screening input, the choice will have an impact that is either autonomous or amenable to manipulation. How this is used and its effectiveness will depend on the motives of the R,D&E managers, their decisions and the consequent actions of both the new stakeholder/participants and those that are already engaged.

Other interventions that were part of CTC2 model could also impact to some extent on the R,D&E processes within the punctuated arena. For example, the survey activities and other forms of data collection and feedback (eg. semi-structured interviews, informal meetings, etc) are not necessarily neutral in their impact on arena behaviour. By

⁵¹ In fact, consistent with the 'garbage can' model (Section C.3.), much research is initiated with some very firm ideas of general outcomes or approaches and which stakeholders to engage and how.

providing additional information or by influencing the perceptions of different stakeholders, power relationships and strategies can be altered. As is the case with the more formal interventions, this can occur autonomously or be managed. The extent to which the latter occurs is also an open decision of the R,D&E managers, tempered by their relationships with the different stakeholder interests.

Which interventions or strategies might be appropriately selected to direct or accommodate the R,D&E process, and their timing, is a matter of sensibly operating according to circumstances. This, in turn, will be dictated by management choice, and is itself ideally influenced by a combination of judgment, experience and context. However, the episodic nature of the R,D&E process (depicted in Figure 8) would suggest that there are potential punctuation points within the life of a project during which some of the interventions might have most impact. These punctuation points, if recognised as such by R,D&E managers, would also seem to be appropriate stages for taking serious stock of where things are going; that is, to engage in 'double loop' review activities. This could be accomplished by the managers acting alone or together with project staff or peers. Alternatively, it could take place within the context of the operation of more formal interventions such as the relevance audit or technical reference group. In fact, the activities associated with the preparation for such interventions can play a significant role in focusing R,D&E teams on their present performance and the direction of their activities. This was evident, for example, for the GLASS team preparation of its 'message' for the focus group meetings (Section B.4.2, B.5.2). Two key questions that would appropriately be addressed at such review points are whether the proposed project outcomes and the means for attaining them are still appropriate. These, of course, were a major motivation for the including the relevance audit and technical reference group in the original CTC2 model.

However, these two specialised interventions could also have played other roles to those envisaged at the time the model was conceived. For example, a major role of the

technical reference group was to assist the R,D&E team in interpreting its findings and/or generalising from them. Nevertheless, it is also likely that episodic review by a panel of technical peers might equally have identified escalation of commitment problems associated with a particular aspect of the project design or its execution. If sufficient early warning signs are available and/or understood, the R,D&E managers might also take the opportunity to seek expert advice to either point it out to the project team or to recommend possible amelioration strategies. Escalation of commitment to technical pathways that can lead to failed outcomes might be avoided in this way. A key requirement would be to maintain flexibility. For example, an annual meeting of a reference panel may not be sufficiently flexible to address these types of issues. The relevance audit was scheduled to occur within the middle life of a project to affirm ongoing stakeholder commitment to objectives determined in the early stages by the focus groups. However, as implemented for the GLASS project, the focus groups largely took on many aspects of this role but were not able to do much to effect changes in the basic research thrust given the pre-existing infrastructure and research design. The Program Managers may have more forcefully used an intervention such as the relevance audit to effect the restructuring that was eventually forced upon them much earlier than did occur. Were this to have been done the escalation of commitment would have progressed less far and potentially carried less of the consequent staff and financial costs.

Another aspect of the CTC2 experience related to the generally disappointing findings concerning team and experimental synergy (Section C.6). These run counter to a general assumption concerning the value of multi-disciplinary or systems-based R,D&E efforts (eg. Stuth et al. 1991). The CTC2 interventions could conceivably act as catalysts for identifying and rectifying some of these problems. This, for example, was argued above to be one effect of the focus group intervention, but would seem intuitively to be a potentially more significant spin-off from the technical reference group.

Section E

Moving towards the 'learning' organisation

E.1 Learning from the 'learnings'

In initiating project CTC2, we were motivated by a strong desire to improve the technology transfer performance of larger scale agro-environmental R,D&E projects. To this point, our reviews have collectively suggested that this ideal is more likely to be achieved if there is a shift in R,D&E paradigm to that of the 'learning organisation'. This is particularly consistent with our argument that technology transfer failures are not the exclusive domain of either the research or extension components of the technology generation and communication process. Such failures may arise through more fundamental failures in the ways that R,D&E problems are formulated and their potential solutions are managed within a both a project and an organisational framework.

The perceived need for a paradigm shift is also consistent with the tight coupling-complex system failure, intelligent failure and strategic organisational learning ('double loop') concepts highlighted within the earlier sections. The punctuated arena model (Section D.3.4) we have developed and presented also highlights the potential value of these concepts in terms of managing the dynamic processes inherent in multiple stakeholder participatory models for achieving integrative R,D&E outcomes.

In large part, many of the insights relating to aspects of poor R,D&E management performance that we have obtained are not necessarily new and could be addressed through immediate action on the part of both the R,D&E-providing agencies and their funding partners. This particularly relates to actions which promote better project design and management, team selection and building and so on. Indeed, some steps have already been taken in this direction. Two examples, are as follows:

- a. New initiatives promoted by IWRRDC in the area of regional land resource planning were planned on the basis of adequately resourced scoping exercises (eg. IWRRDC Commissioned Project CTC8). This approach can promote a more rigorous and fair assessment of the nature of the researchable problem, and more intelligently identify the feasibility of various approaches that might be followed. It also provides an opportunity for the potential R,D&E managers to build up a genuine commitment to the project and its objectives with various collaborators and stakeholders before the implementation of the R,D&E.
- b. Another area for improvement of project design and management that could well be initiated within the existing structure of R,D&E practice is the evaluation of project

performance. The present evaluation systems centred on SMART milestones and GANTT charts are not necessarily effective and can lead to sub-optimal performance under many circumstances, particularly where the milestones become ends in themselves and/or promote escalation of commitment problems. Moreover, many of these performance assessment devices are more appropriate to the former output orientation of R,D&E and have less relevance to the newer outcome orientation. A preferred option might be to seek a mature relationship between projects and their financial sponsors within a learning environment. Under such an arrangement, milestones may be replaced by review points at which the R,D&E teams and their funders come together to examine performance against objectives and explore different options for future actions that are consistent with the context of the research and the desired outcomes as they stand at that time. To a large extent this type of relationship was enjoyed between the CTC2 team, the Program Manager and the Resource Management Committee during the second half of the project.

Beyond these two specific examples, there are many actions that R,D&E-providing agencies are beginning to take that should strengthen project performance and, in turn, promote more favourable technology transfer outcomes.

However, a key insight relates to the fact that even in the many cases where problems are recognised and remedial action is readily available, they are not necessarily acted upon. This is a central theme of the strategic organisational learning process promoted by Argyris (Section C.3.5). Team performance problems, unstable networks or alliances, inflexible project designs, the inappropriateness of milestones to an outcome-orientated R,D&E paradigm, questions of stakeholder involvement and the terms of engagement, and so on, are not new concepts. Their adverse effects have presumably been observed within R,D&E practice for many years. The major issue that now requires attention is the fact that the present organisational and institutional structures within which much R,D&E practice operates seem to place so little value or emphasis on questioning and learning from these experiences. That is, these structures do not encompass or accommodate an environment from within which the problems are directly addressed and acted upon. Organisations promoting and supporting such an environment would be characterised as 'learning organisations'.

Other insights derived from the CTC2 experience are, we feel, genuinely new learning. These are also consistent with the ideal of fostering change through the establishment of 'learning organisations'. For example, escalation of commitment difficulties within an R,D&E organisational context has not been a feature of previous work in this field and there is considerable scope for expanding on the insights of the Ross and Staw escalation and exit model (Section C.3.3) for improving R,D&E performance. This particularly applies to both understanding the forces that can promote an

undesirable escalation and managing appropriate exit strategies when an escalation has been observed. Further development and the potential application of the punctuated arena model offers considerable scope for understanding and improving many aspects of R,D&E performance particularly the nature of episodes of engagement. For example, issues of identifying desirable forms of collaborative alliances or deciding which stakeholders to involve and the terms on which the engagement is managed may be addressed through this model. Another issue for which the model can offer useful insights is the formation and structure of multidisciplinary R,D&E teams. The addition of new specialist or disciplinary skills to a team (eg. economists, sociologists, communication experts) and how the teams are arranged or 'packaged' will alter power balances and potentially impact on the direction in which the R,D&E proceeds. Both examples represent cases which R,D&E managers can either reactively or proactively manage in their attempts to attain projected outcomes.

Therefore, despite the valuable insights that we were able to obtain from CTC2, and the attempt that has been made to truly make the CTC2 experience a positive learning vehicle (ie. an intelligent failure), we feel that our work has proceeded only part of the way towards the ideal we are seeking, which is to more fully entrench organisational learning practice within the prevailing R,D&E culture. To this end, the potential learning from CTC2 remains incomplete.

In the following sub-sections, a proposal is made for further using our experience and the theoretical constructs underpinning the CTC2 review framework to reinforce the thrust for a changed approach to learning from experience and to avoid unnecessary escalation of commitment to benefit the future conduct of R,D&E. This involves a set of activities that necessarily follows on from what we have achieved within the life of CTC2 and is consistent with two major themes of our findings.

E.2 Theme 1: Intelligent failure, early warning signals and experiential learning

Technology transfer failures are best examined within the broader context of R,D&E project planning and management performance, and hence risk. Therefore, an initial set of activities centres on exposing practising managers to such risks, and seeking to have them share their own experiences in the light of ours.

Two key areas for avoiding or mitigating project management risks are 'learning from experience', or using that experience within an 'intelligent failure' context, and recognising early warning signals of imminent 'failure'. Individual managers may be able to recognise early warning signals, or these may be constructed on the basis of reflection. Other managers may have developed decision heuristics to

avoid or overcome the traps. These may relate to escalation of commitment and failure or success in effecting appropriate exit strategies; complex structures and systems (DEPOSE) and tight element coupling; or recognising the nature of punctuated arenas and managing alliances and stakeholder commitments within them. The proposal is to formally capture and share these experiences.

This is to be achieved in the first instance through a process of further development and extension of the evaluation framework discussed in Section C.2 and the punctuated arena model of Section D.3.4. Material drawn from CTC2 and the two R&D case-studies associated with it could be used to start discussion at a series of workshops with other R,D&E managers and funding agency representatives to review that material and compare it with material drawn from their own experiences. This may require a system of several staged exercises to allow the participants time to reflect on the material and draw out their own examples or counter-examples.

The projected achievement or outcome of this component of the proposal is that the managers exposed to this material and process should be able to more quickly identify and manage the consequences of failure-promoting structures and developments within their workplaces. The hope is too that it will promote the opportunity for more open questioning of project performance and procedures and a receptivity for the shift in paradigm towards 'learning organisations'. In this sense, the managers should be able to 'write appropriate scripts' for managing project risk. The challenge of the next stage is to establish a new culture which automatically 'enacts those scripts'.

E.3 Theme 2: Changing R,D&E cultures

The types of learning being advocated under theme 1 are not necessarily rewarded or reinforced within the existing R,D&E culture. Therefore, a concurrent set of additional activities centres on exposing R,D&E policymakers and administrators to the same concepts, with an aim to shifting the prevailing culture towards that of a 'learning' culture.

This stage of the proposed activity seeks, ultimately, to permanently reinforce the 'learning' of the first stage (Theme 1). That is, it seeks to promote the acceptance of 'intelligent failure' and 'strategic organisational learning' as valid concepts within the cultures of R,D&E agencies and funding agencies. By nature, R,D&E is typically characterised by a high frequency of failure. In that case, the key project management issues should not necessarily be related to avoiding failure per se, but rather to positively learn from it in order to make consistently better decisions in the future. However, because few organisations, including R,D&E agencies, actively encourage or reward 'failure' a change in their culture would be required to achieve this ideal.

This would be achieved through a concurrent series of workshops with senior R,D&E managers, policymakers and funding agency representatives that focuses on major aspects of organisational and institutional reward systems and other context determinants that minimise or promote 'intelligent failure' and effective 'organisational learning'. The material drawn from CTC2 and other R,D&E projects can be used to promote the need for 'organisational learning'. Such a forum might also discuss a set of specific recommendations covering a range of topics, including an insistence that final project reports include a section detailing the RD&E management implications of their conduct; the feasibility of academic journals accepting 'negative' results for publication; and the thorny issue of individual versus team reward structures.

Acknowledgments

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The project team also appreciates the willing participation of the R&D teams from the two projects that were selected as case-studies for the CTC2 communication model(s), and the other stakeholders who willingly participated in individual communication interventions associated with the project.

Finally, the remaining team members wish to acknowledge the role and enthusiasm of Mr Peter Vance who was seconded from the Queensland Department of Primary Industries (DPI) to act as project officer for CTC2. It was unfortunate that the severe health problems Peter encountered early within the life of CTC2 were such as to hinder his ongoing research effectiveness leading, ultimately, to the necessity to withdraw from the project in 1994.

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Appendix A Original project objectives

The original objectives for CTC2 as set out in the project schedule were as follows:

- a. To identify and test perceptions held by potential end-users of, and their reactions to, complex land management technologies;
- b. To understand both the bio-physical and socio-economic factors that might promote or hinder the rapid integration by potential end-users of sophisticated R&D-based technologies into complex sustainable land management systems;
- c. To identify differences between adopters and non-adopters of simple and complex innovations involving grazing land management (eg. species selection or using BandSeeding versus weaning and stocking strategies);
- d. To identify cost, economic constraints and spin-off benefits for the learning processes needed by potential end-users of these products, and the proposed communication processes, and assist with the cost/benefit analyses of the R&D products;
- e. To devise an effective communication and technology transfer framework or model to (i) adjust further R&D work to the needs of resource managers and (ii) improve adoption of complex land management innovations;
- f. To identify the relevance of the findings to other resource management R&D projects and extend them accordingly. While focused on the sub-tropical and tropical grazing lands of Queensland, the findings would have national relevance.

Appendix B Publications by project staff 1993–1995

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Appendix C

Project review

Review of draft report by Joel R. Brown, CSIRO Division of Tropical Agriculture, Davies Laboratory, Townsville, Queensland

Background

I was invited to review this draft report from my perspective as a CSIRO project leader and research scientist. I currently lead a project composed of seven scientists, eight technical officers and several students. Our primary role is to conduct research into the sustainable use of tropical woodlands for pastoral enterprises. We focus our work on grazing management, woody weed invasion and general woodland ecology. We receive funding from several external sources such as R&D Corporations as well as from internal CSIRO sources. We collaborate extensively with Queensland, Northern Territory and Western Australia agencies.

In addition, I have had extensive involvement with both technology transfer and research in both the United States and Australia in a variety of ecosystems with a wide range of problems. I am also familiar with the GLASS project and the ECOSSAT project.

Findings in the draft report: Phase I

I especially agree with the finding that producers value “negative information”. As we move from a production-oriented approach to research and technology transfer into the area of land management sustainability, it is important that we recognise that avoiding mistakes may very likely be more important than doing the so-called right thing. There are several authors that have defined the need to “stay in the game” or avoid negative results as more important than capitalising fully on every profit opportunity that presents itself. This approach to communicating the principles of sustainability seems to be much more palatable to land managers than it is to R&D Corporations and administrators only interested in funding “progress”. This is one of the cornerstones of our approach to technology transfer for sustainable grazing management and to-date we have had very good reception from producers.

I am less agreeable with the proposition that R&D managers may also value “negative” information. From my experience, and I have seen little to change my mind recently,

most managers want tangible positive outcomes that can easily be presented (i.e. a software package, a piece of machinery etc). Unfortunately, this also seems to be the attitude of many researchers.

In general, I agree with the finding that “open communication with external stakeholders can increase their appreciation of risks and uncertainties of science”. However, I really question whether most producers really care. Of course, there are some that care because they are interested, some that care because they are invited by R&D funding bodies or research agencies to serve in an advisory capacity and some that can adopt the principles of risk management from research and apply them to property management. In any event, I think we have to consider even an elementary understanding and/or interest a bonus and assume that only a minority will benefit from this understanding.

I am in agreement with the finding that “barriers to R,D &E were identified and conceptualised in a different and more integrative way”. I certainly feel that “a more sophisticated view may focus on a serious non alignment of R&D and stakeholder contexts”. With the current emphasis on Milestone achievement and accountability, it is virtually certain that research objectives will be achieved, but it is entirely possible (even likely) that research projects will do everything right and miss the mark with information transfer. The focus must shift to linking research outputs with information transfer programs focussed on adoption. *This is not the sole responsibility of researchers.*

I think it is also vitally important that research funders and providers consider that the research that needs to be done (for sustainable management) is not going to be overly popular with many producers. After all, if they were operating sustainably, then we wouldn't need the research, would we. After all, we have spent millions on stocking rate research, when even beginning rangeland management students have a good understanding of the general relationship between stocking rate and land condition. As long as there is no penalty for short-term land abuse, selling sustainability is going to rely on the altruism of (some) producers.

Similarly, the next finding “evaluation methods have to be appropriate to the intended aims of the project” is self-evident but seems to be ignored almost universally. It is more than common to see research projects that have very well defined objectives and milestones, but the stated outcomes are so far beyond what could be achieved it is ridiculous. Even further, if the stated outcomes were achieved, there is no conceivable way to measure them.

Findings of the draft report: Phase 2

Escalation of commitment

While I have little first-hand experience on which to evaluate this finding, it inherently makes sense. I have had some experience with “engineering creep” on components of larger projects and I put this in the same general area.

Complexity

I agree that complexity of the problems and the research needed to address them is a major challenge for R, D & E. In many cases (the hard ones), I would suggest that this is impossible and should not be attempted with the resources available. It is probably more realistic to bite off a small bit of the problem and make some progress while trying to hold the problem as stable as possible. After all, it took 150 years to get land in this condition, it is pretty unreasonable to expect that research is going to solve them in 3-5 years.

However, it is certainly no small task to stage this approach. It will require just as much effort and thought as designing the output oriented research we currently enjoy. The most immediate need is for a realistic examination of problems of sustainability and how long it is really going to take to get them under control. It also requires an admission that we are not going to solve the problems quickly or easily.

Difference between human infrastructure and technical infrastructure

I agree

Multidisciplinary R,D & E efforts do not guarantee integrative outcomes

I agree completely with this finding. It is rare that a true interdisciplinary project is attempted, much less has a positive outcome. However, I still think it is vitally important to maintain an interdisciplinary approach to complex land management problems. Perhaps if the emphasis in research projects was shifted to problem solving, including an initial scoping phase with key team members, then subsequent disciplines joining the team might be a bit more focussed. If the current situation (agencies contributing “spare parts”) continues, it is highly unlikely that we will ever develop a smooth running machine. The responsibility for this lies squarely with high level administrators, not with research scientists.

Complexity and tight coupling of project elements and assumed linearity of RD&E

I agree that in the quest for accountability, both funding organisations and research organisations have tended toward the paint-by-number approach to managing research. If there is one thing that is historically characteristic of successful research projects, it is the freedom to pursue new ideas that emerge once the research project is underway. Perhaps a clearer focus on what the research is intended to achieve and less emphasis on making sure everyone jumps through all the hoops on time might allow for a bit more creativity and even result in overachievement.

In spite of the masses of literature and experience that has emerged over the past decade to reject the linear model of research and technology transfer, it remains embedded in agency culture. I think this can be attributed largely to the territoriality continually exhibited by extension agents, research scientists and administrators. It seems to be more of a problem as budget constraints increase. Again, more of an emphasis on solving the problem might lead to a more integrated approach.

Tacking extension onto R&D projects

I agree, see above items.

Inadequate existing infrastructure

I agree in spades. However, I do not feel that merely additional resources will solve the problem. The solution lies in two distinct areas. The extension people must have a strong commitment to working with local people to solve local problems. In order to do this, focus must shift away from agency promotion, self preservation and “serving the minister”. I lack faith that this will occur.

The second is the need for a completely new set of skills. Extension is dominated by simple, production-oriented linear thinking. Few of these individuals have the education, background or desire to attack long-term complex land degradation issues. There has to be the same respect, internally and externally, for extension agents as for research scientists. There are a few around that could serve as excellent role models.

The notion of replication within RD&E

I agree. There has been a lack of scientific rigour applied to rural extension. While there are examples of projects that have worked well, the lack of rigour in monitoring and assessing project performance precludes the development of principles. A possible way to overcome this is the notion of “management by hypothesis”. This approach would allow managers to assess both sociological aspects of technology transfer programs as well as the technological validity of research.

Entrenched norms within the R&D agencies

Agree, see above.

The punctuated arena model for managing RD&E projects

In the short time I have been aware of this model, I have found it to be the most appropriate to date of managing and communicating the conceptualisation, planning, execution and wind-up of projects. My difficulty so far is in getting others to see the utility of this approach in deciding who should be involved at different stages. My hope is that both funding agencies and research organisations will adopt this model and implement in a transparent process.

Overall, I found the report to be an extremely readable document that communicated very well the nature of the research project. In fact, I thought the main body of the report might make an excellent book, with all of the intrigue and plot complexities of a Jeffrey Archer novel. I would like to recommend the Executive Summary as required reading for research managers. Better yet, I would like to have it considered as a required way of operating.

Case Study 5

Emerging Models for Improving Sustainable Resource Management Communication Practices

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Emerging Models for Improving Sustainable Resource Management Communication Practices

Art Shulman, Neil MacLeod and Robyn Penman

The purpose of this section is to bring forward nine paradoxes as a setting for examining the various adoption models that emerged within the program.

These paradoxes are used as a context for examining the progression of models which form the theoretical environment that the individual projects were attempting to improve upon. The section ends with a description of the models which emerged within the program.

Underlying Paradoxes

Improving R&D management practices starts with an understanding of what current practices are being used. When researchers guide, observe, and describe these practices they most often use references to Technology Transfer models, conduits and channels etc. without questioning the paradoxes that surround their use. Paradoxes are indeed plentiful in an age of uncertainty and increasing complexity (Handy 1994). As Handy points out, “paradoxes are like the weather, something to be lived with, not solved, the worst aspects mitigated, the best enjoyed and used as clues to go forward. Paradox has to be *accepted*, coped with and made sense of, in life, in work, in community and among nations.” (1994, p18).

Paradox of ‘sustainability’

A major objective of the program was to identify communication practices that facilitate sustainable resource management practices. Within each of the projects the concept of sustainability was problematic. The problem arises because its meanings are continually being negotiated with different, and often temporary, understandings being voiced by different people (MacLeod and Taylor, 1994). The ambiguity of sustainability has been evident enough for researchers to question its usefulness for engaging farmers in changing their farming practices (Cox, MacLeod and Shulman, in press; Ison 1993; Penman 1994, 1995). The challenge of this paradox is not in solving ‘sustainability’ but of managing within these changing meanings of sustainability. Again generalising from Handy’s generic tools for managing (1994), the time for engaging farmers in

sustainability dialogues is when they have the resources to invest in practices which are consistent with that current meaning of sustainability. Many of the projects conducted within this program took place under severe drought where farmers did not have the luxury of investing in and experimenting with proposed farming practices. Yet to a large degree the funding bodies’ expectations were that the projects would go on regardless of whether the producers had the requisite conditions to shift their land-use practices.

Paradox of ‘collaboration’

R,D&E success is quite frequently a matter of working with and through other people, and is often a function of how successfully individuals can coordinate their activities and, as stated in the previous paradox, how they manage within temporary understandings. All projects within the program involved collaboration of researchers with other researchers and their constituents. These collaborations are not necessarily isolated events and many of them are continuing. However, the paradox is that while people talk as if involvement is continuous and equal, these relationships are not continuous nor are they comprised of persons with equal expertise, authority or power. Involvement of constituents within project teams is at best episodic (Shulman, 1996b). The challenge of this paradox is identifying better ways of facilitating adoption within these episodic and often sporadic encounters, when the rhetoric speaks of continuous involvement and equal participation. Managing within this paradox is a major theme of case study 4.

Paradox of ‘work and efficiency’

This paradox is particularly relevant if we negotiate sustainable practices within a community approach as recommended within the Gray and Dunne project (case study 1). Some of the agricultural technologies to be transferred are aimed at increasing efficiency of production. Yet to take advantage of efficiencies usually means reducing labour time and costs and/or creating larger farming operations. This usually assumes that the time saved can be used for other purposes within the farming community and that a market exists for these additional tasks. However, what usually oc-

curs is that some people have lots of work and little time, while others have little work and lots of time. Forced idleness is the price we are paying for increased efficiency. The result is lumpy employment in our rural communities. The result of this, ironically, is higher taxes to maintain those who have been replaced by new technologies.

Paradox of ‘knowledge’

The Bellamy and Lowes and the Cox and Ridge projects in this program, like many other projects aimed at increasing sustainability, were wrapped around computer decision support or ‘knowledge’ systems. The MacLeod project was also aimed at developing knowledge systems but not tied to the development of software. Such knowledge, whether dependent on use of computers or not, is the new form of property. Yet knowledge does not behave like any other form of property. And, as Handy (1994) points out, herein lies the paradox. It is impossible to give or redistribute or transfer knowledge by decree to potential users (p24). Unlike other ‘products’, even if researchers or funding agencies are able to share the information or know-how with potential end-users, the originator still keeps it. It is impossible to take this new form of property away from anyone, and it is impossible to prevent others from getting it. Patent and royalty issues aside, as with other products, those who do have access to it are likely to have different capacities to use it. In this context, the distribution and useability of agricultural knowledge systems are lumpy. Many of the ‘political loyalty’ and ‘ownership’ barriers to adoption that were identified within each of the component projects can be construed within this paradox.

Paradox of ‘knowledge advancement, timing and funding’

Bytes of data that can lead to better ways of farming production are often unpredictable, and are not evenly spaced in time, space or quality. Furthermore, given the uncertainty of such factors as weather, the opportunities to test their usefulness are often opportunistic and not linearly distributed. Yet as indicated in discussing the paradox of sustainability, scientists are expected to meet milestones and conduct their R,D&E as if scientific enterprises were linear and predictable. The need to manage within this paradox was a challenge for the program and all its component projects, but is particularly well articulated in the MacLeod report (case study 4). Different models for managing within this paradox are presented in case studies 2 and 3.

Paradox of ‘scientific reporting’

Graziers and farmers report that knowing what doesn’t work or having information on practices which yield equivalent results are of real use to them in guiding their farming decisions. For many farmers, if scientists cannot produce

significant differences under ideal conditions then it is not likely that they will be able to do so under the less-controlled conditions which they operate within. This knowledge leads them to save time and money by avoiding the need to trial a more costly, but equivalent treatment and may lead them to choose a treatment which is less costly, but produces equivalent results. Yet scientists do not normally provide information in their field day appearances or in their articles on what didn’t work, only on what did work. It appears as if the scientist often regards confirmation of the null hypothesis of little value to others— besides not being publishable. Documentation of ways of managing within this paradox is presented in case studies 2, 3 and 4. Examples of managing within this paradox are also presented in Shulman (1996a).

Paradox of ‘outputs, outcomes and understanding processes’

The scientist’s attention is often directed at understanding the exact mechanisms that are involved in producing outputs. When a hypothesised underlying process is demonstrated to be wrong, scientists tend to also degrade the output. But end-users may not. Producers are more interested in what works (and does not work—see above) and not necessarily if the reason why it works has yet to be established. The tendency of producers to engage in practices to produce what they value as a good outcome, but not for the reasons scientists believe are responsible for it working, is not new. The projects by MacLeod, by Ridge and Cox, and by Bellamy and Lowes all emphasised the need for scientists and research managers to recognise the differences between engaging in research that concentrates on process-output instead of process-outcome for improving sustainable practices. As can be seen in the next paradox, recognition alone of the paradox of ‘outputs, outcomes and understanding processes’ is insufficient for mitigating the worst aspects of this paradox, but can provide clues to go forward.

Paradox of ‘decision making and accountability’

Current management structures of R,D&E require that forecasts and decisions be made as if we knew the outcomes. As research by Pfeffer (1992) has pointed out, a decision by itself changes nothing. Furthermore, at the moment a decision is made we cannot possibly know whether it is good or bad. Decision quality, when measured by outcomes, can only be known as the consequences of the decision become known. But Pfeffer’s most important observation is we almost invariably spend more time living with the consequences of the decisions than we do in making them (p19). This of course applies to the decisions made by R&D managers and by the producers who are deciding and implementing sustainable resource management practices. And

here lies a paradox. Much of the reward system for R&D managers is wrapped around appearing to know the likely outcomes before the consequences of implementing the decision can be known. They are accountable for providing evidence for decisions, that is outputs, but not its consequences (outcomes) after the decisions are implemented. The project reports for case studies 2–4 do attempt to address the output–outcome gap aspect of this paradox but their authors, like most researchers, will have left this program (and be rewarded for it) before implementation and, as such, are not accountable for its consequences. The same cannot be said for most producers. They are accountable for managing the long-term consequences of the decision to implement sustainable management practices. While the program managers' and project leaders' awareness of this paradox increased as the project unfolded, a shift in institutional reward structures and policy which could provide alternative ways of managing the output–outcome gap within this paradox has yet to occur. An examination of the institutional aspects of this 'decision making and accountability' paradox is related to the next paradox.

Paradox of 'institutionalised learning'

Richard Bawden (1994) pointed out this paradox in his review of farming extension practices. Much of the effort to address sustainability has been directed at identifying new farming techniques. Yet, once identified, we invariably attempt to ground these new practices in old norms, beliefs and structures. We do not build upon these techniques within new sorts of inquiries which resolve incompatible organisational norms by setting new priorities and weighting the norms, or by restructuring the norms themselves. This is regardless of the fact that the radical reform may be needed to create widespread adoption of sustainable practices. Consistent with current organisational learning perspectives, Bowden suggests that the management of this paradox involves first recognising it through reflection and questioning why we are not restructuring the priorities (p258). All the project reports in this volume acknowledge and present their explorations in ways of managing within this paradox.

The above paradoxes are not exhaustive. However, they do form a set of conditions which must be addressed in our models aimed at improving sustainable resource management practices. They also can serve as criteria for examining limitations within the progression of models which form the theoretical environment that the individual projects were attempting to improve upon. The models used to guide and rationalise the practices of the R,D&E managers have largely evolved within four generations of R,D&E models.

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First Generation Models of R,D&E

The first generation models include linear transfer of technology models (ToT) and conduit models. Though often referred to under different names, they remain dominant in current R&D communication practice. All eight paradoxes listed above are ignored and not addressed within this set of models. Without exception, all project leaders initially tried to position their strategy for facilitating the development and adoption of sustainable resource practices as being different from those advocated within first generation models.

These models, which date largely from the 1950s (Roussel et al. 1991), typically portray scientists engaged in R&D as operating independently from others within the larger organisation in which a research team is embedded. The scientists are also assumed to operate independently from potential customers (or end-users) who exist outside the organisation. The parallel communication metaphor is the conduit metaphor, in which communication is something that is sent and received along conduits or held back. The role of communication specialists within these first generation models is to package messages at the invitation of the scientists. Within TOT, communication activities with internal stakeholders typically take place solely to secure resources at funding reviews on a cost-centred basis. Communication activities by communication specialists with parties outside the organisation are largely concentrated after the development stage has been completed. Organisations which follow such practices are seen as having general management remaining aloof and sometimes unaware of what research is being carried out. A manifestation of following these models is that work is done 'under the table' for fear that, should management find out, the research will be discontinued (Roussel et al. 1991, p26).

Reviewers specialising in extension for agricultural and environmental R&D, such as Russell and Ison (1991), Jiggins (1993) and Röling (1992), have concluded that these first generation R&D models (and the underlying conduit communication assumptions) have been of limited help in improving R&D outcome performance. MacLeod and Shulman (1996, 1997) have also reported that scientists who follow such practices are more likely to escalate resources and commitment to unwarranted research paths which may produce outputs, but fail to address the utility of those outputs (ie. outcomes) from the viewpoints of the identified stakeholders. This output–outcome gap is often treated as being symptomatic of an extension or communication packaging failure, although some researchers (eg. Cox 1993; Cox et al. 1996) see the problems as lying at more basic levels. This includes the relevance of the actual questions that are being researched.

These first generation models are still held up as appropriate by many scientists, particularly those wanting to be free to control what and how they go about their business

and take advantage of the serendipity (Roussel et al. 1991). However, pressures from funding sources, under economic rationalism, have forced many researchers to address the eventual use of scientific findings (ie. the scientific reporting paradox). This has led to other sets of espoused models with implications for the functioning of project leaders and extension specialists.

Second Generation (Participatory) Models of R&D

A key feature of the second generation (participatory) R&D models is that researchers seek to communicate with both management and pertinent end-users about what a specific R&D project is to achieve. These models are consistent with a market-driven, or user-first, approach. Some emphasis is placed both on demonstrating the relevance of the R&D activity and in being responsive to the needs of their clients (Roussel et al. 1991, pp30–32.) This second approach, which has been also labelled reverse flows (Roling, 1992) and the halfway house (Cox 1993), is consistent with the transactional model of communication articulated by Shulman (1976). It at least acknowledges a major aspect of the sustainability paradox that different constituents will view sustainable practices differently and at different times and may acknowledge the trade-offs within the ambit of the work and efficiency paradox.

Participatory R&D models involving an interactive dialogue between research providers and identified stakeholders throughout the life of a given project were being increasingly advocated by most constituents across the projects. However, this frequently involves an implicit assumption that participation per se would guarantee successful R&D outcomes. The process by which this occurs is rarely made explicit (Scoones and Thompson 1994) and, more often, participation is simply assumed to bridge the output–outcome gap.

Moreover, attempts to improve the transfer of science by providing feedback and initial consultation of potential end-users through extension or science communicators, operating as a facilitator and/or promoter, have not been very successful. Cox (1993), who was one of the project leaders, points out one reason is that, in practice, the feedback was not direct but selectively filtered both ways by extension or science communication personnel. This two-way filtering preserves the essence of the TOT model and allows scientists to continue to focus on problems which they see as important. Such filtering can also be interpreted as being consistent with the science communicator serving as a surrogate for the end-user. As such, it reflects the call for a market-driven strategy for R,D&E managers (QDPI, 1992). Direct contacts between scientists and their clients, when they occur, are often formalised around milestones, with systems of peer review involving the best talent and/or opin-

ion leaders. Roussel et al. (1991, p34) suggests that, because of differing vested interests of researchers from end-users, results (including negative results) of these formalised inputs are often selectively communicated to clients. Thus, the gap created by having little direct and open contact between researchers and the ‘real’ end-users has been regarded by some as fatal (McDermott, 1987). Some research organisations such as CSIRO in Queensland are at least acknowledging a need to close that gap in their strategic planning efforts (CSIRO, 1992; Shulman, 1996a). Such strategy statements, though a step in the right direction, have not as yet resulted in major changes in the behaviour of scientists or communication specialists. Rather, each has found ways of preserving the status quo of a separation of scientists from their public. The paradox of institutional learning has yet to be acknowledged.

Third Generation Models of R&D

Third generation R&D models, like the generation that preceded them, typically stress the importance of forming partnerships with other parties, particularly potential end-users and the agencies that service them. However, this generation of models specifically recognises that these partnerships will need to serve multiple needs which are commonly associated with different strategic stakeholders’ perceptions on various resource use issues. These differences include such considerations as their importance, posited relationships between cause and effect, and the perceived credibility of different sources of knowledge (eg. MacLeod and Taylor, 1993).

The existence of differing perceptions and interests is not necessarily a bad thing, as exemplified in the sage advice that ‘two heads can be better than one’. That is, the process of bringing together within the dialogue the different perspectives is seen as enhancing the potential quality of the important decisions. However, proponents of the third generation models, such as Roussel et al. (1991), also suggest that rational and fully informed decisions will be made only when there is mutual trust between the parties and a recognition that each stakeholder has a unique contribution to make to the management of R&D. With open communication, a package of projects and objectives can be agreed to which will guide the R&D towards fulfilling end-user objectives. Thus, communication between trusting partners is recognised to be the means of resolving inherent conflicts of interest. Within this framework, no single project would usually suffice to satisfy the interests of all the potential stakeholders. Rather a portfolio of projects is required to strategically balance “priority projects and technologies across business and corporate needs and opportunities” (Roussel et al. 1991, p38). For these authors, the desired technical results are specified at the outset in light of business objectives. Progress is reviewed and results to date are evaluated against expectations whenever significant exter-

nal or business events warrant such review and not against technical milestones (Roussel et al. 1991, p40).

We have some experience with the practical application of this third generation framework at both the project and program level. In two of the projects (case studies 2 and 3), the authors provide limited evidence of researchers, end-users and scientist communicators forming partnerships in which there was an engagement in problem-solving over a period of time that involved more than one project. These cases provide some evidence of the approach failing when mutual trust is absent and for projects moving forward when it is present. The program evaluation by the RDC manager and the commentaries by reviewers of these projects provide further evidence for this conclusion.

While few research organisations have formally adopted the portfolio management component of the third generation models, their underlying philosophy is quite consistent with the broader call for collaborative network structuring of organisations as a means of maintaining flexibility in dynamic environments (Kanter, 1994) and for minimising unnecessary and unwarranted escalation of commitment (Ross and Staw, 1994). It is also consistent, for example, with recent government initiatives in Australia which have led to the creation of Cooperative Research Centres (CRCs) as a means of reducing duplication of R&D effort and promoting synergy through collaboration versus competition for scarce research funds.

Within this set of models, R&D managers are invited to coordinate approaches for carrying on these negotiations and to convey and share the outputs of these joint decisions to other stakeholders. Moreover, this task is to be accomplished in a manner (unspecified) which will encourage trust among the members of the alliance. The assumption about different end-user viewpoints is compatible with those from within a psychological perspective of communication (Krone et al., 1987, pp25–27) However, our experience suggests that this perspective does not provide sufficient direction to R&D managers, in that it yields limited insight into the practical issue of dealing with the negotiations of meanings among the different stakeholders. Neither does it explicitly guide them in facilitating trust and trade-offs among stakeholders over a portfolio of projects. Rather, it treats meanings as being essentially stable, with each exchange represented as a single event. In other words, while this set of models does acknowledge and work within the paradoxes of ‘sustainability’, ‘knowledge’, ‘knowledge advancement, timing and funding’ and, to a limited degree the ‘paradox of collaboration’ (the discontinuous nature of involvement within the paradox of collaboration still needs to be addressed), the other paradoxes remain.

Most, if not all, of the first three generations of R&D models remain essentially linear and continuous in their description of the R&D process, and their authors assume too readily that the participants will be motivated to move towards

shared or negotiated objectives. Examination of the projects within this program and, subsequently, other R&D projects (eg. Shulman and Martinek, 1998) suggests that much R&D is discontinuous and is increasingly focused on alliances of multiple agencies. It involves different episodes of potential engagement with different stakeholder groups, and a shared commitment to a given outcome is not necessarily guaranteed, especially when the externalities, common in land resource management, are central to the underlying R&D problem. The possibility of multiple agendas or objectives and incompatible agency cultures and reward systems is commonly ignored, as is their potential to be both transitory and dynamic. Similarly, the objectives and power of parties who are not invited to participate or are given only token membership are also frequently ignored. When these various interests and power relationships are accounted for, commitment and progress towards common goals become less assured.

This also is a fair representation of the model in action for each of the projects in this program during its first year of operation. The next two models capture the direction of movement of the projects during 1993–96.

Fourth Generation Models of R&D

Fourth generation R&D models, unlike their predecessors, place increased stress on the role of stakeholder empowerment within an R&D setting that is best represented by a political arena. For example, Scoones and Thompson (1994) argue that agricultural R&D and extension activities are typically and wrongly depicted as representing a set of discrete rational and systematic acts. These activities are, in fact, part of a dynamic process of coming to terms with conflicting stakeholder interests, changing alliances and competing world views. Proponents of these models are also more likely to raise moral and ethical questions relating to who should be in control of the research agenda, and the social or structural changes that may be required to shift power back to the end-users. Proponents of these fourth generation models, such as Ison (1993), Jiggins (1993) and Scoones and Thompson (1994), would appear to take positions that are alternatively consistent with constructivist thought Giddens (1984), ‘structuration’ theory, or strategic constituency analyses in which the competing interests of stakeholders are prioritised (eg. Shulman 1993). Within this framework, meanings are not carried or transmitted, but are negotiated, shaped by R&D structures and, in turn, shape those same R&D structures. The models are consistent with calls for science communicators to assist people to build up their own knowledge and increase their capacity to use scientific information better. That is, there is a move towards self-reliance of the end-users, and some evidence is emerging that where end-users are encouraged to do their own research they are successful (Coffey and Clarke 1995, pers. comm.). Moral and ethical questions are more likely to be

asked about control of the R&D agenda and social or structural changes necessary to genuinely transfer power to stakeholders. Meanings are typically negotiated rather than transmitted between parties and shaped by R&D, institutional, community structures and habits, and in turn, shape those structures with an increased capacity for stakeholders to use R&D-sourced information better and/or do their own research. From the viewpoint of managing R,D&E within a political arena, a major concern becomes understanding the nature and rules of the relevant arena and generating and managing appropriate expectations within the partnerships and alliances therein.

From the point of view of managing communication within an R&D arena, our major concern lies with generating and managing appropriate expectations. Appropriate expectations are essentially those that are based on a realistic conception of the communication process and its inherently problematic nature. When the possibility is accepted of misunderstandings representing the norm rather than the exception, we will become much more alert for the problems and more able to manage them. In this sense, more realistic expectations will widen the scope of the R&D science communication role to become both an enabling and constraining device, depending on how well it is implemented and used.

Given this indeterminacy and instability of meaning and expectations, the management of meaning can be better construed as one of autopoietic deviation, amplification and counteraction. For example, Nord (1985, pp188–189) has argued that managing involves understanding both the conditions where small deliberate changes can produce a self-sustaining (deviation-amplifying) change in the complex system, and the conditions where the change will be overwhelmed by the system (deviation counteracted). When R&D actions are managed as if it were an innovation, then deviation-amplification occurs. When new technology is managed as if it were a substitution, then deviation-counteraction occurs. Either style of management depends on managing meanings.

However, recognition of these issues has provided very little direct insight into what constitutes good R&D outcome performance. In essence, the fourth generation models have not gone far enough. They commonly ignore or avoid specifically addressing the moral question of what are good communicative practices in situations characterised by the involvement of multiple and changing constituents. Nor do the authors of these models typically address pragmatic questions concerning methods to minimise the escalation of resources, while maintaining flexibility within an R&D program to accommodate the unexpected. Moreover, they fail to address the implications of discontinuous involvement of different constituents over the life of any given R&D project. Unfortunately, recognising these issues is, alone, insufficient to prescribe what might constitute good R&D outcome performance or how to achieve such performance. The fourth

generation models remain incomplete—commonly ignoring or avoiding difficult questions concerning appropriate communication and management practices for arenas characterised by multiple and changing constituents, or avoiding unwarranted escalation of resources or undue influence from particular stakeholders leading to less integrative outcomes. Importantly, they fail to address the outcome implications of discontinuous involvement of different participants over the life of an R,D&E endeavour. We attempt to do this via a fifth generation R,D&E model.

The Punctuated Arena Model—Fifth Generation R,D&E

In moving to a fifth generation of model we build upon an arena model (Cunningham and Barawryh, 1993) for addressing the *output–outcome* gap by emphasising (a) the opportunities for addressing the gap within changing and punctuated compositions of R,D&E arenas over the life of a project, and (b) how these opportunities are also likely to address the moral question of ‘what are good outcomes?’. The model is pragmatic and consistent with constructionist assumptions underlying an indeterminate learning organisation.

Arena theory suggests that the composition, predisposition, and relative power of different stakeholders will, ultimately, shape the range of possible inputs, outputs and outcomes including the size of the *output–outcome* gap (MacLeod, 1995). The management of arenas requires skill in activating the interest and engagement of some potential stakeholders and minimising the influence of others throughout the life of a given project. It is also necessary to identify and contrast their power, objectives and available resources and to devise communication and coordination strategies and tactics that are appropriate to meeting project objectives or re-establishing them in a mutually acceptable, or at least recognised, direction. While scientific technical infrastructure and luck are important in affecting the probability of outcomes, the selection and entry of additional stakeholders to the arena and their exit from the arena necessarily change the distribution of power and rules of engagement. In particular, the addition of stakeholders affects how decisions will be made and how the consequences of those decisions will be managed. Because these consequences can never be known until after the decision has been made (Pfeffer, 1992), how the arena dynamics are managed and changed to deal with these consequences is the major challenge that R&D managers face. These potential effects of changing the dynamics of the arena are importantly overlooked by most of the earlier models.

When the episodic nature of R&D is specifically considered, the probability of recognising the composition, context and control structure of an arena will increase. The arena so construed becomes a ‘punctuated’ series of are-

nas which may be both spatially and temporally related. We argue that this recognition within this punctuated arena model fosters a closing of the output–outcome gap in three ways:

1. It provides an opportunity for reflection within and between arenas. Such reflections are key indicators of having rational, transparent decision procedures. And in general, the use of rational decision procedures in complex situations, when accompanied with an implementation skill base, has been shown to lead to better outcomes for strategic innovations (Dean and Sharfman, 1996). When built into the episodic nature of R&D, the episodic use of these procedures gives rise to possibilities which can shape subsequent control structures and engagements, including minimising unwarranted escalation of commitment.
2. It provides opportunities for managing other inherent conflicts and unanticipated and unwanted consequences of R&D decisions that are consistent with action learning and theories of the learning organisation. But unlike the second generation participatory models, managing R&D as punctuated arenas creates possibilities for using the episodes to utilise the learning and strategically manage the involvement of constituents (MacLeod et al. 1996).
3. It increases the probability that a moral knowing of what are good outcomes will be recognised.

Any question of what is good—including what is good R&D performance—is necessarily a moral one, and R&D scientists have tended to treat morality as a concept that exists independent of the participants involved. However, under the fourth generation R&D model, we have argued that ideas do not exist independently of the participants involved nor can the meanings be completely determined. We draw on Penman's (1994, 1997) development of the implications of this constructionist view for addressing the question of what is good.

Penman (in press) uses the arguments of Hans-Georg Gadamer and John Shotter, two twentieth-century authors, that draw on different, but compatible, traditions. Both argue that moral knowledge is about doing. But Shotter expands on this by arguing that it is something that is about doing with other people. Moral knowing does not exist independently of a social situation, it is brought about within it. It is an understanding that arises from within the communication and reflecting upon the possible consequences of the R&D actions. It does not arise within the person but in the interactions of constituents. You cannot reiterate a long list of professional ethics for this form of knowing from; it emerges from what you do, your engagement with others. For Penman, this does not mean researchers and managers can or should avoid retrospective analysis. She extends Dewey's argument that both participation and reflection are

necessary—but that one precludes the other. You cannot be looking back—to study antecedents—while looking forward—to understand the possibilities—within the same communication process. For understanding the possibilities of R&D managers to foster good R,D&E performance we need to look forward. In looking forward we are presented with the unfolding of options and the closing off of others. Thus, by using the opportunities for selecting constituents, and then engaging constituents within an arena with reflection within its punctuations, the R&D manager and the participating constituents are in a better position to recognise and close the (moral) gap between output and outcomes.

The above argument has major implications for future research about R,D&E systems. It strongly suggests that the R&D system researchers and the managers understandings of the possibilities and constraints for minimising the *output-outcome* gap can best be advanced by actively engaging in the communicative activity of R&D and not just studying it at a distance. The episodic nature of R&D teams, documented through participant observation by MacLeod and Shulman (1996), provides the opportunities for researchers and managers to sequentially act in, and reflect on, R,D&E system processes. This is, in essence, best practice of good organisational learning (Argyris 1994).

When insights from the arena model are applied to managing R&D for successful outcomes, it becomes compelling to suggest that past attempts to initiate improvements in technology transfer may have failed because either (a) the R&D managers did not recognise the context of the arena they were involved within, or (b) the R&D project champions were unable to change the structure and performance of these arenas. When the episodicity of R&D is specifically considered, the probability of failing to recognise the context of the arena and control structure and make-up of an arena will increase. The arena then becomes a 'punctuated' series of arenas which may be both spatially and temporally related.

Based on our analyses within the post-termination episodes of a major project (MacLeod, 1995), it also appears that the temporal relationship can affect the perceptions and evaluations of outcomes recursively; acceptance of former outputs is often changed because of reinterpretations within a current arena—and visa versa. Failure to recognise and manage this punctuation will also increase the probability of a failed outcome (MacLeod 1995; MacLeod et al. 1995). We argue that the recognition of this punctuated arena structure and the appropriate strategic management of power relationships within a changing network of purposive stakeholder involvement can increase the scope for R&D outcome success.

A second major difference between these punctuated arena models and the previous R&D models is the attention given to these punctuations as significant opportunities for

science communicators to actively reflect and engage in the process. This gives rise to the possibilities which can shape subsequent engagements, including minimising unwarranted escalation of commitment. However, this new set of models views these opportunities for reflection as bringing with it a moral obligation (Penman 1996).

In this section we have provided a view of the evolution of R&D models and their implications for improving communication management of R,D&E. An analysis of the program projects gave rise to fifth generation R&D models in which a punctuated arena was proposed as a useful metaphor for understanding and managing communicative activities within R&D projects. Issues of avoiding unwarranted escalation and maintaining flexibility are addressed through the management of membership in a changing arena.

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