

Themes and experimental protocols for sustainable grazing systems

Edited by G. M. Lodge

NSW AGRICULTURE, CENTRE FOR CROP IMPROVEMENT

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The valuable input of many different groups and individuals into the development of the philosophy of an SGS experiment, the evolution of site and theme teams, and the establishment of protocols for data collection is much appreciated. Martin Andrew, AACM International, Adelaide coordinated the protocol development process. Databases for the national sites were constructed by Colin Lord, University of New England, Armidale and the SGS pasture model was written by Ian Johnson, Greenhat Software, Armidale.

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Summary

The rationale for the development of a national experiment within the Sustainable Grazing Systems (SGS) Key Program is outlined, together with a brief description of the sites, their focus of study and the results of a pre-experimental modelling process at three locations. The location and pasture types being studied for the six sites in the national experiment (North-West Slopes, NSW; Central Tablelands, NSW; Wagga Wagga, NSW; North-East Victoria; Western Victoria, and Western Australia) are described. The national experiment is also organised into themes (pastures, animal production, water, nutrients, biodiversity and economics) which have developed hypotheses based on the expected outcomes from the national sites collectively. Themes are fully integrated across sites by the use of a common database to exchange information, an SGS pasture model developed for use by the researchers and the requirements of the economics theme for data driven, biophysical models.

Protocols are outlined for data collection in the pastures, animal production, water, nutrients, and biodiversity themes. These protocols have been separated into minimum data sets and optional, additional data set that may be collected at each of the six national sites. Minimum data set must be collected at each of the national sites, using the procedures outlined in the protocol and at the frequency specified. While specific to these studies, the protocols also provide a valuable general reference for data collection in grazed temperate pastures.

Introduction:

Outline of the SGS national experiment

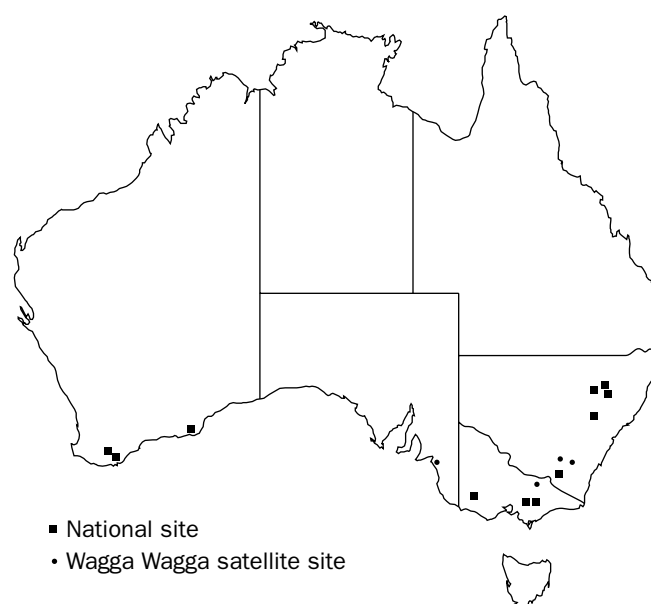
WARREN K. MASON¹ AND MARTIN H. ANDREW²

Sustainable Grazing Systems (SGS) is an initiative of Meat & Livestock Australia (formerly the Meat Research Corporation) and includes a range of collaborating partners. SGS is the second phase of a two phase process begun in 1993—the first phase was the Temperate Pasture Sustainability Key Program (TPSKP). SGS focuses equally on production and sustainability issues for the beef and sheep industries in the high rainfall zone (HRZ; >600 mm per year) of southern Australia.

The perennial grass based pastures in this region have the potential to meet the demands from premium markets, but the quality of the pastures has declined over the past decade or more. Pastures have not been managed appropriately; fertiliser use has reduced; pastures have not been resown; and pastures have been over-grazed in summer and autumn, and under-grazed in spring.

Figure 1

Location of the experimental studies at the national sites in the SGS national experiment



SGS combines the efforts of producers, researchers and extension agents into a focused partnership to develop, implement and manage grazing systems that are more profitable and more sustainable. There are three interacting elements within SGS: PROGRAZE[®] to provide training and skills development for producers; a network of 11 regional producer committees to manage local delivery; and a national experiment to develop the principles, tools and indicators that are needed for assessing and improving the profitability and sustainability of grazing systems.

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One of the features of SGS has been the high level of producer input from planning through to regional delivery, and this aspect of the program has been reported elsewhere (Mason *et al.* 1997). The focus here is the development and operations of a national experiment examining the hypothesis “that management practices can improve the profitability and sustainability of grazing systems in the HRZ of southern Australia”, and outlining its innovative features.

Planning the national experiment

Planning began in August 1996 with a call for expressions of interest from multidisciplinary teams who wanted to be involved in developing the processes, and conducting the experiment.

Experimental proposals were not part of the expressions of interest. Teams were selected on the basis of the skills of members and their apparent enthusiasm to become involved in developing and implementing an integrated experiment, tempered by a need for a geographic spread of the sites (see Figure 1 on page 1).

Research teams led by Greg Lodge (North-West Slopes, NSW), David Kemp (Central Tablelands, NSW), Anna Ridley/Bob White (North-East Victoria), David Chapman (Western Victoria) and Paul Sanford (Western Australia) were selected from the expressions of interests, while a team led by Bill Johnston (Wagga Wagga, NSW) was funded independently by the Murray–Darling Basin Commission to join the experiment.

Over a six-month period, site teams individually and collectively designed the activities for each site. While the individual experiments at each site are quite different, the common feature is a focus on grazing management within realistic animal production systems, with plots of sufficient size to allow reasonable expression of the important processes and outcomes for both production and sustainability.

Collectively, the sites planned to explore all the major production and sustainability issues within the following objectives:

1. to demonstrate that grazing management can increase pasture productivity and longevity;
2. to determine the profitability of the various grazing strategies within sustainability parameters;
3. to determine the management needed to provide critical groundcover for erosion and soil health;
4. to develop strategies which maximise wateruse and minimise rising watertables, salinity and acidity;
5. to identify strategies which optimise animal production and reduce nutrient losses, and
6. to determine the impact of grazing systems and management intensifications on biodiversity.

In the process of designing, planning and implementing the individual sites, the collective research team implemented three innovative steps: the creation of theme teams to manage the cross-site integration; undertaking a comprehensive, pre-experimental modelling exercise to ‘test’ the likely impact of treatments before they were implemented; and the development of a database system to both manage the huge data sets at each site and provide a mechanism for the theme teams to operate across sites.

Table 1
A brief description of each site in the national experiment

North-West Slopes, NSW	Three sites (two native and one improved), focused on groundcover, run-off, soil and nutrient loss, water infiltration, soil microbial activity and carbon cycling, and how these interact with productivity and profitability.
Central Tablelands, NSW	A native pasture site with a range of strategies, from low to high input (physical as well as managerial) to allow assessment of the productivity, profitability and sustainability of each option, and the impact of intensification of pasture systems on biodiversity. This site incorporates a lamb production and finishing system to produce large lambs out-of-season.
Wagga Wagga, NSW	A core site at Wagga Wagga, with a range of satellite sites in NSW, Victoria and SA to determine the extent to which native grass pastures in the Murray–Darling Basin can be managed for improved profitability and sustainability. The key focus is wateruse to reduce groundwater recharge.
North-East Victoria	Two sites, each with three unreplicated catchments (5–10 ha) to focus on catchment scale water and nutrient movement. Pastures at each site are: a typical pasture based mostly on annual species, and two improved perennial grass-based pastures with either high or medium inputs.
Western Victoria	A single site to optimise wateruse and animal production by managing interactions between grazing management, nutrient use, green leaf production, wateruse and animal nutritional requirements. This site incorporates a lamb finishing system.
Western Australia	Two sites at Albany and one at Esperance strongly focused on the role of perennial pastures to increase profits and wateruse. The biggest sustainability issue is dryland salinity, so there is a major focus on trees in grazing systems. The Esperance site includes the only beef production site in SGS; a comparison between beef production systems on annual or perennial pastures.

Themes

There are six ‘themes’ running across the national experiment. These are:

1. Animal performance and productivity;
2. Pasture production, composition and quality;
3. Wateruse, deep drainage and run-off;
4. Nutrient use and losses;
5. Biodiversity and nature conservation; and
6. Economics.

Modelling is not a theme; it operates across all themes.

There is a *team* (drawn from the site teams) for each *theme*, with the initial roles of:

- establishing a cross-site network of technical specialists;
- specifying the experimental protocols so that sites collecting the same information, use the same methods and the same recording system to facilitate cross-site analyses and modelling;
- specifying the minimum data sets that must be collected at all sites (including those without a major interest in a given theme) to enable modelling to be used for filling in the gaps at those sites; and
- agreeing on individual site specialisation.

As the experiments develop, each theme team has the responsibility for reporting annually on progress within their theme, and then for developing the principles, guidelines and indicators—and in some cases a suite of useable computer models. These will be provided to PROGRAZE and the regional producer network, for delivery or local demonstration. Theme teams and the associated modelling support are budgeted independently from the site/experimental budgets.

Every site must collect the agreed minimum data set for every theme—sites add to the minimum for those themes where the site team has a higher level of experience and/or interest and/or theme responsibility, as shown in Table 2.

Table 2
The matrix of sites and themes for the national experiment

Sites	Themes					
	Animals	Pastures	Water	Nutrients	Biodiversity	Economics ³
North-West Slopes	x ¹	xx ²	xxx	xx	xx	x
Central Tablelands	xxx	xxx	xx	x	xxx ²	xxx
Wagga Wagga	x	xx	xxx	xx	x	x
North-East Victoria	x	x	xxx ²	xxx	x	x
Western Victoria	xxx ²	xxx	xx	xx ²	x	xxx
Western Australia	xxx	xxx ²	xxx	x	x	xxx

1 x, xx and xxx indicate a low, medium or high input to the theme at that site. x represents the minimum data set.

2 Location of the leader of the theme team.

3 The economics theme team leader, Gary Stoneham, is located with the Victorian Department of National Resources and Environment, Melbourne.

All site teams meet annually in February to report on the previous growth season, and the theme teams have until June to integrate the site information into theme progress reports.

Pre-experimental modelling

This study (Bond *et al.* 1997) challenged both modellers—to link production and water models, and researchers—to quantify realistic scenarios. This significantly advanced both the way large-scale land management research is planned, and the links between modellers and researchers. The study showed that perennial pastures in winter rainfall areas (Victoria and south-west Western Australia) use a lot more water than annuals, roughly halving deep drainage (ca. 200 v. 120 mm/yr) and run-off. However, these perennial pastures cannot control rising groundwater and salinity in the long-term. To be sustainable, well managed perennial-grass based systems must be combined with trees or other deep-rooted species.

On the North-West Slopes of NSW deep drainage under perennial pastures was much smaller (5–25 mm/yr) than from the winter rainfall sites. This difference reflected the evapotranspiration pattern of the region, with most rain falling in summer, when evaporative demand is high, providing little opportunity for soil saturation and drainage below the root zone. Maintenance of groundcover was likely to be important in this environment for reducing the run-off and erosion from intense summer storms, and for reducing evaporation from bare soil to maximise transpiration.

Well managed, perennial-grass based pastoral systems appeared to be sustainable in this environment, at least as far as the water balance was concerned. The analysis emphasised the importance of different sustainability issues at the different sites and identified research goals for consideration by the various research teams as follows:

- The grazing treatments evaluated for perennials at the Western Victoria site appeared unlikely to result in significant water balance differences. A clear issue which emerged here was the importance of persistence of the desirable perennial species.
- The introduction of kikuyu and fescue pastures at the Western Australia site appeared promising, improving both the economic returns, and the sustainability of the system. Alley farming projects at the site also appeared well directed as the pasture system alone was not capable of controlling deep drainage.
- The North-West Slopes, NSW site reflected the climatic differences between southern Australia and northern NSW. The northern NSW summer-rainfall-dominant climate appears more conducive to supporting pasture systems which are sustainable in terms of water balance, with the management of surface vegetation cover being particularly important to manage erosion, run-off and evaporation.

Databases for the national experiment

The concept behind the theme teams in SGS was to shift the focus of the national experiment away from data analysis and reporting at individual sites, and towards interpretation across sites to facilitate the development of principles. These principles will then be made available (through PROGRAZE and the Regional Producer Network) as guidelines, indicators and/or best management practices for producers to customise for their individual circumstances and properties.

The mechanism for the theme teams to integrate data across sites is through relational databases specifically developed for each site.

Through the University of New England, SGS has developed a series of relational databases—one for each site in the national experiment. For an individual site the database provides:

- an extremely efficient data storage system: where all data from every aspect of the site, over the life of the experiment can be stored—data can be entered directly or through the importation of Excel spreadsheet or ASCII files from field data collection systems;
- improved quality of data stored: a quality assurance system scans all data as it is entered so that even very large data sets such as weather records can be trusted;
- enhanced ability to understand linkages between different data sets and improved data access which facilitates understanding of complex data sets without having to develop tables of means for the variables of interest;
- detailed interrogation tools to allow easy development of complex queries so data can be readily accessed for writing reports, graphing results, obtaining subsets of data for statistical analysis; and
- data in a form whereby related data sets can be gathered for modelling purposes: GrassGro, for example, can generate many different output graphs and the database allows data sets to be put in a form which can be compared with those model outputs.

For the theme teams, the common database structures will facilitate the analyses of theme data from across all sites to give full effect to this national experiment. In other words, the databases for each site are extremely useful, and likely to become standard operating procedure for all future, large scale experiments. Just as importantly, for the SGS sites, is the fact that all the development and the training of site teams in the use of their individualised database was provided by one person to ensure compatibility across sites. This will give the theme teams an extremely powerful mechanism to examine issues across all sites.

SGS has provided a new model for the collective development of large research programs, and for integrating research across geographical and organisational boundaries. In addition, the research is closely linked with the industry as it feeds directly into local testing and demonstration through the regional producer network, and into producer training through PROGRAZE.

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Background to protocol development

The SGS national experiment required that a minimum data set be collected at each of the six national sites to meet the objectives of the pasture, animal production, water, nutrient and biodiversity themes. These data must be collected using the methods and frequency of data collection outlined in the individual theme protocols. Protocols for optional or additional data are also given in each theme protocol. These optional data sets will not be collected at all sites, but will reflect the major focus of the individual sites. Obviously data other than those specified in the protocols may also be collected and again these will reflect the emphasis of each site. Each site is located on a commercial property (except at Wagga Wagga, NSW), has a site leader and associated group of researchers and technical staff (Appendix 1 on page 63) and the members of the individual theme teams have been drawn from these groups (Appendix 2 on page 65).

The development of the theme protocols was initiated at a workshop in Melbourne in December 1996 and has been an ongoing, evolving process since that time. Minimum and optional data sets were finalised at a workshop in Hamilton in March 1998. It has been a necessary, but time consuming task as individual groups have consulted widely and had to consider the problems posed by environments and pastures different to those that they are familiar with. The protocols developed reflect the input of a large group of people and not all of their efforts can be adequately acknowledged.

Working papers for the protocols have been circulated since February 1997 and these have been used by the national sites in the establishment phase of these studies. Some of the working paper protocols provided more detailed information than has been published here. In particular, the largest protocol (pastures theme) contained useful information on sampling precision and insect pests of pastures. Initially, there was also a separate soils theme, but its role and function was combined with the water and nutrient themes to avoid duplication.

Associated themes and activities

Modelling

As well as having themes for pastures, water, nutrients, animal production and biodiversity the SGS national experiment has a theme for economics and a modelling component. These latter two are an integral part of the theme and site data collection process, but do not have separate, detailed protocols. Instead, the data requirements of these groups have been incorporated into the individual theme protocols. To facilitate the process of themes accessing and interpreting data across the national sites all data will be stored in a common format in databases written in Microsoft Access.

An SGS pasture model has been developed to meet the specific needs of the national experiment. The model integrates pasture production and utilisation with water and nutrient dynamics. The individual components are each based at a similar level of complexity, or simplicity, and virtually all parameters are accessible from within the user interface. This gives the user a high level of control over the model implementation, which is essential for uptake and use by researchers. Since the model has been developed for this project, it can be readily modified to meet the needs of the national experiment. This applies to the model structure, interface and data access. For ease of use, a seamless interface will be written to use data from the databases constructed for each of the national sites. Combining the model and database, gives a foundation for integrating and interpreting the results from the national experiment, as well as providing a mechanism for on-going data analysis as the project develops. The SGS national experiment is in an excellent position to take advantage of available data, enthusiasm for modelling, and current model development, to provide insights and understanding of the processes of water and nutrient dynamics in pasture systems, within a framework that allows the whole model to be accessible.

Economics

An objective of the national sites is to examine the impact of different grazing management systems from a profitability and resource sustainability perspective. Applying economic principles to sustainable land management issues is made more complex by:

1. Spatial links, often referred to as externalities;
2. Temporal links such that land use in one period of time has an impact on the productivity of the land in the future; and
3. Non-market impacts, where changes to land management can have an impact that may not be directly reflected in a dollar value (eg. biodiversity).

Simple economic and budgeting tools are not suitable for use on land management problems that have spatial and temporal characteristics. However, Dynamic Programming (DP) methods do represent a suitable economic framework to investigate optimal grazing management strategies, since they can consider alternative land management strategies as pathways of resource use and can identify the pattern of resource use that generates the highest net income over all time periods.

The economics theme (led by Garry Stoneham, Victoria) intends to apply DP methods to the SGS national sites. This framework will initially be developed and tested on data already collected from a previous multidisciplinary experiment conducted at Book Book near Wagga Wagga, NSW as part of phase 1 of SGS.

Site characterisation protocol for all SGS national sites

MALCOLM R. MCCASKILL¹, ANNA RIDLEY², PAUL SANFORD³ AND WARREN KING⁴

Site details

For all sites in the national experiment, latitude, longitude, altitude and a map reference are to be recorded with sufficient precision to locate the paddock. The position of soil pits, treatment boundaries and contours should also be recorded on a site plan.

Details are also to be provided on:

1. Land use history, years of sown pasture; fertiliser history, type(s) of animal enterprises; cropping history if any, and previous chemical applications; and
2. Current status of the pasture, initial species present, and why the site was selected.

Define which species are to be encouraged or discouraged and the species composition, herbage mass, or groundcover objectives in terms of the national experiment. Treatments should be allocated after statistical analyses of herbage mass and botanical composition data to ensure initial differences among plots are not significantly different. For all sites an events diary must be kept to record details of sampling times, stock movements etc.

Soils at each site are to be classified according to the Australian Soil Classification (Isbell 1996) using soil profile pits dug to 1.5 m in each soil type or phase. Soil properties should be described in detail using standard terminology (McDonald *et al.* 1990). Each soil horizon should be sampled for bulk density, soil waterholding characteristics and soil chemistry. Horizons may be further subdivided into smaller depth increments for soil sampling.

The following minimum set of analyses should be conducted on samples from representative pits:

- pH in both water and CaCl₂;
- electrical conductivity (EC);
- cation exchange capacity;
- exchangeable sodium percentage; and
- clay content (field or laboratory method).

Laboratory methods suitable for the above analyses are described by Rayment and Higginson (1992). Where pH in CaCl₂ is below 4.5, reactive Al should be measured in CaCl₂ and KCl (method 15G1, Rayment and Higginson 1992) and expressed both as meq/100g and as a proportion of cation exchange capacity (method 15O1). Effective cation exchange capacity should be calculated using method 15J1, and exchangeable sodium percentage calculated by method 15N1.

Organic carbon is only required for the Australian Soil Classification if more than 12% total carbon is expected in the top 10cm. The site characterisation analyses described here are also sufficient to classify the soils to family level under US taxonomy.

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Depth to the B horizon should be noted, at the time that neutron moisture access tubes are installed. Details are provided in the nutrient theme protocol for other standard chemical soil test (Olsen, Bray or Colwell P and KCl-extractable S) to be sampled at each site.

Table 3
Summary of the minimum data sets required to be collected for site characterisation at each of the SGS national sites

Records and measurements	Comment
Latitude, longitude, altitude	
Location of plot fences, soil pits, contours	
Land use details	
Current pasture status	
Aims and objectives	
Treatments and design	Use initial herbage mass and botanical composition data to allocate treatments.
Soil classification	Use the Australian Soil Classification.
pH in both water and CaCl ₂	Sample key horizons.
Electrical conductivity (EC)	Sample key horizons.
Cation exchange capacity	Sample key horizons.
Exchangeable sodium percentage	Sample key horizons.
Clay content	Sample key horizons. Use field or laboratory method.
Bray, Olsen or Colwell P	Sample 0–10 cm.
KCl extractable S	Sample 0–10 cm.
Depth to B horizon	Note when installing NMM access tubes.
Photographic record	Photographic standards every 12 weeks.

Photographic protocol

This protocol details the minimum requirements for a photographic record of each of the national sites. The objective is to maximise the compatibility of the images despite differences in scale, topography and species. It is envisaged that the photographs described here will be additional to those routinely taken at each site.

Equipment and techniques

A 35 mm, single-lens reflex (SLR) camera is required. Modern compact cameras are not acceptable. While two lenses would be ideal (50 mm for the close-ups and a wide-angle for general views), some sites only have a 'standard' (50 mm) lens. A tripod is essential and an 'accessory arm' would also be useful. Use a slide (transparency) film with a speed rating of ISO (ASA) 100 or less.

Table 4

Summary of the minimum requirements for the photographic protocol at each of the SGS national sites

Essential Equipment		
35 mm single-lens reflex camera		
50 mm lens		
tripod		
ISO 100 slide film		
Activity	Frequency	Comments
Pasture close-ups	Seasonally	At least one photograph per plot in every replicate, at BOTANAL ¹ sampling points Use a target size of 0.75 x 0.5 m. For the standard target size take an overhead shot, oblique is optional. If a larger target size is used, take an oblique shot, overhead is optional.
General Views	Seasonally	At least one photograph per plot in every replicate, from BOTANAL sampling points
Databasing	Seasonally	Scan slides, enter in site database.

Points to remember when taking the photograph

1. When using slide film, exposure becomes more important. Generally, an automatic-exposure camera will adjust exposure (either shutter speed or aperture, or both) to suit the prevailing light conditions. Cameras with manual exposure controls will indicate correct exposure by a meter in the viewfinder. However, care should be taken to confirm the accuracy of the exposure system by a close visual inspection of the resulting slides. Consistent under or overexposure (too dark and shadowy, or too light and washed-out looking, respectively) should be noted and compensated for.
2. Slide film has more inherent contrast than negative (print) film and most photographs will be taken on sunny (and therefore high contrast) days. Consequently, some slides will exhibit excessive contrast (both dark shadows and bright highlights, lacking in detail), even when correctly exposed. Without elaborate diffusers or multiple artificial light sources this is largely unavoidable. On the other hand, photographs taken on heavily overcast days will appear 'flat'—the relative lack of light can lead to other problems. Ideal lighting conditions ('bright hazy') may be elusive and critical control of contrast and lighting in the field is impractical.

1 BOTANAL is a technique to estimate forage on offer by botanical composition utilising the dry-weight-rank method (see page 15).

Photographing close-ups

The area of pasture that needs to be covered ('target size') will be largely determined by the size of the species present. A 'rule-of-thumb' for estimating the size of a sampling quadrat is that its diameter should be about five times the diameter of the canopy of the largest species present. In pastures that are closely grazed, this may be less than 0.5 m; in more laxly grazed pastures or those containing tussocky species, it may be closer to 2 m. Given that the dimensions of the 35 mm film format have a ratio of 3:2, then a target size of 0.75 x 0.5 m would seem an appropriate compromise for all but the 'coarsest' pastures where the minimum size may need to be increased for the larger species. Scale indicators (a bar, about 5 cm wide, placed across the full width or length (or both) of the photograph). Mark 10 cm long blocks of contrasting colours to provide a scale. Also, allow for the plot number, date, etc. to be marked on the scale bar. A frame will be made up for the standard target size and distributed to each site.

A direct overhead view of the pasture will give the best idea of 'cover' and has the potential advantage of being free of perspective. However, an oblique view will give a better 'feel' of pasture herbage mass. Overhead views are more difficult to set up, while oblique views need to be controlled for distance from target and height above target to be truly repeatable. Ideally, both should be taken but if there is only one close-up then it must be an overhead shot. For target sizes much larger than that specified above, the camera height required to cover the larger area makes an overhead shot impractical and so an oblique shot must be taken. For an overhead shot of a target 0.75 x 0.5 m, the camera height will be approx. 1.3 m. To minimise parallax errors (diverging and converging parallels) centre the camera directly over the middle of the quadrat. For accurate positioning an accessory arm on the tripod is useful. Avoid taking overhead shots in the middle of the day to reduce problems with tripod-legs and shadows.

The exact location of each photograph will be determined by several factors, including pasture and topographic variability, but should be fixed throughout the experiment period. Use the fixed points already established for BOTANAL sampling (see pasture theme protocol on page 15) and photograph at these points. In this way, the pasture data for a sampling quadrat (and any other data collected from these points) can be related to a particular photograph. Take at least one photograph in each experimental plot, with the site chosen to represent the pasture variability.

Photographing general views

If possible use a wide-angle lens for the general plot view, otherwise use a standard 50 mm lens. Use a tripod to take these photographs at a height of around 1.5 m; the field of view will be largely determined by the lens length. What remains to be outlined relates only to the actual framing of the photograph. Points to remember include:

1. Use horizontal (ie. landscape) format only.
2. Choose one of the fixed BOTANAL sampling points (or any other fixed point) to photograph from—presumably near a boundary.
3. Align the edge of the frame with a prominent landmark and note the general direction in which the camera is pointed. Since a 'standard' lens does not have a particularly wide field of view, it will be unlikely that a single photograph will adequately cover large plots and so more than one photograph may be useful.
4. Incorporate some sky into the frame, but not more than about 10%. It may be necessary to point the camera down slightly to achieve this.

Databasing

For archiving, each slide should be scanned and files stored within the site database. Scan slides at a resolution of about 1000 dpi and save images in JPG format to give files of around 200 kilobytes that retain sufficient detail. A slide scanner is required—a flatbed scanner will not do. If a slide scanner is not available, slides can be sent to Orange, NSW for scanning.

Pasture theme protocol

PAUL SANFORD¹, DAVID KEMP², GREG LODGE³, DENYS GARDEN⁴, MIKE GRIMM¹ AND JOHN GRAHAM⁵

Introduction

The core, minimum data set for pasture for all of the national sites is outlined in Table 5. The pasture theme hypothesis is that these data will significantly contribute to an improvement in the conversion of available water/solar energy to pasture biomass and sustainability of pasture systems in the high rainfall zone of southern Australia. The major outcomes will be:

1. An understanding of the effects of management on pasture production and stability; and
2. To quantify the response curve between rainfall and pasture production for various soil types, fertiliser levels, management etc.

The minimum data set must be measured using the methods outlined in this protocol. There are also several additional optional protocols that may be undertaken at particular sites which are examining certain issues in greater detail (Table 6).

These protocols are largely based on those developed within the Temperate Pasture Sustainability Key Program (TPSKP, Anon. 1993, Lodge and Garden 1998) but, include some additional measurements.

Table 5
Summary of the minimum data sets required to be collected for the pasture theme protocol

Measurement	Frequency	Method
Pasture composition (% , kg DM/ha)	12 weeks ^a	BOTANAL
Herbage mass (kg DM/ha)	12 weeks ^a	Estimation; ranked sets; probes
Green and dry forage-on-offer (kg DM/ha)	12 weeks ^a	Estimation
Presence of all species	Spring and autumn	Taken in BOTANAL quadrats
Forage quality	Six times/year	Digestibility, crude protein and metabolisable energy
Basal cover	Autumn	Point quadrat
Groundcover (%) ^b	Run-off events	Estimation

Also required:

Experimental diary

Insect and disease control

a Sample at six weekly intervals when pasture is growing rapidly in winter–spring in the winter rainfall zone.

b Groundcover is a core measurement for sites with run-off installations.

1 Agriculture Western Australia, Albany, WA 6330

2 NSW Agriculture, Orange NSW 2800

3 NSW Agriculture, Tamworth, NSW 2340

4 NSW Agriculture, Canberra, ACT 2600

5 Agriculture Victoria, Hamilton, VIC 3300

Table 6

Optional, additional data sets that may be collected in the pasture theme protocol and the sites at which they are being collected

	North-West Slopes NSW	Central Tablelands NSW	North-East Victoria	Western Victoria	Western Australia	Wagga Wagga NSW
Pasture growth rate						
by measurement or derivation	✓	✓	✓	✓	✓	✓
Leaf area		✓		✓	✓	
Plant frequency		✓				✓
Plant, tiller and stolon densities				✓		
Phenological development		✓				
Seed and bud banks		✓			✓	
Seedling recruitment		✓				
Roots	✓				✓	
Endophytes						
Trees			✓		✓	

General

Cutting height

It is recommended that pasture be harvested to ground level. If there is a valid reason for not cutting to ground level, an alternative approach may be used provided the amount of herbage left below the cutting height is reliably estimated using coring or similar techniques.

Cutting pasture to ground level is the technique used by TPSKP, Prograze, and in Victoria and Western Australia.

Calibration

Many pasture assessment techniques rely on an estimate which is then related to an actual value by the use of calibration eg. visual estimation of herbage mass. Typically calibration involves a range of samples covering the values encountered during the assessment, which are then measured accurately and plotted against the operators estimate of the calibration samples. The regression obtained is then used to convert estimates into actual values.

Points to remember:

1. Calibrations must be done at the same time as the pasture estimates are taken.
2. Samples taken for calibration must cover the range of estimates made in all plots assessed. Generally linear regressions account for the most of the variation in herbage mass data. Always plot calibration points to provide feedback on the assessment.
3. If two or more operators are used to assess pasture then use separate calibrations for each operator based on their assessment of the calibration samples and apply the calibration to each operator's data.
4. For herbage mass estimates, do not sample evenly across the range of estimates; ensure that there are three–five estimates at the high and low end of the range.

Compatibility with Prograze

Prograze is a course developed by the previous Meat Research Corporation (now Meat & Livestock Australia) aimed at training producers and others in pasture and animal assessment and how to utilise these skills in decisions of grazing management.

A segment of the Prograze manual is dedicated to pasture assessment. Growers are taught to estimate forage on offer by visual rating, botanical composition utilising the dry-weight-rank method (BOTANAL) and how to take pasture samples for analysis. It is desirable for extension and training purposes that researchers adopt the techniques taught in Prograze.

When estimating herbage mass the amount in kg DM/ha is preferred to some arbitrary scale, since this is the value used in Prograze. This will allow to producers to relate to the values in a meaningful way, training them to develop this assessment skill, and allowing a common language to be spoken at field days etc.

Insect and disease control

Insect and plant diseases must be controlled at all sites, unless they occur as a result of an experimental treatment.

Pasture management rules for drought

For all sites the emphasis during a drought will be to manage the perennial grass component of the pasture so that it survives the drought. Rules for pasture management during drought for different grasses are as follows:

Phalaris—Light to moderate grazing is essential since repeated heavy grazing reduces regrowth potential and plant density. De-stock once herbage mass falls to below 1,500 kg DM/ha.

Cocksfoot—de-stock when herbage mass falls below 900 kg DM/ha, otherwise plants will be weakened and die.

Perennial ryegrass—graze leniently and de-stock when herbage mass falls below 1,500 kg DM/ha.

Tall fescue—reduce grazing intensity and de-stock when herbage mass reaches 900 kg DM/ha.

Kikuyu—Maintain grazing intensity unless stocking rate is very high. Grazing during dry periods can renovate kikuyu swards since a lot of low quality material is removed. De-stock when herbage mass falls below 800 kg DM/ha.

Native pastures—unfertilised native pastures should be de-stocked when herbage falls below 800 kg DM/ha to prevent overgrazing.

Annual pastures—prevent soil erosion by removing stock once dry herbage mass residues reach 800 kg DM/ha.

When supplementary feeding stock for survival during drought, feed on a 'sacrifice area' not on the plots.

Minimum data sets to be collected at all sites

BOTANAL

BOTANAL (Tothill *et al* 1992; Hargreaves and Kerr 1992; McDonald *et al* 1996) is a technique for the visual estimation of botanical composition and herbage mass of pastures. Since several other estimates can be made on each quadrat, the method is quick and suitable for sampling small or large areas. The range of other measurements includes:

Botanical composition—The dry-weight-rank technique ('t Mannetje and Haydock 1963) with the modifications proposed by Jones and Hargreaves (1979).

Total green and dry herbage mass—Direct visual assessment (kg DM/ha).

Presence—The proportion of quadrats containing particular species.

Percent green, percent clover, etc—The method allows the collection of extra components by estimation (eg. if percent green is required in addition to other measurements in order to estimate green herbage mass).

Outline of procedures

Frequency of sampling

All treatments should be monitored at a minimum of every 12 weeks, at each change of season. If pasture is growing rapidly, or composition is changing then measurements should be taken at six week intervals. In winter rainfall zones, sampling in winter–spring may be a six week intervals, while in summer and autumn before the break it may be every 12 weeks.

Number of observers

While the use of several observers will reduce bias, the method is quite robust and the use of a single observer is acceptable. Each observer must sample every plot at each particular sampling (ie. it is not acceptable for different observers to sample different replicates).

Number of quadrats

A minimum of 20 quadrats per grazed plot, at fixed locations is required. Quadrats can be randomly located in fixed transects (minimum of two per plot) or in randomly located fixed positions.

If using transects, two diagonal transects per plot should be random located at the start of the experiment in each plot. Mark transects locations with a permanent marker 5–10 m from one corner or the fence line of the plot and place quadrats at sufficient intervals to ensure they are located centrally within the sampling area. Permanent markers should be of a type that does not attract stock to rub, etc. At subsequent sampling's, quadrats should be placed in the same orientation at the same interval.

Quadrat size

The method is not sensitive to quadrat size. A square quadrat of about 0.1 m² (30–40 cm) is recommended.

Measurements (taken within the quadrat)

Botanical composition by dry-weight-rank ('t Mannetje and Haydock 1963)

All records must be taken at the species level, not the species group level. Also it is important to remember that the procedure estimates dry-weight and so the contribution of green pasture (with higher moisture content) relative to dead pasture needs to be taken into account.

Species are ranked first, second or third according to their estimated contribution to dry pasture herbage mass. BOTANAL estimates can be improved by not rely solely on using single ranks (ie. only allocating 1, 2, or 3). If one species is dominant (eg. > 85% of the quadrat dry-weight), use a cumulative ranking, giving it both a first and second rank. If species have similar dry weights then use ties. When species are tied, the ranks are divided equally between them. For example, if two species are tied for first, they each receive 0.5 for first and 0.5 for second (0.33 for three ties). Botanical composition is expressed as kg/ha for each species.

Total herbage mass

Directly estimate herbage mass in kg DM/ha. This value is then corrected using the estimated and actual values from the calibration quadrats.

Herbage mass may also be estimated separately using calibrated rising plate meters (Earle and McGowan 1979; Cayle and Bird 1991) and pasture probes (eg. Tothill 1978) or by destructive harvesting using a median quadrat ranked set method (McIntyre 1952).

Green and dry herbage mass

Directly estimate green and dry herbage mass in kg DM/ha (Campbell and Arnold 1973). This value is then corrected using the estimated and actual values from the calibration quadrats. For the minimum data set separation of species is not required.

Alternatively, estimate percent green and calculate green and dry herbage mass. Correct the values by estimating total herbage and percent green in the calibration quadrats.

Species presence

Data on all species present in the BOTANAL quadrats are required by the biodiversity theme. Data are to be collected on individual species in spring and autumn each year.

Calibration quadrats

Calibration quadrats sampled at each harvest are required to relate estimated and actual values of herbage mass and percent green. When pastures are variable and herbage mass is high use a minimum of 30 quadrats for calibration; if pastures are uniform and herbage mass is low as few as 10 quadrats may be used after testing that the coefficient of variation is adequate. Before sampling commences the observer(s) should examine the treatments and estimate the range of herbage mass. Quadrats selected for calibration should be estimated individually when there is more than one observer. Ensure that three–five quadrats cover the high, and another three–five quadrats represent the low, end of the expected range of herbage mass. During the calibration process observers should agree on species and compare estimates to ensure that they are following the correct procedures. Calibration quadrats should be harvested to ground level, stored in cool, non-drying conditions and taken to the laboratory for processing as follows:

- separate samples into green and dead. Dry separately at 80°C and weigh.
- record total or bulk dry weight if herbage mass is being estimated.

These data are used to derive calibrations for each observer. Linear regressions of actual herbage mass against estimated (with r^2 values over 0.7) can be regularly achieved by experienced observers. However, observers are generally less consistent in estimating percent data (eg. percent green) and r^2 values are lower. For percent green, regressions based on both fresh and dry weights may improve the r^2 value. Factors such as percent clover may also improve percent green estimates. Some exploratory analyses are often needed to derive a reliable approach for calibrating percent green estimates.

Algorithms

The following information may be useful in understanding the methods:

Dry-weight-rank

Constants have been developed which weight the number of first, second and third ranking's for each species. Then when all first, second and third ranks are totalled for each species, they are multiplied by the constants 8.04, 2.41 and 1 and added together to give a total 'weighting' for that species. This figure is then divided by the total weighting for ALL species and converted to a percentage (70.2, 21.0, and 8.7%), giving the contribution of each species to total dry weight. Considerable testing by the original authors ('t Mannelje and Haydock 1963) and various others since (eg. Jones and Hargreaves 1979) have determined that the constants are very robust and apply to a wide range of pastures including tropical, subtropical, temperate and arid zone communities.

Herbage mass and percent green

Data from calibration cuts is used to develop a regression for each observer relating estimated against actual data. Each regression equation is then applied to each quadrat to determine a value for herbage mass and percent green. These values are meaned to obtain a plot value.

Forage quality

To estimate the impact of treatments on animal performance the quality of the pasture as well as its quantity needs to be measured. The minimum sampling for quality is six times per year in two contrasting treatments, with each sample separated into green and dead. Green fraction should be further separated into clover, grass and other, particularly if the site has an animal production emphasis. Samples are to be bulked on the basis of treatment and analysed for dry matter digestibility (DMD), crude protein and metabolisable energy. The methods of collecting and preparing samples for analysis can have a large impact on the estimation of quality so standard procedure must be used across SGS sites.

Samples of herbage must be taken from within pasture cages prior to them being shifted or from ungrazed areas. Do not take samples from grazed pasture, as these are less likely to represent what the animals are selecting. After cutting, place herbage in a plastic bag and store in an esky containing ice packs or crushed ice. Up to 100 g DM is needed per plot, and this material needs to be sorted into green and dead components before analysis. Samples from each replicate must be kept separate if statistical analyses are required.

Bulked samples may be reduced in size by quartering. The material to be sub-sampled is first spread evenly on a bench. If herbage is very long it may be cut into shorter lengths using hand-shears. It is then mixed well and divided into quarters and opposite quarters are collected together (this could take two–three minutes with careful separating and mixing). The two remaining heaps are then inspected, and if similar in appearance one heap is discarded, and the other sorted. If the sample is still too large, the quartering procedure can be repeated until the required size is achieved.

Sample preparation

1. Samples should be dried at 60°C . Dried herbage should then be sealed in plastic bags and stored in the dark until sorting into the green clover, green grass, green other and dead components. Sorting can be done prior to drying, but this is often a busy time, and it is best to get the samples dried quickly and to sort them later. After sorting, the green and dead components should be weighed to determine the proportion of green.

2. After sorting, samples should be ground, preferably with a Tecator Cyclotec mill (1 mm screen) or equivalent. Consistent particle size is important. It is possible to submit unground samples, but there will be an additional fee (~\$5/sample).
3. A minimum of 10 g of dried, ground sample should be submitted, so slightly more than this should be milled. The ground samples should be submitted in small screw-top plastic containers with labels. Legible labelling is essential, and lids must be tight. These containers can be returned for re-use.
4. Unground samples can be sent in sturdy paper or plastic bags (not freezer bags). Do not use a 'texta' to write on the bags. There must be a cardboard label inside each bag, with all details legibly written.
5. In all cases, labels must include the name of the site, the plot number, whether green or dead and the sampling date.
6. Each site is responsible for the cost of delivering samples. Mail or courier can be used. Ensure packaging is secure, attach a sample submission form and send with each batch of samples to:

Postal address:

FEEDTEST

Agriculture Victoria Hamilton

Pastoral and Veterinary Institute

Private Bag 105

Hamilton Vic 3300

Location: (for courier services)

FEEDTEST

Pastoral and Veterinary Institute

Mount Napier Road

HAMILTON Vic 3300

(DX 216373)

Long-term storage of pasture samples

After analysis, samples can be stored for years in air-tight plastic vessels at room temperature, provided that they have been dried correctly and contain very little moisture. Store in a dark room on shelves with adequate labelling.

Reference samples for comparison between feed analysis laboratories

To account for variation between laboratories it is proposed to submit two standard herbage samples to all laboratories involved, twice a year.

Basal cover

Basal cover, is a measure of the presence of a species as measured by contact with a plant base, is commonly used to measure plant persistence. Since measurements are taken at the plant base it is less affected by grazing, seasonal conditions and phenological development than other measures of persistence (Brown 1954). Measurements are best used in tussocky perennial grass pastures or for species with a well defined crown or plant base. It can be measured in quadrats or by using a point method in transects. For the minimum data set the basal cover of the perennial grasses needs to be recorded. Basal cover data is a reproducible measure that has some advantages over more subjective groundcover estimates, but is more difficult to measure.

Quadrat method

Sample 200–300 points in two–three quadrats per grazed plot, in autumn. Where possible allocate quadrats to strata and use fixed sampling points to reduce variance. Use a 1 x 1 m square of weldmesh with 10 x 10 cm mesh to give 100 cells per quadrat. A fixed position of the quadrat can be permanently located by pegs placed in diagonally opposite corners of the 1 x 1 m frame. Each quadrat should be initially located using a stratified procedure.

Subdivide the plot into equal areas and then locate the quadrat within a 'typical' portion of each area. This could be aided by using BOTANAL procedures to estimate composition across each area and then defining the median site. Ensure the quadrat is away from other fixed sampling positions and that it is easy to relocate the fixed position, with the same orientation of the quadrat for each set of measurements.

The frame needs to be located close to the soil surface so measurements are best taken after the treatment has been heavily grazed. Try to sample when plants have about the same amount of regrowth each time. If plants are more than 5 cm in height and the frame is flattening the vegetative material use legs on the frame (10 cm long). Weld nuts into diagonally opposite corners and screw in a threaded bolt 10 cm long to make legs.

Plant basal cover estimates can be taken at the same time as optional frequency estimates, using the same frame, or as separate measurements. The intersection of the rods on the weldmesh can be considered as cross points, similar to a point quadrat. Standardise on which side of the frame you start by painting one edge a distinctive colour and always count say left to right so that each crosspoint measured is in the same relative position each time. Count the number of plant bases (defined by live and dead material) that are directly under 100 cross-points. The best way to do this is to use a fine stiff point such as a bicycle spoke or wire pin to determine what is directly below the cross-point. Do not use your finger or large nails, as these are likely to overestimate basal cover. Use a numeric counter to tally the scores. Basal cover is expressed as a percentage for each species. Expect low values—a good perennial grass pasture may only have a total basal cover of 5% for all species.

Point methods

Point methods use frame, step or wheel techniques to record contact with plant bases. When using point methods 200–300 points per plot should be sampled along fixed transects in autumn. Since data for point methods are taken at 25–100 cm spacings they are more applicable to larger plot sizes and allow a larger proportion of the area to be sampled. The use of these techniques and their application has been reviewed by Levy and Madden (1933), Goodall (1952), von Broembsben (1966), Evans and Love (1957) and Tothill (1978).

Groundcover

Groundcover is an important factor in influencing surface run-off by affecting raindrop impact and splash. In small plot studies (Lang 1979), it has been shown as the proportion of pasture groundcover increases the occurrence and magnitude of run-off decreases. 75% groundcover was found to be a critical level, above which run-off was low and below which run-off and soil loss increased rapidly.

For those sites with surface run-off installations groundcover must be measured for each run-off event, so that run-off volume and soil loss can be related to percent groundcover. Measurements are quick and easy to make and non-destructive. Within small plot run-off areas a minimum of 10 quadrats should be sampled; for larger areas use up to 50 quadrats. Alternatively, estimates over time can be made at the same time as BOTANAL measurements, using the same quadrats. This would give a minimum of four estimates per year at the start and end of each season.

No specialised equipment is needed and no calibration is required. Groundcover is an extremely useful, simple measure for graziers to use and understand. In general, low groundcover is associated with low plant and animal production and low sustainability. If groundcover is low, it is a good easy-to-understand warning signal that some sort of management is required to bring the level back to about 75%.

Groundcover is an estimate, to the nearest 5%, of the proportion of the ground that is covered by plant bases, standing dry matter (green and dead), litter and dung. The converse of groundcover is bare ground which can be directly impacted by raindrops. It is measured on a 0–100% scale. The easiest way to estimate groundcover is to place a quadrat (30–40 cm square) on the ground, and standing over it (ie. viewing from the top) estimate what proportion of the quadrat would intercept a raindrop as it falls. One way of doing this is to judge whether or not all of the material would occupy one-quarter, one-half, or three-quarters of the quadrat, which corresponds to 25, 50, and 75% groundcover. Include in the estimate anything that is not bare, exposed ground, such as plant bases, stem and leaf material that is standing, but spreading from the base and litter lying on the soil surface. Groundcover may be separated into projected cover (standing herbage mass) and contact cover (cover in contact with the soil surface) and each estimated separately. Surface roughness on an arbitrary 1–5 scale can also be estimated.

Since groundcover depends on dry matter, plant crowns and litter it maybe a surrogate measure for their presence. For example, with high dry matter availability it would be expected that groundcover is high. This can be tested at each site by including a groundcover estimate in the BOTANAL calibration quadrats

Pest and disease incidence

SGS has a major emphasis on developing sustainable, productive pasture ecosystems. There are many trophic levels within ecosystems and some of the organisms present are considered pests and diseases that can have an adverse effect on the ecosystem. Procedures are needed so that we can monitor these problems and identify how they are influenced by management practices. Monitoring these organisms is also important as part of the study of biodiversity within pasture ecosystems.

When measuring and controlling pests and diseases the following points should be kept in mind:

1. There are insufficient resources of time, staff or expertise to adequately monitor and assess the pest profiles of pastures in the national experiment. Pests are highly likely to develop damaging populations at some time during these studies.
2. Different pest profiles will develop across treatments and years. Some plots may have reductions in herbage mass or changes in botanical composition as a consequence of insect and mite feeding. Grazing pressure, which is partly a function of stocking rate, is a major determining factor in the population dynamics of arthropods living in pastures. Different grazing pressures will be generated across each site by the different treatments, and will be moderated by seasonal factors that govern pasture growth rate.
3. Above ground pests that feed on leaves, stems and flowers are generally amenable to control by application of insecticide.
4. Soil dwelling pests feeding on roots, stem bases and soil organic matter are generally not able to be controlled with insecticides.
5. Notes should be taken regularly on presence or absence of insects and mites. Preferably, this should be done each time pasture assessments are made of herbage mass or botanical composition. Absence of obvious damage or insects may be as important as noting that leaves are chewed or silvered.
6. Presence of soil dwelling pests are much more difficult to record, since plant damage is not always immediately obvious and insects are hidden. Opportunities to observe pests may arise when soil cores are taken for other purposes, such as root studies, soil water measurements, nutrient status of soil, etc.
7. Ideally, specimens found should be kept in alcohol, and labelled with date, treatment, and where they were found. If possible have the pest identified.

Protocols for additional, optional data

Pasture growth

Estimates of pasture growth are most accurate from cages when the differences in yield, leaf area index (LAI) etc., between the pasture in and outside the cages are minimal. It is therefore best to move the cages more rather than less often. Movement of cages to new locations should coincide with seasonal treatment changes, with additional moves every two–three weeks during periods of rapid growth to a maximum of six weeks (half season) when there is little growth.

Net pasture growth (NPG)

NPG can be estimated by assessing the change in herbage mass in areas from which animals are excluded for periods of two–six weeks by either rotational grazing or pasture cages. A circular cage about 1 to 1.5 m in diameter (3 m circumference) made from welded wire mesh (eg. 'Riverina mesh') makes a suitable enclosure. The cage should be pegged securely to the ground if cattle graze the pasture.

For each period of t days, the *NPG* rate of pasture is calculated as:

$$\frac{HMC_t - HMC_0}{t}$$

where HMC_0 = herbage mass in the cage on day 0 and HMC_t = herbage mass in the cage on day t

Number of cages

To reduce variance sites for measuring growth should be chosen using a stratified random procedure. If n cages are to be measured per plot, the area should be divided into n approximately equal areas and the cage positioned on a site that is close to the mean yield, composition and green leaf content for that area. View a range of random quadrats across the (sub) area before selecting a site close to the mean.

Numbers of cages per treatment will depend upon the variability in pasture composition, yield and green leaf content. Some preliminary sampling needs to be done for each pasture type to satisfactorily estimate the number of cages required. Remember that the area sampled within a cage is a very small proportion of the total pasture area.

Where treatments have stock excluded for any period, pasture growth can be directly estimated over the whole plot. During these periods cages are not needed. However, calibration equations for ungrazed areas are likely to differ from those for grazed plots.

Measurements

Herbage mass at each time can be measured by estimation and calibration to actual values; calibrated falling plate meters or pasture probes, or by harvesting paired caged and uncaged quadrats to ground level.

Leaf area index (LAI)

Pasture wateruse and growth is dependent on green leaf area. Leaf area measurements need to be synchronised with pasture growth and herbage mass assessments and to be taken at least every six weeks.

Destructive methods

All destructive techniques require samples to be collected and sorted, sub-sampled and measured in the laboratory. Two methods of measurement, the planimeter and flatbed computer scanner are outlined.

The number of samples to be taken per plot will be determined by the precision of the estimate required to demonstrate a significant difference between treatments. Leaf area measurements are time consuming so realistic numbers of samples need to be taken. Sample treatments of particular interest or those in which you expect the biggest differences in LAI.

Randomly select sample locations within a plot. Quadrat sampling size depends on the nature of the sward, but is likely to be of the same dimensions as that used for sampling herbage mass.

Prior to measurement harvested leaves should be stored in dark, humid, cool conditions; storage on wet tissue paper in a self-sealing polythene bag in a refrigerator is recommended.

Often an adequate estimate of LAI can be obtained from a sub-sample. These should be representative of the whole sample in terms of leaves of different type, size, age and stages of development. Quartering procedures may be used to obtain a representative sub-sample.

Sub-samples are hand-sorted into green and dead components. These are then separated into leaves and other plant parts (eg. stems) and if required other categories such as grass and clover, or young and old leaves.

MEASUREMENT WITH PLANIMETER

Individual leaves move at constant speed between a light source and a detector and their area is electronically integrated and displayed. Result can be recorded for a single leaf or the area of a number of leaves can be accumulated. Calibrate by using test pieces of known area with a shape approximate to that of the leaves being measured. Moving belts should be kept free of dust and dirt since these can affect readings.

MEASUREMENT WITH FLATBED COMPUTER SCANNER

A software package (Win/Mac Folia, Regent Instruments Inc) requires a flatbed scanner linked to a PC or Mac to measure leaf area. Leaves are placed on the scanner, digitised and area calculated. For more information on this contact; Regent Instruments Inc., 165 Fatima Ave, Quebec Qc. G1P 2C7, Canada Tel/fax: 418 871 4581 or 418 561 8888 Internet: www.regent.qc.ca Email: sales@regent.qc.ca

Non-destructive methods

PLANT CANOPY ANALYSER

A leaf canopy analyser (Li-Cor) calculates LAI and other canopy attributes from radiation measurements made with a 'fish-eye' optical sensor (148° field of view). Measurements made above and below the canopy to determine canopy light interception at five angles. LAI is computed using a model of radiative transfer in vegetative canopies. For accurate measurements the distance from the sensor to the nearest foliage at an angle of 30° needs to be at least four times the leaf width, limiting its use in short pastures. Further information is given by Welles and Norman (1991) or contact: Li-Cor, 4421 Superior Street, PO Box 4425, Lincoln, Nebraska, 68504 USA Ph: 402 467 3576 Fax: 402 467 2819.

Other techniques also exist to measure LAI indirectly based on the close coupling between radiation penetration and canopy structure, such as fisheye photography, traversing a sunward-pointed sensor between the canopy, by linear light sensors and by pushing metal probes through the canopy. Detailed discussion of these techniques are in Goel and Norman (1990).

Plant demography

Plant frequency

Frequency measures the occurrence or presence of a species in a sampling unit (Brown 1954) and so is a measure of species persistence. The method described uses a quadrat 1 x 1 m with 100 cells and with measurements taken at a fixed location (see basal cover section for a complete description of the sampling quadrat).

For a 1 x 1 m frame with 100 cells, each cell is scored for the presence (or absence) of the species of interest. Presence of a species in a cell is recorded if any part of the plant occupies a cell (eg. if the same plant is in four cells its presence is counted as 4). Numeric counters can be used to tally the number of presence/absence scores. If there is a lot of bareground it is faster to count absence and subtract the tally from 100.

These scores give a relative measure of plant frequency, which over time builds up a picture of how composition is changing. Data can be expressed in two ways. Percent frequency can be presented as the percent of cells where a species was present (ie. in isolation from all other species) and, or the percent frequency of the total 'presence' for all species over all cells. This latter term is not so readily understood and needs careful interpretation.

An option is to record data on sheets showing which species are in which cells. With appropriate recording sheets this may not take much longer than tabulation methods. This procedure can help in mapping actual distributions, and determining the spatial arrangements and clumping of species. This is of use where the aims are to investigate microscale effects. When this is done the associations in nested quadrats can be done eg. species richness in 1, 2, 4, 8 etc., quadrats. A version of nested quadrats is used in some surveys of species presence/absence and associations.

Plant, Tiller and Stolon Densities

PLANTS

Counting of plants per unit area assumes that individual plants can be reliably identified. Plants may be counted in part of a frequency quadrat (see plant frequency section); sample a sufficient number of squares to count about 50 plants. Take at least 10 randomly placed quadrats per plot. Counting all plants in each quadrat, or about 50 plants if sub-sampling. Counts should be taken in late winter–early spring when the plant bases are obvious, without the need to remove foliage and stems.

TILLERS

Tillers can be counted where discrete plants are difficult to identify, or the large basal area of individual plants make plant counts inappropriate. In these cases, production is more likely to be determined by tiller rather than plant densities. Tiller numbers can be counted in a frequency quadrat by counting a sufficient number of squares to give about 100 tillers. Count tillers in at least 10 randomly placed quadrats per plot and count at least 100 tillers if sub-sampling. Counts should be taken in early-spring in temperate pastures.

For counting ryegrass tillers, precision can be improved by visual selection of a median. Use a board with five holes, each 5 cm in diameter, randomly placed on the pasture. The median group of tillers is then estimated by eye and a core taken from that hole. Tillers can then counted in the laboratory. At least 20 cores are needed from each plot. Mean tiller size can also be recorded.

The timing of tiller counts is important. Measurements in late-winter or early-spring are likely to indicate the upper densities, while measurements in late-autumn or early-winter would be near the minimum. Counts at the latter time may also provide information on summer survival.

STOLONS

Stolon density can be determined from shallow cores (50 mm diameter x 20 mm deep). Sample 20 random placed cores in early-spring. Bulk cores within plots. Separated stolons from soil in the laboratory and measure their length to determine total length per unit area (stolon density). Little extra effort is required to remove any appendages (roots and leaves) to obtain an estimate of total stolon mass per unit area. Number of rooted nodes per unit area may also be estimated.

Additional to stolon density, growing point density may also be counted in the same way as grass tillers (and in the same quadrats). Growing point density is often used to estimate white clover stand density in New Zealand. Estimation is time consuming in the field, but there is no subsequent laboratory processing.

Phenological development

Reproductive development is important for plant growth, competition and persistence and the timing of grazing strategies. This information is relevant to any understanding of the population dynamics of species and can lead to an understanding of species productivity and resilience over time.

Record the time and sequence of flowering for important species in control plots and in those treatments where species composition differs from the control.

Record flowering and seed development, for the principal species (ie. >5% of sward) in the control. Data from cages and ungrazed treatments can also be useful, since flowers are not grazed. Take measurements as often as practical. Where a more detailed record is required, observations can be taken twice a week.

Record the average stage of flowering for major species within a quadrat (or on each randomly harvested stem) noting:

- time of elongating stems (1 cm long or more);
- flowers in boot ie. about to emerge;
- emerging heads;
- flowers (or florets) open;
- anthesis;
- seed maturation; and
- seed fall.

This will define the start, duration and cessation of flowering, seed development and shedding. Timing of reproductive development may be consistent from year-to-year because of the large influence of daylength and periods of low temperatures

Record phenological information whenever taking other measurements. The first stem to flower may be an aberration hence the need to monitor frequently. Only a few perennial plants may be flowering.

An alternative to collecting data on plants in quadrats is to select 30 random tillers or stolons from the plot and record the number in each of the stages of flowering given above.

Monitor treatments that contrast with the control, particularly those rested during flowering (eg. spring) or those with the large differences in biomass from the control. Record the time of seed fall.

In some pastures, animals and predators may consume seeds. Knowledge of these losses is important for understanding population dynamics. For treatments of interest, cut five standard quadrats (eg. 30 x 30 cm) and count the number of flowering stems of each species of interest with intact, partially consumed or missing seedheads. This sampling may be combined with other measures and should be done at least every two weeks from anthesis until it is apparent that all the seed has dropped or predation ceases.

Early reproductive development

Apical development data should be collected if studies are investigating the effects of reproductive development on plant growth rates, tiller dynamics, mechanistic models of pasture growth etc. Regularly sample tillers from major grass species and dissect their apices. Leaf growth of grasses increases from the time reproductive development starts, peaking when the terminal spikelet primordia forms on the apex and declining before flower initiation. These data may explain variation in winter growth rates between grasses. After reproductive development commences on a tiller, initiation of new tillers is likely to be suppressed, only tillers already developing will grow until flowering is completed.

Sample 30 tillers of each species (caged or ungrazed plants), arrange them in increasing size and dissect apices from the median four tillers. Count the number of mature (ie. ligules visible), emerging and enclosed leaves, and the number of primordia on the apex. Primordia accumulate on the apex, from the time reproductive development occurs.

A more precise estimation of this time can be obtained by plotting cumulative number of primordia over time. These data should follow a two-phase function, with the junction defining the time that the switch to reproductive development occurs. To successfully use this approach areas of tillers need to be marked at intervals, identifying the youngest fully emerged leaf with a spot of paint ('white-out' is often very useful). These provide a reference for counting cumulative primordia. Time can be measured as days, but a better procedure is to use thermal time, from some reference point such as the autumn equinox. Use a simple measure of thermal time, such as cumulative mean daily temperatures, recorded as close to apex level as possible. A reasonable compromise is temperature just below the soil surface.

Sampling for early reproductive development needs to start in late-autumn as this switch can occur up to three months before stem elongation. In cool climates, sampling should start in May at weekly intervals. When primordia appear to be increasing on the apex, sampling should be increased to twice a week. Type of primordia and numbers in each class could also be recorded for more detailed analyses of development. Primordia start as single ridges (ie. leaf primordia) and then form double ridges, and progressively develop into spikelets with many florets etc. The double ridge stage is a clear sign of reproductive development and is easy to record, but can occur at some significant time after the actual switch to reproductive development.

Seed and bud banks

Sustainable pastures need to maintain plant numbers, which usually requires recruitment of new plants. This section aims to measure the sources and density of potentially new, plants. Measurements are the potential number of currently germinable seeds in the soil during the main period when seedlings would establish. This excludes dormant and hardseeds that may germinate at some later stage. Measure the control and treatment(s) likely to significantly influence recruitment. Autumn is likely to be the major period for recruitment at most sites.

To estimate the potential source of plant recruitment, take 20 (minimum) random cores (50–75 mm diameter x 50–75 mm deep) per plot, in early autumn ie. before the break in southern areas.

Place intact cores in a protected area, water often, and count and identify seedlings that germinate or plants that regenerate, over time. Record if plants come from seeds or buds. Count and removal emerging plants over a two–eight week period. Seeds that remain will either be dormant or hardseeds which can be extracted and counted to estimate total seed bank. Sample often and as soon as seedlings start to emerge. Cores may be placed in a glasshouse, provided temperatures are not likely to cause abnormal patterns of germination.

To assist unknown seedling identification, sow seeds of the main species of interest in pots at the same time as the cores are taken. Seed for this purpose could be collected the previous spring.

Additional data, including total seed or bud bank weight can be obtained. For perennial plants, the density of underground buds may be more important for regeneration than seeds.

Seedling recruitment

Seedling recruitment is essential for the long-term persistence of perennial pastures. Measurement of seed and bud banks will indicate the potential for recruitment, but it is important to determine the actual levels of recruitment in the field.

Measurements of perennial grass seedling recruitment can be made on the control and at least one other treatment, particularly those that encourage recruitment or flowering.

Counts of new seedlings and older plants can be made in fixed quadrats used for frequency measurements. Count seedlings in a fixed sub-section of the quadrat (eg. 50 x 50 cm, paint area of the quadrat a different colour to delineate the sub-section). Count and record seedlings and mature plants separately for each of perennial species of interest in the same area of the quadrat each time.

Not all seedlings that emerge will survive, so some will have to be tagged to understand when and at what stage seedlings disappear. To measure seedling survival tag 20 seedlings within fixed quadrats using roofing nails or U shaped fencing wire as markers. Tags should be colour-coded for species, date (of tagging) and origin (seed or bud). Some tags will go missing but this is unavoidable in openly grazed plots. Coloured telephone wire or paper clips may also be used as markers.

Tagged plants should be revisited every three months (minimum) to record the presence or absence of seedlings. Counts of mature and seedling plants should be taken every three months and these times may coincide with seasonal.

Roots

Sustainable pastures depend upon having effective root systems to capture and retain nutrients and water from the soil. Data on depth of rooting can be obtained from soil cores or by recording water use using a neutron moisture probe, since water use is correlated with root activity.

Root biomass is best determined from soil cores. This involves a core sampler which removes a small volume of soil from a known position in relation to the surface. Roots are washed free of soil on a sieve (0.3 to 0.45 mm) and their dry mass determined after drying for 24 hours in an oven at 60°C. Root biomass should be reported on a soil volume basis or area of pasture.

When using the soil core method, obtain a sample of known volume with the minimum of disturbance. Screw augers are not recommended because it is difficult to obtain a sample of known volume, they may drag roots from outside the sample area and part of the sample can easily be lost when transferring into a container. For further information on the design and construction of a core sampler see Troughton (1981).

Soil can be washed from the roots within 24 hours of collection or the sample can be stored in a cool room at 0°C or slightly lower and processed at a later time. Washing of roots samples is easier after a short preliminary soaking in water and if pressurised spray water is used. The small quantity of roots that pass through the sieve may be recovered in a container placed below the sieve, floated and collected with a hand-held sieve.

Endophytes

Endophyte infection levels should be assessed at least once over the experimental period. If ryegrass or fescue staggers, or other toxicities are suspected, then herbage samples should be collected to determine toxin levels.

Trees

Trees pose some problems in measurement that are of a different scale to the pasture plants. Tree measurements need to be taken annually.

Diameter

Diameter can be measured from age four onwards, using a diameter tape. This parameter is known as diameter at breast height over bark (DBHOB). Stems are measured 1.3 m above ground level (up-hill side). Measurements are taken at right angles to the long axis of the tree and to the nearest 0.05 cm.

Where the mark falls on a branch whorl, it is moved up or down to the middle of an interwhorl position or off the swelling. Measurement positions are usually marked with 'Paintstik', but this may be impractical on some Eucalypt species with annual bark stripping. Some branch removal around this position may be necessary to provide better access the breast height mark. Avoid obstructions behind the breast height point eg. branches or scrub.

For Eucalypts, if a tree is forked below 1.3m, record the fact, treat it as two or three stems, but calculate its actual diameter as their geometric using the following formula;

$$\text{Diameter} = \sqrt{d1^2 + d2^2 + d3^2}$$

where: $d1$ = diameter of fork 1, $d2$ = diameter of fork 2 and $d3$ = diameter of fork 3.

For pines, if a tree is forked below 1.3 m treat it as single stems. Do not measure any dead trees, but record their presence.

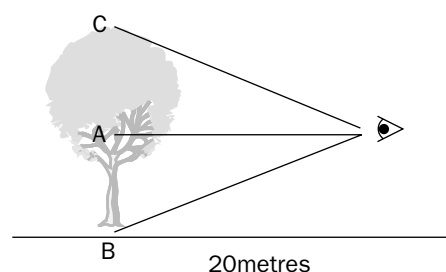
Height

If measuring with a 'height stick', measure to top of growing tip on approach side of mound, measure to nearest centimetre. Tree height above 10 m is measured with a clinometer (on level ground) with the following method:

Sight to top of tree (C) and read % scale for A–C = 63%.

Sight to bottom of tree (B) and read % scale for A–B = 7%

Add the two readings together 63% + 7% = 70% and then multiply by the distance (20 m) = 14 m. Therefore, the tree in this example is 14 m high. If the first reading is greater than 100%, move back 5 m from tree.



Biomass

Assessment of standing biomass for trees is a destructive measurement, related to diameter and height (see above). Once a relationship is established the diameter and height of a tree can be used to calculate its biomass. Trees harvested for biomass can be separated into product and remainder or leaves, branches, trunk etc.

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Animal production theme protocol

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Introduction

The core, minimum data set for pasture for all of the national sites is outlined in Table 7 (page 32). The animal production theme hypothesis is that these data will significantly contribute to:

1. An understanding of the trade-off between animal production and natural resource capital and how to manipulate this sustainability; and
2. Develop 'best' grazing management systems for sustainability, including production, profitability and environmental issues.

The minimum data set must be measured using the methods outlined in this protocol. There are also several additional optional protocols that may be undertaken at sites which are examining certain issues in greater detail (shown in Table 8 on page 33).

General

Welfare guidelines

All sites should be covered by an animal ethics committee. Minimum condition based on fat scores must be decided upon prior to the study commencing, and a feeding or destocking strategy implemented when animals reach these minimum scores.

If animals reach a fat score of 1.5 consideration should be given to either supplementary feed, or reduce stocking rates. Animals should not be allowed to become emaciated.

Mob/flock size

Stock numbers should be sufficient to allow for unexpected deaths which may occur. Spare animals of a similar type to the experimental mobs should be run in an adjacent area, under similar conditions to the control treatment, so that replacement livestock are of similar condition. Five sheep or three cattle per plot would generally be considered a minimum, with at least three replicates.

Management

Where livestock are removed from the plots, detailed measurements (quality and quantity before and after grazing) of the pasture they graze on during removal, liveweight changes and stocking rate should be recorded. This would allow some economic judgement to be made when assessing the treatment as a whole-farm enterprise.

Drought considerations

In dry periods, supplementary feeding of livestock may occur. In prolonged dry conditions, reduce stocking rates or destock so that pastures are not adversely affected by overgrazing.

Supplementary feed should be tested for protein, digestibility and dry matter percentage. Record the amount fed and date of feeding. Grain is easiest to measure and feed as a supplement, however it should be free of weed seeds to avoid contaminating plots. Cost supplements on a protein or energy basis, depending upon the animal requirements at the time.

As a guide to supplementary feeding use the following target scores for mature sheep and steers. Fat scores for prime lambs and maiden ewes should be close to the top end of the range shown.

Stage of reproductive cycle	Target Score
Sheep	
Joining	2+ – 3+
Pregnancy	2–4
At lambing	2–3+ ¹
Lactating	2–3
End of spring	3–4
Wethers and dry ewes	1–3
Rams — Non mating	2–3
— Pre-joining	3–4
Steers	No lower than 1+

¹ Ewes lambing in April–June should be towards the top end of this range.

If livestock are nearing a minimum condition, stocking rate could be reduced or supplements fed. If supplementing, record the following:

- Date, liveweight and fat score of stock when feeding started;
- Amount of supplement fed; and
- Date and liveweight at end of feeding.

When reducing stocking rate, decrease livestock numbers on a percentage basis, so that the relativity of treatment stocking rates remains the same. If stocking rate is reduced, record the following:

- Date and liveweight and fat score when stock are removed, number of animals remaining on plots; and
- Date and liveweight at any stage of removal, and number of animals remaining.

Stocking Rate

Exact numbers of stock on all plots throughout the year should be recorded, with dates of any changes recorded so that stocking rates can be calculated. Stocking rate on the control plots should be realistic for the district and soil and pasture type.

Diary

A diary of all events should be kept, so that at the end of the study records of inputs can be easily followed: ie. supplements, dates fed, quantity, quality; any changes made to animals, drugs given, drenches, inoculations, fertiliser applied, quantities, dates, timing of autumn break etc.

Animal measurements

Allocation of animals to treatments

Animals should be allocated randomly to treatments on a stratified liveweight and fat score basis (preferably on an empty liveweight), so that all treatments commence with animals of similar mean liveweight and fat score. For pregnant ewes scanning allows initial allocation to take into account the fecundity of the ewe, so that treatments commence with ewes of similar pregnancy status (all pregnant, and carrying a similar number of lambs, ie. a similar number of ewes in each treatment carrying singles and twins). This should also occur whenever animals are changed.

Table 7
Summary of the minimum data sets required to be collected for the animal production theme protocol

Measurement	Frequency	Comment
Ewes and lambs		
Weight and fat score	Six weeks pre-joining At joining Mid-pregnancy Pre-lambing At marking At weaning At change of season (12 weeks)	Weight of both ewe and lamb. Weight of both ewe and lamb.
Number of live and dead lambs	Weekly	
Ewes requiring assistance at birth	Weekly	
Lamb deaths per plot	Total	
Lamb weight	Marking and weaning	
Lamb numbers	Marking and weaning	
Wethers, steers and weaners		
Weight and fat score	At change of season	(12 weeks)
Progeny (weaners)		
Full live animal assessment	When leaving plots	Alternatively, do a full carcass assessment of lambs for slaughter.
Liveweight	When leaving plots	
Fat thickness (fat score)	When leaving plots	
GR mm	When leaving plots	
Skin value	When leaving plots	
Also required		
Animal ethics approval		
Records of stock numbers		
Diary		
Wool cut (kg/hd)	Annually	
Wool quality	Annually	
Fat score and liveweight if supplementary feeding	Before supplementation	
Minimum fat score for supplementary feeding		
Faecal egg counts	Prior to drenching, in winter, February and four–six weeks post-break	
Drench resistance test	At start of grazing	
Drench	1 November and as required	
Drench name and volume	At drenching	Also record animal weight, fat score and pasture description.

NB. All animals and products must be fully described when they leave the plots to allow their full economic value to be assessed.

Table 8

Optional, additional data sets that may be collected in the animal production theme protocol and the sites at which they are being collected

	North-West Slopes NSW	Central Tablelands NSW	North-East Victoria	Western Victoria	Western Australia	Wagga Wagga NSW
Progeny leaving plots						
CALM assessment	NA ¹			✓		
Lambs at birth; weight, date, dam identification	NA	✓				
Ewes requiring assistance identification and number	NA	✓		✓		
Lamb population dynamics live and dead per day	NA	✓		✓		
Fecundity; scan ewes	NA	✓		✓		
Eye muscle assessment of lambs at slaughter	NA	3				

1 Not applicable.

Liveweight and fat score

Liveweights should be recorded straight-off pasture (without prior fasting), at the same time of day for each weighing. Fat score at the same time. For the commencement of each trial if possible, animals should have both a full and empty liveweight. Keep in the yards off water for 24 hours for empty weight. Likewise, when the animals are removed from the plots at weaning, to make way for a new lot of animals at the start of a new year, it is good practice to get both a full and empty liveweight.

Where animals are moving on and off plots, they should be weighed onto and off the plots with each change, with core animals remaining on the plots being weighed and fat scored at the same time. In some instances this may coincide with the routine assessment of liveweight (approximately every 12 weeks).

Timing of liveweight and fat scoring measurements

If possible, liveweight and fat score should be measured at the same as estimates of herbage mass, so that the relationship between feed on offer, stocking rate and liveweight change can be examined.

Lambing ewes

Minimum data set is to weigh and fat score:

1. Six weeks pre-joining;
2. At joining;
3. Mid pregnancy;
4. Pre-lambing;
5. At marking—ewe and lamb;
6. Weaning—both ewe and lamb; and
7. At change of season—end of winter—spring; spring—summer; summer—autumn, and autumn—winter (some of these may coincide with other times of measurement).

If supplementation of livestock is needed to overcome feed shortages, a pre-supplementation liveweight and fat score should be taken, and the amount of supplement calculated using this measurement. After starting supplementation, weigh more frequently to monitor the feeding strategy.

Record the number of dead and live lambs on each plot at least weekly if not daily, to indicate if there are any treatment differences in wastage from pregnancy testing to marking, and enable a calculation of average birth date. Weigh lambs at marking and weaning, so that lamb growth rates can be calculated. Ewes requiring assistance at lambing should also be recorded.

Optional measurements include; birthweight, date of birth and to identify the dam. For each plot record the number of dead lambs, and if possible scan the ewes post-mating to determine likely lambing percentage (whether a ewe is single or multiple bearing).

Wethers, steers and weaners

Weigh and fat score animals when they are placed on, or removed from plots. The minimum data set is to weigh and fat score animals from all plots at each change of season; end of winter–spring; spring–summer; summer–autumn, and autumn–winter.

If supplementation of livestock is needed to overcome feed shortages, a pre-supplementation liveweight and fat score should be taken, and the amount of supplement calculated using this measurement. After starting supplementation, weigh more frequently to monitor the feeding strategy.

Progeny leaving plots as weaners

Stock weaned off the plots should have a full live animal assessment—liveweight, estimated fat thickness (fat score) (GR) in millimetres, and skin value estimated. The live animal GR assessment should be done by an experienced livestock officer, who is competent in estimating fat score and fat thickness in millimetres. A CALM assessment is optional.

If lambs are going to be turned off for slaughter, a full carcass assessment is required. This should include dressing percentage (need to get carcass weight), and fat thickness (GR and C site fat measurements). Measurement of eye muscle area is optional.

Choosing a representative selection of animals to measure

Where flock sizes are large, ie. 100 or more, a representative sample (20%) of sheep can be tagged with different coloured tags and weighed, rather than weighing all sheep each time. However, all sheep should be weighed at the first and last weighing of each season. To obtain a representative sample of 20% of the flock, stratify the all sheep liveweights by dividing them into 20 groups and randomly select one animal from each group. This will give a similar liveweight distribution pattern to the main flock. Ensure that the fat score is of a similar average to that of the main flock, if not, re randomise. Selected animals can be either drafted from the main mob and then measured, or all animals run through the scales and only the selected ones measured.

Wool

The minimum data set requires and estimate of wool cut per head and wool quality to assess fleece value.

Wool cut per head

Weigh individual fleeces, unskirted, with bellies at shearing.

Wool quality

Midside sample at shearing for quality measurements (a sample from each fleece of around 50 g). Stored in a separate plastic bag with a label recording animal number. These bags should be stored in a box with moth balls. At a later time samples may be bulked by weighing out a standard amount of each sample and bulking to around 50 g (eg. if you have 20 samples weigh 2.5 g of each sample). Bulking samples reduces costs, but allows an estimate of fleece quality and value to be made.

For fibre strength, at least 30 staples are needed per treatment (eg. for a mob size of 15, that means two staples from each midside sample). For flocks of around 100, a random selection of 60 midside samples, with a staple from each sample is required. Fibre diameter cost approximately \$3.00 per sample, and staple strength \$0.75 per staple. For tender wool, measure where any break occurs.

Fat scoring sheep and lambs

Scores are based on actual soft tissue depth at the GR site (Figure 2). The GR site is 110 mm from the midline over the 12th rib. Fat scores (Table 9) vary from 1-score (leanest) to 5-score (fattest), (Jeffries 1961).

Figure 2
Position of GR site

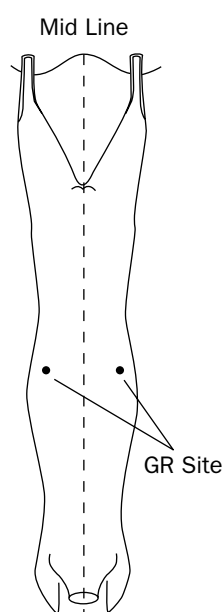


Table 9
Description of fat scoring sheep

Fat score	1	2	3	4	5
GR tissue depth (mm)	0–5 mm	6–10 mm	11–15 mm	16–20 mm	20 mm +
Long ribs	Individual ribs felt very easily. Cannot feel any tissue over the ribs.	Individual ribs easily felt but some tissue present.	Individual ribs can still be felt but can feel tissue.	Can just feel ribs and fluid movement of tissue.	Ribs barely felt. Tissue movement very fluid.

To achieve a reliable score, have the sheep or lamb standing in a relaxed state, preferably in a race or liveweight scales. The animal will not be bruised if assessed in the correct manner by palpation with the fingertips and thumb. The scorer must work fingers through the wool to skin level, before feeling for fat cover over the bones (Figure 3).

The best site to feel when assessing fatness is over the long ribs (Figure 4). This includes the GR site, where fatness is measured on the carcass. Generally, at the same weight ewe lambs will be fatter than wether lambs, which will in turn be fatter than ram or cryptorchid lambs.

Figure 3
GR fat measurement

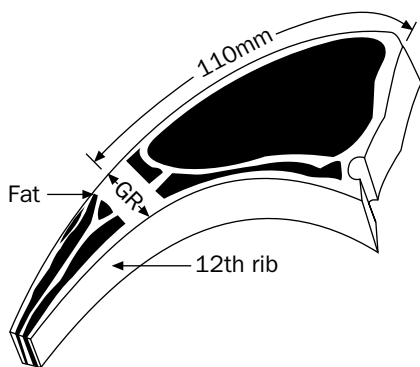


Figure 4
Fat scoring sheep by palpating the long ribs



Fat Scoring Cattle

Cattle should be fat scored according to the criteria in Table 10. This score can be used to estimate fat thickness, that applies to current marketing descriptions. Note that this system is slightly different to the old condition scoring system, since there is an additional category.

Figure 5
Fat scoring cattle

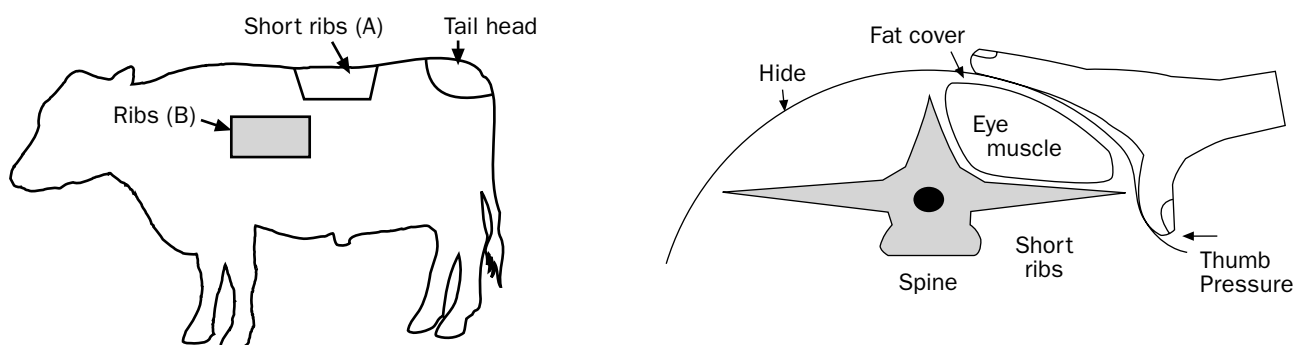


Table 10
Description of fat scores for cattle

Description	Cows		Steer/heifers (20 mths old)	
	Score	Fat (mm)	Score	Fat (mm)
Emaciated	0		0	
The individual short ribs (site A) are sharp to the touch, no tail fat. The hip bones and ribs are prominent.	1 ^A	0–2	1	0–2
The individual short ribs can easily be felt, but feel rounded rather than sharp. There is some tissue cover around the tail head. Individual ribs (site B) are no longer visually obvious, at the higher end of this score (2H).	2	3–6	2	3–76
The individual short ribs feel increasingly rounded. Ribs (B) easily felt with firm pressure.	3	7–12	3L	7–9
The short ribs can only be felt with firm thumb pressure. Areas either side of tail head have fat cover which can be easily felt.	4L	13–17	3H	10–12
The short ribs cannot be felt and fat cover around the tail head is easily seen as slight mounds, soft to touch. Folds of fat are beginning to develop over ribs and thighs. Ribs (B) are hard to feel.	4H	18–22	4L	13–17
The bone structure of the animal is no longer noticeable and the tailhead is almost completely buried in fatty tissue	5	23+	4	17+

A The score can be varied half a score depending upon the amount of tail head fat. For example, if the score at the tail head is 2, but ribs 3, the score would be 2.5.

Animal reproduction considerations

Check rams prior to joining:

- Check scrotal size and consistency;
- Check for any scrotal or penis abnormality;
- Check if any lameness or signs of ill-health; and
- Record ram condition score and weight.

Repeat above ‘check’ post-joining to determine possible ram effects on reproductive performance of experimental mobs.

- Record total number of lambs Born—Lambing %.
- Record total number of lambs Marked—Marking %.
- Record total number of lambs Weaned—Weaning %.
- It is optional to scan ewes four–six weeks after the end of mating—Pregnancy %.

Animal health

All mobs should have a faecal egg count (FEC) prior to all drenches, with the possible exception of the first summer drench. Where possible coincide FEC at the same time as fat scoring and weighing.

FEC should be based on at least 10 samples per mob, results reported either as a bulked average per mob or individual results for each sample. Only highly effective drenches should be used.

In southern Australia, a first summer drench in November of a highly effective drench is required regardless of FEC level. All mobs should have at least one FEC in winter and sheep should be monitored at least prior to lambing to decide if they need drenching.

Data required at time of FEC and or drench

Record :

- drench name and volume used;
- weight and condition score of sheep; and
- pasture description (volume and type).

Sites where barber's pole (*Haemonchus* sp.) and or fluke (*Fasciola hepatica*) are present in significant numbers need to make appropriate adjustments to above protocol. Keep similar records for these treatments as described above.

Additional faecal egg counting information

February FEC : guide for predicting subsequent winter paddock worm levels if < 50 epg second summer drench not required. **Autumn–winter FEC:**—Commence four–six weeks post autumn break. Autumn break for hatching worm larvae from faecal pellets is around 30–50 mm of rain, sufficient to establish and sustain a green cover of pasture.

FEC monitoring frequency during winter will depend on: age of sheep (two–four weekly < 12 months, less frequently in older sheep); paddock worm levels; nutritional status of pasture ,and condition of sheep.

A drench resistance test should be carried out prior to the trial commencing. Each mob should have at least one larval speciation conducted annually if FEC is > 200 epg.

Pasture parasitic worm larval culture conducted on each site in mid-winter, is optional, but would provide an indication of paddock worm levels. Use 1 kg of pasture collected from across paddock. IMVS Adelaide conducts this test for \$20.00. Pasture worm larval tests enable estimates of paddock worm levels. Whilst not as accurate as using autopsies of tracer sheep, it is a cheaper and easier.

Data handling, spreadsheet field names etc

To ensure that all sites use similar terminology, the field names associated with animal measurements are as follows:

Treat	Treatment number
Rep	Replicate number
Plot No	Plot or paddock number
Tag	Ear tag number
Lamb Tag	Lamb ear tag number
Ewe lwt	Ewe liveweight (kg)
Lamb wt	Lamb liveweight (kg)
LWT	Wether, or weaner or steer liveweight, where dry animals are used (kg)
Mark wt	Liveweight of lamb at marking (kg)
Wean wt	Liveweight of lamb at weaning (kg)
Fat Score	Fat score of any animals scored
GR live	The fat measurement in mm at the GR site on the live animal
GR Car	The GR measurement on the carcass (mm)
B Date	Birth date (dd.mm.yy)
B Wt	Birth weight (kg)

Sex	Sex of progeny, male or female (M or F)
Lmb %	Lambing percentage,
Mk %	Marking percentage
Wean %	Weaning percentage
Fleece Wt	Fleece weight (kg)
Supp	Supplementary feed
SR	Stocking rate

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Water theme protocol

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Introduction

The core, minimum data set for pasture for all of the national sites is outlined in Table 11 (page 41). The water theme hypothesis is that these data will significantly contribute to:

1. An understanding of how much water and what quality is required at different points in the landscape;
2. An understanding of the impact of vegetation type on water quality and quantity and water pathways in the landscape;
3. An understanding of the impact of management practices on water use and water movement by various pathways;
4. Determine sustainable land use practices; and
5. Develop strategic policy guidelines, addressing the on-site and off-site impacts of water.

The minimum data set must be measured using the methods outlined in this protocol. There are also several additional optional protocols that may be undertaken at particular sites which are examining certain issues in greater detail in Table 12 on page 41.

This protocol serves two purposes:

1. To identify the minimum data set to be collected at each of the national sites to enable cross-site comparisons to be made of the water use efficiency of various pasture types under a range of grazing management practices.
2. To identify a more comprehensive set of measurements to be made at the North-East Victoria sites (Ruffy and Maindample) to enable water fluxes, both lateral and vertical, to be measured and modelled at a realistic catchment scale.

From these data, it should be possible to make estimates of the lateral and vertical water fluxes, at a catchment scale, at sites other than North-East Victoria. It may also be possible to model these fluxes using validated models at other sites.

A secondary role is to quantifying lateral and vertical nutrient fluxes at the North-east Victoria sites, using procedures outlined in the nutrient theme protocol. Depending on the availability of data at other national sites, it may be possible to quantify nutrient fluxes at these sites and to model nutrient movement.

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Table 11**Summary of the minimum data sets required to be collected for the water theme protocol**

Measurement	Frequency	Comment
Meteorological data		
Rainfall	30 min	Also use manual raingauge.
Humidity	60 min	
Maximum air temperature	60 min	
Minimum air temperature	60 min	
Solar radiation	60 min	
Wind speed	60 min	
Soil water content	12 times per year	Use a neutron moisture meter.
Bulk density of key soil horizons	As required	
Water retention curve	Measure once	Also required for site characterisation.
Diary of events		

Table 12**Optional, additional data sets that may be collected in the water theme protocol and the sites at which they are being collected**

	North-West Slopes NSW	Central Tablelands NSW	North-East Victoria	Western Victoria	Western Australia	Wagga Wagga NSW
Gravimetric soil moisture (0–10 cm)	✓	✓				
Hydraulic conductivity	✓					
Whole catchment flumes			✓			
Run-off plots	✓	✓				

Minimum data sets to be collected at all sites**Meteorological data**

These data are required to quantify the two main terms in the water balance equation—precipitation (rainfall) and evaporation. Minimum meteorological data requirements for each site are as follows:

Rainfall

Measured with an automatic recording raingauge. Use a short time step (eg. 30 minutes) so that changes in rainfall intensity with time can be monitored. Install the instrument well clear of obstructions, ie. at least as far from a tree or building as the height of the object above ground level. The top of the gauge should be 30 cm above ground level. Also use at least one manual gauge read on a daily basis where practical, or at least weekly.

Humidity

Can be measured with psychrometers (wet and dry bulb thermometers) or hygrometers (calibrated relative humidity values). The Penman-Monteith equation for calculating evapotranspiration requires a measure of the vapour pressure deficit, which is the difference between average saturation vapour pressure and average actual vapour pressure, on a daily basis. Average saturation vapour pressure can be obtained from the saturation vapour pressures at T_{\max} and T_{\min} , where T_{\max} and T_{\min} are respectively, the maximum air temperature (early afternoon) and minimum air temperature (early morning). Daily average vapour pressure is best determined from a relative humidity measurement at T_{\max} and T_{\min} . Use continuous data loggers with measurements recorded at hourly intervals. Details are given in FAO (1992).

Temperature

Maximum and minimum air temperatures are required (FAO 1992).

Net solar radiation

Measure net radiation using a net radiometer. If a net radiometer is not available, net radiation can be calculated from solar radiation, temperature and humidity (see FAO 1992).

Wind speed

Measured continuously at 2 m height (measurements made at other heights can be converted to this height—see FAO, 1992). Measurements should not be overly protected or exposed site.

Frequency of measurement for all data, except rainfall should be hourly. Meteorological data (except rainfall) will be used to calculate the potential or reference evaporation ET_o (evapotranspiration) by the Penman-Monteith (FAO 1992) and Priestley-Taylor (1972) equations, on a daily basis. Both calculations be done and results compared to identify atypical values.

Use SI units for all measurements. Soil heat flux is a small but necessary part of the energy term in the ET_o calculations. It can be measured on an hourly basis, using a soil heat plate inserted horizontally at a depth of 5 cm. However, if equipment is not available, the soil heat flux can be estimated for a daily time step from an empirical equation given by Jensen *et al.* (1990) (see FAO 1992). Data loggers should be down-loaded at two–three week intervals.

Soil water measurements

Soil water content, measured with a neutron moisture meter (NMM), is an essential soil water measurement. This measures volumetric soil water content (θ_v) in units of m^3 water/ m^3 soil.

Type and number of access tubes per treatment

Aluminium tubes sealed at the base should be installed at a minimum of two tubes in each plot. For larger areas, a minimum of one tube/ha should be installed. If the site has uniform, flat relief and the same soil phase, tubes can be installed on a grid. However, if topography is variable and subtle differences in soil phases have been observed, then tubes should be sited to cover the variability.

Tube installation

A soil core, the same size as the external diameter of the access tube, must be extracted. Sufficient slurry (a mixture of kaolinite and cement (3:1) and water) should be poured into the hole. The slurry rises to the soil surface when the tube is pushed into the soil core hole. Horizon depths should be noted for each core when tubes are installed.

Depth of tube installation and readings

Tubes must be installed below the estimated bottom of the root zone of the deepest rooting species (approximately 1.5 m for phalaris, but this depth may be greater for kikuyu). Tubes should protrude from the soil surface by 10 cm and so will need to be cut 10 cm longer than the depth of installation. Each tube should be sealed with a rubber bung when not in use and protected from stock by a PVC pipe-end or heavy-duty wire cage.

The first reading should be taken at 20 cm depth (below the soil surface), and thereafter in 20 cm increments. Shield counts must be taken before each day's measurements and averaged. Any changes in average shield count must be noted. If average shield counts change markedly have the probe checked. NMM readings are expressed relative to the average shield count, as relative NMM count.

Frequency of measurement

As a minimum, soil water content must be measured 12 times per year, approximately monthly (to enable reality checking for models). Measurements should be more frequent when the soil is rapidly wetting or drying, and can be less frequent during prolonged dry periods in summer. The maximum period without measurement must not exceed two months. At least two measurements should be made in winter when soil may be at its mean maximum water content. This value should be checked in successive years. Soil profile water content at this maximum water content (converted to mm) is used to calculate soil water deficit (SWD) at other times of the year.

Assessment of the appropriateness of installation depth

Data from the deepest soil depth need to be checked regularly to determine whether the full depth of the root zone has been sampled. Soil water content at this depth should not change markedly between summer and winter; if it does than some deeper tubes will need to be installed

Calibration of the NMM

The NMM needs to be calibrated for each site. Since calibration is destructive, extra tubes must be installed for calibration purposes. Calibrations must cover a range of soil water contents from dry to wet, for at least two times of measurement. Take intact soil cores to the full depth of measurement, with minimum compaction, in a circle around an existing access tube. Record NMM readings in the access tube just before cores are removed. Cut cores into segments of known length (generally segments correspond to soil horizons). Dry cores at 105°C to a constant weight and calculate gravimetric soil water content (θ_g) using equation 2. Calculate soil bulk density (ρ_b , equation 3) for each core segment, and derive volumetric soil water content (θ_v) from;

$$\theta_v = \theta_g \rho_b \quad (1)$$

take four cores around each access tube and sample at least two access tubes sampled per site. Repeated these measurements under wet and dry conditions. Plot values of θ_v from equation 1 for each depth segment against relative NMM count to determine the calibration function, which should be linear. Data can be pooled to obtain an overall calibration function for each site if there are no significant differences between depths (horizons) in their slope and intercept. If calibration lines are different use a separate calibration for each depths.

Bulk density of key soil horizons

A measure of bulk density (ρ_b) of key soil horizons is essential for calibration of the NMM. Bulk density (ρ_b) is the ratio of oven-dry mass of an intact soil sample to its bulk volume, in Mg soil/m³ of soil volume. Mass is obtained by drying the soil to constant weight at 105°C. Intact core samples should be taken for each soil horizon using an internal core diameter of at least 75 mm and 50–75 mm in length (Cresswell and Smiles 1995).

Cores can be extracted either vertically, or horizontally from a pit face. McKenzie and Cresswell (1995) describe the equipment used for vertical extraction of soil cores. Once extracted, the core should be trimmed with a sharp knife. Remove the sample and transfer it to a weighed container (W1). Record the weight of container plus soil sample (W2), dry the soil to constant weight at 105°C, cool in a desiccator, and weigh (W3). The internal diameter and length of the coring tube should be checked with calipers (diameter = 2r, length = l), and its volume calculated as $\pi r^2 l$.

Calculations

For gravimetric moisture content, volumetric moisture content and bulk density use the equations outlined by Cresswell and Smiles (1995), which are as follows:

Gravimetric soil moisture content (Mg water/Mg oven-dry soil),

$$\theta_g = (W2-W3)/(W3-W1) \quad (2)$$

Bulk density is calculated by,

$$\rho_b = (W3-W1)/(\pi r^2 l) \quad (3)$$

Volumetric soil water content is given by

$$\theta_v = \frac{\rho_b}{\rho_w} \theta_g \quad (4)$$

$$\text{ie. } \theta_v = (W2-W3)/(\rho_w \pi r^2 l) \quad (5)$$

where, ρ_w , is the density of water (1.0 Mg/m³).

Water retention curve (soil moisture characteristic)

This is the relationship between soil volumetric water content and matric potential (or soil water suction). Collect intact soil cores (50–75 mm diameter x 50–60 cm long) from the field and determine the soil water retention curve on ceramic plates (Soil Moisture Equipment) in the laboratory. Wrap the base of each core in an inert material of coarse mesh to prevent soil from falling out. Wet cores to saturation by standing them in shallow dishes of water. Suctions in the range 0.1 to 10 kPa (head 10–100 cm) can be applied using a ‘hanging’ water column. Higher suctions are applied through a pressure plate (compressed air with a pressure regulator). Measurements should be made on the A and B horizons if they differ markedly in texture and structure. The most useful range for drainage purposes is at relatively low suctions (0–100 kPa). For details of the procedure, refer to Cresswell and Smiles (1995).

The water retention relationship can be measured in the field, if tensiometer potential (see below) and θ_v measurements are made in close proximity at the same time. However, the laboratory method is recommended since it is less prone to instrument failure and gives a reasonable representation of the water retention curve, provided that a minimum of four replicate measurements be made for each treatment or each major horizon. If the precision of measurement is <10%, additional cores should be sampled and measured. Water retention curves need only be measured once.

Protocols for additional, optional data

Most of these measurements are required for modelling water flow in one or more dimensions. Choice of measurements will depend on the type of model being used.

Soil water content

Other techniques

Other than the NMM probe soil water content may also be measured using capacitance probes (frequency domain reflectometry, FDR), TDR probes (time domain reflectometry) or calibrated gypsum blocks. The latter are the least desirable for drainage studies; they do not work well at the wet end of the water content range (0–100 kPa suction). They may also deteriorate if left in the soil for a long period of time. Performance of FDR probes can be satisfactory provided they are calibrated and a sufficient number are installed to cover the full range of site variation in soil water content. TDR probes are also satisfactory provided that the probe heads are properly sealed to prevent water ingress in wet soils. There are limits to the length of coaxial cable through which a signal can be satisfactorily detected using multiplexed probes, so for measurements at the scale of these field experiments TDR probes may have to be read manually.

Water potential

Tensiometer potential

Install tensiometers to measure water potential at several depths in the soil, to calculate head gradients for water movement. It is recommended that sets of tensiometers be installed between depths of 20 and 180 cm. In non-swelling soils, tensiometers measure the sum of matric and gravitational potentials (the tensiometer potential). Gravitational potential is usually measured relative to the soil surface. If gauge tensiometers are used (eg. Soil Moisture Jet-Fill), they should be calibrated to read the correct gravitational potential at the depth of installation, when matric potential is zero. Gauge tensiometers need to be protected from frost. Alternatively, tensiometers with a portable pressure transducer (eg. a Loktronic sensor) can be used. Install tensiometers by augering slightly larger than its diameter, to a depth 10 cm less than the full depth of installation. Core the remaining 10 cm to the exact diameter of the tensiometer's porous cup, which is then pushed in to the appropriate depth. Back-fill the space around the tensiometer shaft with a soil slurry and sealed the top 2–3 cm with a plug of bentonite clay.

Preferred units of matric potential are kPa; those of hydraulic head in the unsaturated (vadose) zone are usually in centimetres or metres.

Piezometric head

Tensiometers work best in the vadose zone, although they can indicate when, and at what depth, a perched watertable occurs (commonly at the top of the B horizon in duplex soils in winter). Piezometers can measure piezometric head of water in the saturated zone (below a regional watertable). Piezometers consist of a PVC pipe (5–7.5 cm diameter), slotted at the end (for 15–20 cm). Slots should be covered with a strong gauze to prevent soil particles falling into the piezometer when it is installed in the ground. Install the pipe vertically to the required depth (open at the base) and sealed around the top with bentonite clay (as for the NMM access tubes). Piezometers should be fitted with a removable cap to prevent water entering the pipe.

Piezometric head (h) is the sum of the pressure potential, which is directly proportional to the depth (p) below the watertable at the point of measurement, and the gravitational potential, which is directly proportional to the depth (z) of the point of measurement below a reference level (usually the soil surface), ie.

$$h = p + z \quad (6)$$

By convention, z is measured positively upwards. The units of head will normally be metres.

Tensiometers and piezometers should be read as frequently as possible, but on average once a week. Read more frequently when soil is wet compared with when it is dry.

Hydraulic conductivity (K)

There are several methods available, ranging from *in situ* field measurements to laboratory methods using intact soil cores. In general, field measurements are preferred. In duplex soils, K values for both A and B horizons will be required. A major problem with hydraulic conductivity measurements is their extreme spatial variability, especially for saturated hydraulic conductivity (K_s). Therefore, field methods for K_s which offer some integration of short-range spatial variability are preferred (eg. drip infiltrometer). Disc permeameters are a surface technique that can be used in the field and have an advantage that hydraulic conductivity can be measured at very low suctions (*c.*0.1 kPa), eliminating some of the short-range variability related to the presence or absence of macropores.

To measure the B horizon, excavated soil to the top of this horizon and take intact cores for laboratory measurements of K_s (eg. one-step outflow method). Alternatively, a drip infiltrometer or disc permeameter can be used at the top of the B horizon in the field. Field measurements should be made when the soil is at or near field capacity. For hydraulic conductivities at greater depth (well below the A–B boundary), a well permeameter can be used. The methods described measure K vertically, except for the well permeameter which measures a combination K value for vertical and lateral flow. Where vertical and lateral flow occurs in the saturated or unsaturated zone, it is usually assumed that the soil is isotropic for hydraulic conductivity.

Details of these methods are given in Klute (1986), Cook (1995) or by Cook and Broeren (1995). Note that field measurements of saturated conductivity, even by the drip infiltrometer, are usually only *c.*0.95 K_s as measured on saturated soil cores in the laboratory because of air entrapment in dead-end pores. A correction should therefore be made before comparing between field and laboratory saturated conductivities.

Surface run-off

Surface run-off can be measured for whole catchments, such as at the North-East Victoria sites, by installing weirs or flumes with continuous flow measuring equipment. If the catchment is not hydrologically distinct, surface barriers (PVC sheet or earth banks at least 15 cm high) must be installed to ensure that there is no run-on from outside the catchment, and all run-off channelled through the weir or flume. Discharge rate (volume/time) should be measured continuously and the total discharge during an event obtained by integration of the area under the hydrograph. Use the area of the catchment, to calculate discharge in mm (10m³/ha).

Surface run-off can also be measured using bounded run-off plots with a minimum length of 22.6 metres, orientated down the slope. Barriers are used to prevent run-on and run-off, except at the bottom of the plot where a trough or gutter is installed level with the soil surface to collect run-off water, sediment and nutrients from the plot (Hudson 1981). Run-off either falls directly into a tipping bucket attached to a data logger or can be led by pipe to a tipping bucket flow meter (with data logger) to estimate discharge rates. Discharge (mm) can be calculated from the area of the plot. For plots longer than the minimum length or of different slope, soil loss data can be adjusted to the Universal Soil Loss Equation (USLE) unit plot slope of 9% and plot length of 22m using USLE S (slope) and L (length) factors.

Run-off can be sampled for measurement of nutrient and suspended sediment concentrations (see nutrient theme protocol). Samples should be taken at a frequency proportional to flow rate (eg. a sample collected for each mm of discharge). Samples can be analysed individually, or bulked over a period of time. If collected individually, they should be analysed within 24 hours of collection. Otherwise, they should be treated with a preservative (eg. phenyl mercuric acetate, see nutrient theme protocol). Samples should be kept at 4°C during transport and storage. There is little point in collecting water samples for analysis, unless the flow rate at the time of collection is measured or can be estimated, because solute and sediment concentrations can change markedly with flow rate. Where surface run-off is believed to be occurring, but is not being measured, visual observations of any surface sealing or crusting should be noted, in addition to estimates being made of percent groundcover (see pasture theme protocol). An Emerson aggregate stability test could also be used.

Data recording

All data should be recorded in Excel spreadsheets. Each treatment should have a separate sheet with times of measurement being allocated sequentially to rows (with times in Eastern Standard Time). Assign replicates to columns, with measured values and derived calculations grouped in blocks of columns. All sheets and columns must have a heading. Use standard units (Table 13), which must be clearly displayed.

Table 13

Units for water measurements in the minimum data set

Variable	Units	Variable	Units
Rainfall	mm	Vapour pressure	kPa
Relative humidity	%	Volumetric water content	m ³ /m ³
Temperature	degrees Celsius	Suction	kPa
Radiative flux	MJ/m ² /d	Bulk density	Mg/m ³
Wind speed	m/s	Core length	mm
Soil heat flux	MJ/m ² /d	Soil depths	cm

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Nutrient theme protocol

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Introduction

This protocol identifies the minimum data set (Table 14) to be collected at each of the national sites. Together with the site characterisation protocol it will allow soils to be classified according to the Australian Soil Classification (Isbell 1996), and to describe soil fertility in a way which can be easily related to graziers. The nutrient theme hypothesis is that these data will significantly contribute to:

1. An understanding of the positive and negative effects of nitrogen and phosphorus both on and off-site; and
2. Useable models to evaluate the risks and benefits of various fertiliser strategies.

The minimum data set must be measured using the methods outlined in this protocol. There are also several additional, optional measurements that will be undertaken at particular sites which are described later in this protocol.

Table 14
Summary of the minimum data sets required to be collected for the nutrient theme protocol

Measurement	Frequency	Comment
Surface soil (0–10 cm) Olsen, Colwell or Bray P, KCl-extractable S, extractable cations, pH in water and CaCl ₂ , and EC	Start and end of experiment	Sample plots at start; all fertilised plots at end.
Cross-laboratory standards (0–10 cm) Olsen, Colwell and Bray P, KCl-extractable S, extractable cations, pH in water and CaCl ₂ , and EC	Spring 1998 and spring 2000	Sample all replicates of two treatments.
Archiving of cross-site samples (dried and frozen)		All sites responsible.
Cross-batch internal standards	With each batch of surface soil samples	Two cross-laboratory standards included in each batch.
Labile carbon	Each spring	Sample control and one other treatment.

Minimum data sets to be collected at all sites

Standard soil tests

Samples for standard commercial soil testing should be taken from all plots as soon as possible after the start of studies at each of the national sites. A fixed sampling transect should be used to reduce the effect of spatial variation on temporal changes. Transects should avoid camp areas and headlands, and should sample across any variation which resulted from fertiliser spreading (ie. transects should not be parallel to the direction of fertiliser spreading). A scientist or technician responsible for soil sampling should be present during fertiliser spreading to check on evenness of distribution.

Between 20–30 cores should be taken from each plot to a depth of 10 cm and bulked to form a composite sample. Core length should be regularly checked during sample collection, to ensure that only cores of at least 9.5 cm are included in the sample. Inadequate core length can be caused by stones or soil adhering to the inside of the sampling tube. Thorough cleaning of the tube can often overcome inadequate core length. Soil moisture conditions which are either too wet or too dry make it difficult to sample to the correct depth.

Samples should be either air-dried or dried in an oven at 40°C, and analysed for the following:

- Olsen, Colwell or Bray P;
- KCl-extractable S;
- extractable cations;
- pH in water and CaCl₂; and
- EC (1:5).

Samples should be collected in autumn prior to any fertiliser application, and as an additional option may be collected annually in either spring or autumn for the remainder of the experiment. Fertilised treatments need to be sampled at the end of the experiment as part of the minimum protocol.

Cross-site samples and sample archiving

Laboratories which participate in cross-laboratory testing through the Australian Soil and Plant Analysis Council (ASPAC) are recommended for analyses. It is, however, recommended that SGS national sites have their own cross-laboratory standards taken from each sites. The same samples will also be used to compare across the three phosphorus extraction methods in common use in Australia.

Each site team will collect samples from three replicates of a high fertility treatment and three from a low fertility treatment in spring 1998 and 2000. At the North-East Victoria site, a representative area of each of the six catchments will be sampled. About 1 kg of soil will be collected from the 0–10 cm layer in the sampling transect of each of these six plots in spring 1998, and about 0.5 kg in spring 2000. Each sample will be dried at 40°C then split by the site team so a portion (~100 g) can be analysed by the site team's regular laboratory and the remainder by a central laboratory. At the central laboratory, samples will be analysed for Colwell, Olsen and Bray P. Unused ground sample from the 1998 collection will be returned to the site team to be stored frozen.

Whenever the site is sampled for other regular soil analysis, two of the frozen cross-site standard samples will be included in the analytical run as a quality check. One of these will be from a low fertility plot, the other from a high fertility plot. At 50 g per analysis, 500 g of dried ground sample would be sufficient as an internal standard for 10 analyses.

If, at the end of the experiment, a check needs to be made on changes, for example, in pH or total nitrogen, the six frozen cross-site samples can be used as a benchmark. It is advisable to also retain dried frozen sample from at least one sampling of topsoil from all plots, taken early in the study at each of the national sites, so that there is statistical sensitivity in any analyses undertaken.

Labile carbon

Sample collection and preparation

Soil will be collected for labile carbon analysis from the 0–5 cm layer on transects in the same six plots as the cross-site samples in the spring of 1998, 1999 and 2000. Visible roots will be removed and the soil air dried and ground to 0.5 mm. If samples cannot be processed and air dried immediately after sampling then they will be stored at 4°C until drying. Both paper and plastic bags are suitable for storage. About 20 g of processed soil is required for the analysis.

Sample analysis

Samples will be analysed at the University of New England using the procedures outlined by Blair *et al.* (1995) to determine:

- total carbon (and total nitrogen, N₁₅, delta carbon), and
- labile carbon (proportion of C oxidised by 333 mM KMnO₄).

For analysis, processed soil samples will be sent in labelled glass or plastic jars to:

Dr G. Blair
Division of Agronomy and Soil Science
University of New England
Armidale NSW 2351

Protocols for additional, optional data

Optional protocols that may be undertaken at particular sites are listed in Table 15.

Table 15

Optional, additional data sets that may be collected in the nutrient theme protocol and the sites at which they are being collected

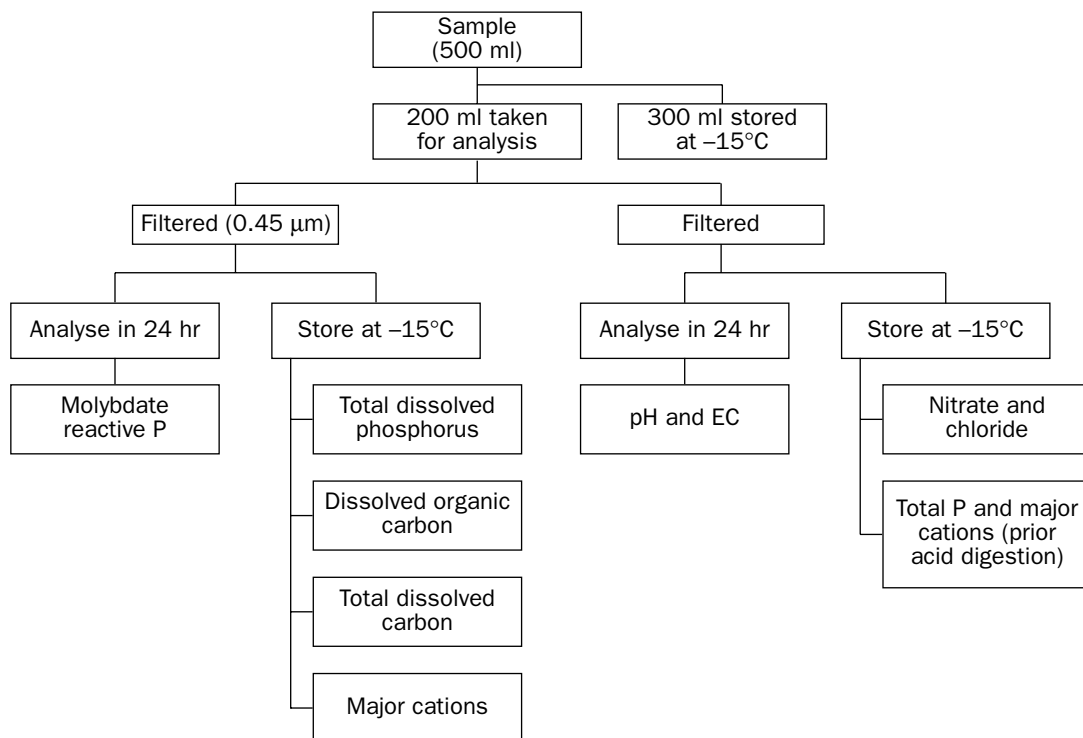
	North-West Slopes NSW	Central Tablelands NSW	North-East Victoria	Western Victoria	Western Australia	Wagga Wagga NSW
Water quality	✓		✓	✓		
Treatment audit			✓	✓		
Plant tissue samples				✓		
Fertiliser test strips				✓		

Water quality

Water samples require great care to ensure that P does not adsorb to the surface of collection equipment, and that biological transformation of P and N forms is minimised. Samples should be collected in polyethylene bottles which have been prewashed in 1M HCl. Samples of at least 0.5 litre should be collected to enable determination of both P and N. Samples for inorganic P and nitrate and ammonium N should be filtered through 0.45 mm filter paper either in the field or immediately upon return to the laboratory, then either stored at 4°C and analysed within 24 hours, or frozen until analysed. A summary of storage procedures used in studies by Cox *et al.* (1995) is shown in Figure 6 on page 52.

Figure 6

Procedure for analysis of water samples taken from surface and subsurface flows. Source: (Cox et al. 1995).



Where only total P and N are required, sample preservation is less critical. Two drops of concentrated HCl can be placed in each sample collection bottle when setting up an autosampler, and after sample collection the acidified samples can be stored for one–two weeks. However, longer periods of storage increase the risk of biological action affecting samples and so quality checks should be done on stored samples.

P and N determinations should be made by autoanalyser using method H1b of Rayment and Higginson (1992) for total P, method H2b for inorganic P, and method G4a for nitrate. Nitrate determinations include nitrite, which is usually present in only trace amounts.

Where automatic sampling equipment has been installed, there can be up to 24 samples from each flow event. Not all of these need to be analysed; composite samples can be made representing early, mid and late stages of the flow hydrograph, reducing a flow event to as few as three samples.

Treatment audit

This will be conducted at the start and end of the experiment. Soil cores collected during the installation of neutron access tubes are suitable for the treatments audit, provided there are at least three tubes per plot. Samples should be bulked for each depth across tube holes.

Depths sampled: 0–5 cm, 5–10 cm, then in increments of between 10–20 cm to the bottom of the root zone. The following analyses should be conducted:

- total P, S and cations (to 20 cm);
- pH (to bottom of root zone);
- total N (to 10 cm); and
- organic carbon (to 10 cm).

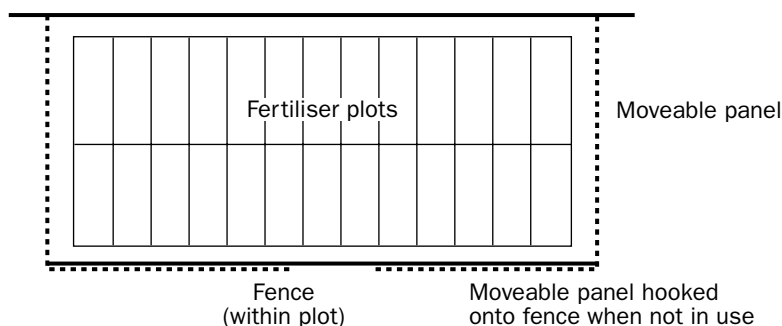
Analyses below the listed depths did not show statistically significant differences in the audit of the long-term phosphorus experiment at Hamilton, Victoria and are unlikely to show significant differences in the shorter term SGS studies. Initial samples should be taken in 1997 and final samples four years later, in autumn 2001.

Plant tissue samples

Plant tissue sampling is useful to check whether micronutrients may be limiting productivity. It is most likely to be useful on high-fertility treatments where macronutrient deficiencies have been corrected and micronutrients may be limiting production. Young leaves and petioles of subterranean clover or annual medic should be collected in late-winter or early-spring, prior to flowering. Phalaris shoots could also be collected at the same time, to build up information on nutritional problems that may limit its longevity. Samples should be dried at 60°C and analysed for P, K, S, Ca, Mg, Na, Cu, Zn, Mn, Fe, Al, Mo, and B. At least 100 g of fresh material should be collected, and samples kept cool between collection and drying. Guidelines for interpreting tissues analyses are presented by Reuter *et al.* (1997).

Fertiliser test strips

Test strips are a tool for informed fertiliser decision-making. Responses to N, P, K, S and micronutrients can be measured on test strips 2 x 5 m which are part of a grazed pasture, but fenced with Ringlock panels which can be opened and closed as required. A starting measurement of herbage mass should be made. The area is then closed for four weeks and herbage mass measured prior to opening. The area can be closed again after grazing for a week



Results from the Hamilton group, using this technique, have shown that:

- the response curve to P fertiliser using this technique indicates higher optimal P rates than the traditional mown plots (Cayley and Hannah 1995);
- unimproved treatments have a negligible response to fertiliser because the responsive species are not present; and
- the proportional response to extra P is similar in autumn, winter and spring, but there is no response in summer.

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Biodiversity theme protocol

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Introduction

This paper outlines the core, minimum data sets and other optional, additional measurements required by the biodiversity theme and discusses an approach to the study of biodiversity from the perspective of ecosystem function within sustainable grazing systems. biodiversity studies are a new field for agriculture. The biodiversity theme will draw on the information collected within other themes.

The biodiversity theme hypothesis is that these data will significantly contribute to:

1. An understanding of the impact of using land for grazing on biodiversity; and
2. An understanding of relationships between biodiversity, productivity, and sustainability of grazing systems.

Across the national sites the main emphasis and additional measurement will be on plant biodiversity and productivity in relation to management treatments. The outcome at the end of the national experiment will be a knowledge of the impact of management practices on biodiversity in grazing systems and the relationships between biodiversity, productivity and sustainability. The core, minimum data set for pasture for all of the national sites is outlined in Table 16.

Table 16

Summary of the minimum data sets required to be collected for the biodiversity theme protocol

Measurement	Frequency	Comment
Species present in BOTANAL quadrats	Autumn and early-spring	Record at the individual species and quadrat level in addition to normal BOTANAL records
Species present in plots	Autumn and early-spring	List species not found in quadrats, but in plots
Estimate of primary productivity	Seasonally	Use pasture growth or calibrated model estimates
Earthworms	Early-spring, year 3	
Pests and diseases	As required	Record locations, time and species involved

Minimum data sets to be collected at all sites

Core biodiversity measurements across all sites will emphasise the flora. The minimum data set will record what species are present (including small, minor components) within all BOTANAL quadrats sampled in every plot at least twice a year. These measurements are to be taken in each of the fixed quadrats used for BOTANAL ratings, recording all additional species present, but which are not ranked for dry-weight. This will provide a rating of species abundance in a minimum of 20 quadrats (see pasture protocol) per plot. Data recording system needs to be at the quadrat and species level. In addition, species within plots that do not occur in quadrat positions, but which contribute to herbage mass will also need to be recorded.

Table 17***Optional, additional data sets that may be collected in the Biodiversity theme protocol and the sites at which they are being collected***

	North-West Slopes NSW	Central Tablelands NSW	North-East Victoria	Western Victoria	Western Australia	Wagga Wagga NSW
Species present in caged quadrats		✓				
Recruitment and 'gap' studies		✓				
Amount of litter each season	✓					
Litter breakdown and nutrients	✓					
Microbial mass	✓	✓				

Measurements should be taken in autumn and early-spring. Records for other times of the year are optional. Autumn samplings will mainly record perennial components, while early-spring measurements will include most of the other species in the pasture. These data will enable analyses of the patterns and structure in vegetation. In addition, spatial arrangements within plots will be described. Data recording system needs to be at the quadrat and species level. Grouping of species should only be routinely done for very minor species that are similar.

Each site needs to have an estimate of primary productivity for each plot from pasture growth data or calibrated model estimates. This data will be used to investigate the relationships between species abundance, groups and productivity.

Each site needs to develop a system to train personnel in species identification. This would include field books of plant specimens, photographs and where necessary growing-out species in pots to enable positive identification. Records of pests and diseases, incidences and the plots in which where they occur will also be required.

Earthworm measurements in early-spring in the third year across all treatments, will provide additional data on the functioning of the grassland ecosystems. A detailed protocol will be developed by the biodiversity theme.

Training and species identification

To identify all the plant species at each site it will be important for a training program to be implemented. This will need to be done at each site. The biodiversity theme will help coordinate any across site training and can help fund the expenses of bringing in specialists. Competence needs to be developed in identifying species in vegetative and reproductive states. For local training the following procedures have proved helpful:

1. Develop a local field book of herbarium specimens. For some groups seeds and both seedlings and mature plants would be needed. Seedlings are difficult to identify, but the seed which is often still attached, can be. Pressed plants can be placed on sheets with a description, drawing, photograph and, or key on the back and then laminated or put in plastic sleeves. Photographs are very helpful—black backgrounds often help to show distinguishing features. Photocopies of relevant material save having to take the books to the field. Once established a field book can usually help resolve most field problems quickly.
2. Any plants that prove difficult to identify can be potted and then grown out in a glasshouse for later identification.
3. Arrange to bring in an expert at key times (near sampling) to help identify species.

The initial identification and preparation of a field book could be done as part of a student project in biodiversity. It may not be always possible to identify a species completely, but it is usually possible to identify the type. *Danthonia* spp. are difficult and the best procedure is to identify them as types 1, 2 etc. The same will often apply to annual grasses and genera such as *Lolium*. Keep a sample of each 'type' for later identification (eg. as a pressed specimen if reasonably complete and, or by growing them out in a pot). In general, it is better to identify species as much as possible when taking records in the field. If they are grouped too much they cannot be separated at a later stage.

Additional, optional data

A list of the species present in cage quadrats used for growth measurements can also be recorded. This will enable a direct relationship between species richness, functional groups and productivity to be established. Also, amount of litter in each season is important for ecosystem function, especially nutrient cycling and is an optional measurement. Additionally litter may be collected in spring and autumn to determine if it is being broken down effectively and if nutrients are accumulating in the litter layer.

Additional studies will be undertaken at specific sites to obtain more information on the functioning of grassland ecosystems, including; soil invertebrates (Central Tablelands, NSW), and the relationship between microbial mass and labile carbon (North-West Slopes, NSW) and successional studies on a microscale to identify which species are most influenced by weed invasion (Central Tablelands, NSW).

Outcomes required from the biodiversity theme protocol

Impact of management on biodiversity

A central aim is to define how various grassland ecosystems and management practices influence biodiversity. This will be analysed in terms of species richness and functional groups.

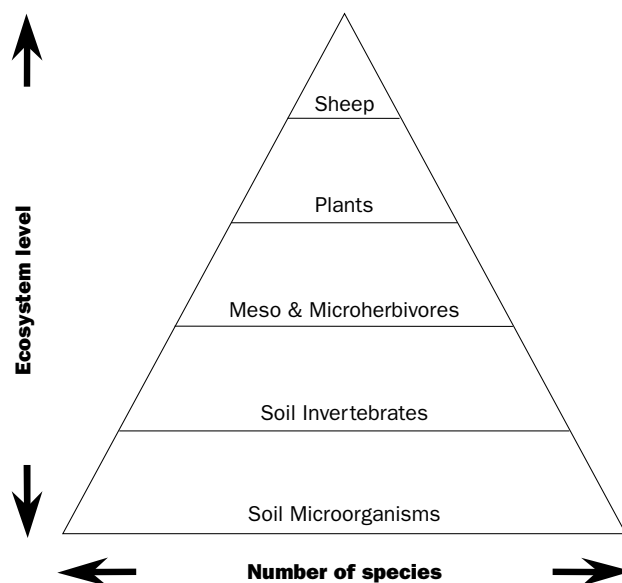
Characterising biodiversity and effect

The biodiversity of each grassland ecosystem and the implications for resource use requires data on the species present and information on resources across ecosystem levels. What is the effect of biodiversity on the productivity and stability of different grassland ecosystems? It will not be possible to sample all species at all levels (as shown in Figure 7 on page 58) in all grassland ecosystems. Measurements will be taken of most of the macroherbivores and the plants at each site ie. species relative abundance and productivity, in each functional group within each grassland ecosystem. The Central Tablelands, NSW site will record some data on microherbivores and more on the soil invertebrates. Indirect measurements (eg. labile carbon), may help characterise soil microbiological mass. Resources at each ecosystem level can be characterised by biomass and nutrient content.

Species uniqueness vs functional groups

All species are unique in some way, but some have more traits in common than different. The national experiment can contribute to the issue of species 'equivalence/redundancy'. Can one species be readily replaced with another without major effects on the ecosystem and productivity? Ways of assessing the functional groups (guilds) within grasslands will be investigated using data sets collected at each site. Classification of species into functional groups will enable ideas in grassland structure to be developed and more readily transferred to producers. Tools such as the 'Grassland Species Composition Matrix' will be further developed and used to evaluate research results and for technology transfer.

Figure 7
Species abundance and ecosystem level



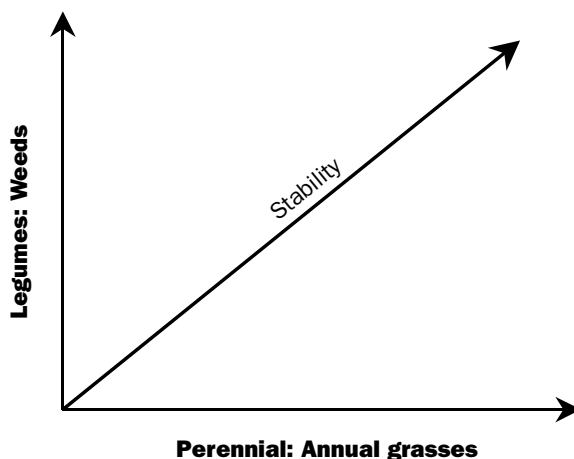
What are the benefits from individual species?

Results from the national experiment will be able to build on previous work and summarise the role of many different species in grasslands, rather than only the more prominent. This will build a perspective among producers and their advisers of the role of biodiversity. Some minor species may never be very productive, but their presence, for example, may fill ‘gaps’ and limit weed invasion. Assessment will also be made of ‘keystone’ species ie. those that are of central to ecosystem sustainability.

Does diversity enhance longer-term stability?

Unfortunately the four-year term of the national experiment will mean that only short-term effects can be studied, though some trends may be detectable. An aim of the biodiversity ‘theme’ will be to consider other ways of investigating diversity and stability. An important aspect of this will be to investigate the relationship between diversity, functional groups and yield stability over time (eg. Figure 8).

Figure 8
Relationship between pasture components and stability



Scales of diversity

Effects of scale often mean that diversity increases with the area being sampled. Analyses need to assess both the local and landscape association between species. Some species may only associate on a small-scale in response to local microenvironments, eg. communities of rushes. Paddocks need to be sampled based on community structures so that processes and productivity for the different communities can be discerned. Ways of using this information at the farm-scale will need to be explored.

Are different grassland ecosystems functioning efficiently?

Data will be collected on many components of a wide range of grazing systems. The biodiversity theme will consider this issue. One approach is to determine if resources are accumulating, or leaking from the system. How do we use knowledge of biodiversity to enhance both the sustainability and productivity of grassland ecosystems?

Specific issues

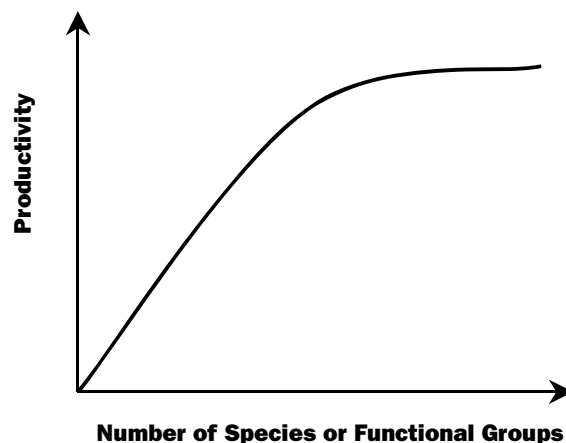
Theories developed by Tilman (1996) were often based on grasslands that were harvested once a year. Would the same results apply for grazed plants, or those harvested frequently? Do you get the same or different species filling the gaps arising from different perturbations, eg. what happens after grazing vs drought vs fire vs fertiliser etc.

Species richness and productivity

- The mechanisms are uncertain. Where species richness relates to greater yield (Figure 9) what is the relationship between species and yield, eg. is one species dominant? Does that species produce the greater yields because it is more resistant to predators?

Figure 9

Relationship between species abundance and productivity



- Are less abundant species that contribute to total biomass of use as 'grassland' species? What is likely to be their function? What 'niche' do they occupy? This leads to defining the 'biomass' of the more 'desirable' species in grassland vs total biomass. The 'desirable' group can be native's vs exotics or for animal production, ie. palatable vs weeds.

- The national experiment will use the existing diversity in grassland plots. In some cases, additional studies would be useful to locate different combinations of species across a site. These combinations should be both at one fertility level and along (measured) fertility gradients. Many data points would be needed, eg. a minimum of 20 (1 x 1 m plots) combinations, measured often. Cage data used to estimate pasture growth rates provides an opportunity to take these measurements. This may not apply at some sites, particularly if treatments create more uniform plots.
- Tilman (1969) proposed that grassland function is influenced by biodiversity; promoting 'diversity–stability' and 'diversity–productivity' hypotheses, rather than a 'species–redundancy' hypothesis. However, there does appear to be some saturation of species richness, ie. above some limit extra species have little significant impact (approximately 10 in his grasslands), suggesting some redundancy is occurring. Consequently, loss of species where richness is low will have bigger effects than in very diverse communities. More recent data supports the proposal that functional groupings may be more important than species richness.

Competition and succession

- Biodiversity exists because resources vary spatially and temporally. No one species is able to satisfactorily exploit, or dominate, all available resources. Species characteristics are also important; poor competitors survive because they have high rates of seed production (Tilman 1969) and, or associate with other poor competitors within more aggressive communities (Silvertown *et al.* 1994). Characteristics of each species at each site will need to be defined in some way.
- Within communities there is often a trade-off between competition and colonisation ie. species more competitive for utilising nutrients and other resources may not have adaptive features for colonising new areas. These processes are not always differentiated in 'competition' studies ie. dispersal to new sites vs spread at existing sites. Such differentiation is important when considering productivity and sustainability issues. The C-S-R model (Grimes 1977) will be applied to data interpretation.
- Where do grassland species 'fit' in relation to successional sequence? Are perennials 'later' than annuals, and what does this mean for their ability to use resources, particularly deeper soil nutrients? Perennials are also likely to have lower potential relative growth rates than annuals, with less competitive seedlings. However, perennials probably put more resources into root growth. At low fertility more competition among roots would be expected than is likely to apply at high fertility.
- How does competition vary between species in response to 'disturbance' (need to classify types) vs fertility?
- For the main species in a grassland who are their main competitors? Do annual grasses mostly compete amongst themselves when germinating? Are the perennials 'active' competitors using nutrients and water or do they simply occupy space, reducing that available for annuals to germinate?

Fertility

- If greater diversity does lead to greater productivity then this assumes greater utilisation of nutrients and hence reduced nutrient loss. This leads to a 'diversity–sustainability' hypothesis.
- Along a productivity gradient (measured by total soil nutrients and, or total biomass production) there is evidence that species richness peaks at low to medium levels and then declines as habitat productivity increases, ie. peak diversity in natural ecosystems does not coincide with peak productivity.

- It has also been proposed that more species have evolved to utilise habitats of ‘intermediate’ productivity (ie. fertility) than low vs high. In consequence, more species would be expected in ‘intermediate’ habitats.
- With higher productivity as fertility increases, there is less chances for colonisation, ie. no spaces left.

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