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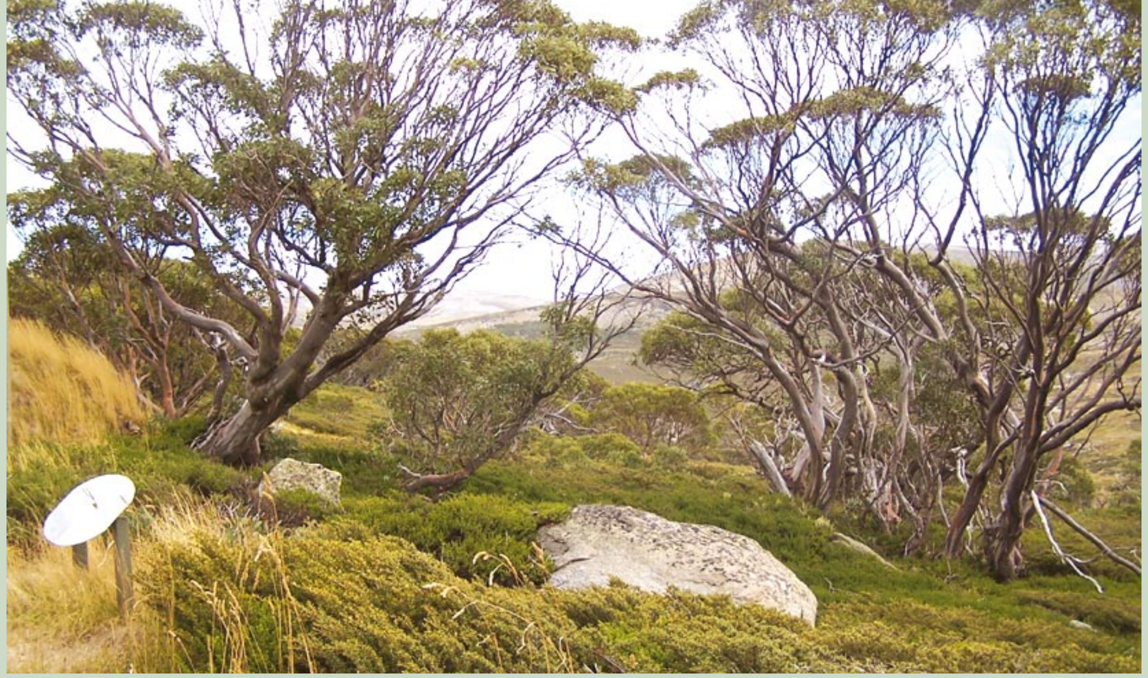
Senior Research Fellowship
report

knowledge for managing Australian landscapes

Creating Markets for Environmental Goods and Services: A Mechanism Design Approach

By Gary Stoneham

Research project number DSE3 of the Social and Institutional Research Program of Land & Water Australia. Project completed June 2007



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Most Senior Research Fellows produce a publication which outlines their ideas and visions. These works are often thought-provoking and challenging, representing leading-edge thinking in their respective fields.

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Senior Research Fellowship Final Report

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Cover photo: Mapping out areas for tree planting.

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Executive Summary

Land-use change is recognised as one of the two major threats to the environment

The United Nations Intergovernmental Panel on Climate Change identified land-use change and fossil-fuel use as the two important human-induced influences on climate change and the environment. In many countries, the extent of land-use change is now threatening key environmental assets including species extinction in the Amazon, Africa and Australia; pollution of lakes in Canada; silting of the Panama Canal; and flooding in the Ganges delta.

Private landholders do not take account of all of the costs of land-use decisions

While the environmental impacts of land-use change are different from site to site, the underlying economic problem is the same. Landholders own land but do not take account of all of the costs or benefits of land-use decisions. The accumulated impact over long periods of time and across many landholders becomes evident as species extinction, poor water quality and loss of productive agricultural land.

Markets for environmental goods and services are missing

In many sectors of the economy, markets are the institution that organises production and consumption. Markets embody incentives that lead to wealth creation through efficient allocation of resources, yet markets for some goods and services, namely the environment, are missing.

This leads to inappropriate land-use decisions and unwanted environmental outcomes. Economists frame this as a missing market problem.

A mechanism design approach is needed to design efficient and effective institutions

An emerging methodology is now available to assist economists to design and test new institutions that will provide incentives for efficient production of environmental goods and services (EG&S). Mechanism design involves five steps:

- diagnose the cause of market failure;
- apply economic theory to propose new institutions;
- test theoretical propositions in the economics laboratory and/or field pilots;
- evaluate performance; and
- adopt or refine design.

The seminal applications of this approach have been in non-environmental sectors such as the allocation of mobile phone spectrum, intern matching, medical exchange programs etc. These examples demonstrate that careful design, testing and refinement of new institutions can resolve previously intractable policy problems.

Markets for EG&S are missing because of the public good characteristics of the environment. Information about individual and collective willingness to pay for additional units of environment is not available and does not influence resource allocation decisions.

Markets for EG&S fail because of demand-side problems:

- *EG&S have public good attributes*

There are also information problems on the supply-side that cause markets to fail. Three fundamental problems exist:

Markets for EG&S also fail because of supply-side problems:

Adverse selection – information about which landholders are low-cost producers of EG&S is not available; it is hidden from decision makers.

- *Adverse selection*

Moral hazard – information about the actions of landholders is hidden from those purchasing EG&S.

- *Moral hazard*

Values come in packages and lumps and there are third party interests to be resolved.

- *Synergies and non-convexities*

Markets for EG&S can be created if information problems, synergy and non-convexity problems can be resolved. Three new institutions are needed to bring the environment into the economic environment of landholders.

Three institutions are needed to bring the environment into the economic system:

Tradeable emissions permits resolve information problems for EG&S that are point-source emissionss. A cap on emissionss reflects social preferences about the extent of environmental damage that is acceptable (the demand-side). Tradeable, enforceable rights to pollute resolve the decentralised information problem in the same way as regular markets (the supply-side).

- *Tradeable permits for point-source problems*

Specialised markets will be needed to facilitate transactions where offsets are required by developers. In many cases, especially for native vegetation offsets, there are package problems to be resolved on both sides of the market.

- *Offset markets – where synergies and non-convexities exist*

A well-designed auction of conservation contracts will address adverse selection and moral hazard problems for non-point-source emissionss. Adverse selection is resolved by auctioning conservation contracts, but a substantial investment will be needed to develop biophysical models and biological information systems to meet specific information deficiencies. Moral hazard is resolved through efficient contract design.

- *Auctions of conservation contracts – for non-point-source problems*

It is difficult to elicit private information about willingness to pay for environmental outcomes. Techniques employed to reveal demand-side information must resolve the incentive problem of acquiring the private information that agents have about their preferences for public goods.

It is difficult to resolve information problems on the demand-side

It is now recognised that there are significant impediments that prevent the efficient supply of EG&S. Economists have developed ways of overcoming these impediments. It is possible to translate approaches developed in other domains of the economy to the environment sector and to dramatically improve the efficiency of environmental programs.

There is scope to dramatically improve environmental programs by addressing supply-side problems

If impediments on the supply-side are addressed, field pilots show that it is possible to facilitate efficient transactions in EG&S. When landholders are exposed to a 'complete' set of markets for EG&S, decisions about how to deploy land, capital and labour are influenced not only by commodity markets and production costs, but by the returns from supplying environmental goods and services.

Field pilots and laboratory experiments are needed to refine ideas and to observe performance

The way land is employed and managed has a significant impact on the environment. Based on analysis of one region it has been shown that landscape change reduces environmental amenity and increases the variability of environmental services provided. It has been estimated that changes in the landscape over the last 200 years have: significantly increased the volume and variability of stream flow; reduced the quality of water in rivers and stream; increased the variability of water quality; marginally increased the area of dry-land salinity; reduced the amount of carbon sequestered in the landscape; and caused a large decrease in the stock of terrestrial habitat. Biophysical models suggest that degradation of the environment can be reversed if private landholders invest in land-use change/management.

Results from a field pilot that exposed landholders to a 'complete' set of environmental markets include:

Land use has a significant impact on the environment

The mix and quantum of environmental outcomes generated from land-use change are heterogeneous from site to site being influenced by: the type of land-use change; the type of intervention/action; the location of intervention/action; and the timing of outcomes. Environmental outcomes are probabilistic rather than deterministic because of the stochastic influences of weather, pests and other threatening processes.

The environment is heterogeneous and outcomes are probabilistic

The pilot reported in this paper recognised that most investments in land-use change/management generate multiple environmental outcomes. Over 70% of sites generated two or more EG&S.

Multiple environmental outcomes arise from land-use change

When landholders are exposed to markets for EG&S, transactions to supply EG&S occur. These transactions are made possible by designing and creating new institutions that reveal relevant information and process this information in ways that introduce competition into the environment sector, and because of incentives embodied in supply contracts. When private landholders are exposed to these new institutions they are required to make trade-offs between investment in commodity production and investment in supplying different classes of EG&S. Due to the private and heterogeneous nature of information, landholders are best placed to make these trade-offs rather than central planning authorities. It has been estimated from the pilot data (under a fixed outcome objective) that a 30% saving in the procurement budget could be made by auctioning conservation contracts to discover landholder 'type' compared with a mechanism that does not address adverse selection (e.g. a random draw).

Transactions in environmental goods and services are facilitated because of new institutions

Economic efficiency improvements of at least 30% can be shown if adverse selection is addressed

Policy implications:

Planning and legislative solutions require all landholders, irrespective of whether they are high- or low-cost providers, to undertake investments in conservation. Excluding problems that require full enrolment, centralised approaches will raise the cost and diminish economic efficiency of environmental programs.

Planning and legislation have limited but well-defined roles in the policy mix

For the same reasons, other policy mechanisms, such as fixed-price grants and simple incentive schemes, will display similar efficiency and cost-effectiveness problems.

Fixed-price grants are inefficient where there are heterogeneous agents and heterogeneous impacts

Unless adverse selection is specifically addressed, it is landholders who hold market power in these transactions because they have private information about the cost of land-use change/management. The government and/or the environmental authority will come off second-best in this transaction because they are information poor. A number of studies confirm this finding, observing that many environmental programs pay excessive information rents to landholders.

Landholders, not government, benefit most from poorly designed environmental programs

By investing in information systems (biophysical models) and new institutions, the purchaser can reduce, but not eliminate, information rents. There is some optimum where the marginal cost of further reducing information rents equates to the marginal efficiency gains. The adverse selection problem is less important where landholders transact EG&S with private good attributes such as through a tradeable emissions permit scheme. In this institution, landholders are price-takers and will self-select into supply contracts according to type. In this case moral hazard is a more important design problem than adverse selection.

Government must invest in biophysical information systems... but only to the point where this investment is recouped by improved efficiency

The pilot provided some insights into the moral hazard problem relevant to the design of conservation contracts. Although economic theory clearly suggests that incentive-compatible contracts will involve the landholder sharing some of the risk involved in achieving environmental outcomes, this has proven difficult to achieve in practice. Four problems have been identified. For some EG&S, such as water quality, the observed environmental outcome arises from the combined actions of a team of landholders. Different incentive structures will be needed to deal with the free-rider problem in this situation. A second problem arises because each investment by landholders has been shown to generate multiple outcomes. While a simple solution to this could be to pro-rata incentives according to the ratio of different EG&S generated, it is not clear whether the incentive effects of this approach are efficient. A third problem involves the long time scales (up to 200 years with groundwater systems) between investment and environmental outcome. Over such long time scales, the incentive effects of contracts will be lost. In this event, measures of outputs, such as tree growth, were used as the signal for incentive payments to landholders. Biophysical modelling can assist in identifying appropriate output signals and the translation between outputs and outcomes. The final problem with contract design arises because in the initial periods of a contract, many landholders do not have technical knowledge about how inputs transform into environmental outcomes. While they are generally efficient at transforming inputs into commodities, they are often unfamiliar with the production of EG&S, at least in the early stages of the contract. One proposed solution could be to define two stages of the contract, the first where landholders are provided with an incentive structure that rewards learning about the production of EG&S, and a second phase that includes incentive-compatible bonuses for outcomes. All of these contract design problems warrant more research.

Efficient contract design is important. Design problems include:

- *Team contracts*
- *Multiple outcomes but one contract*
- *Long time scales*
- *Learning contracts*

The pilot provided important insights into the way markets for different EG&S interact. There will be economic efficiency implications where some markets for some EG&S are missing. Environmental programs that do not take all EG&S into account could sponsor changes to the landscape that cause environmental decline. Tree planting schemes could arguably cause streams to dry up, threatening aquatic species and reducing the value of irrigation farmers' property rights for water. Where markets for some domains of the environment do not exist, it would seem appropriate to impose a tax or regulation to prevent unwanted environmental outcomes. Tax or regulatory interventions are second-best policies mechanisms because they do not have the information revelation attributes of markets.

A full set of markets for all environmental goods and services is needed

A second implication of the observed interaction between markets for different EG&S is that there are significant cost savings to be made by environmental authorities as a result of the multiple outcomes obtained from land-use change. Sequestering carbon, for example, automatically generates a bundle of EG&S with public good attributes. For a fixed outcome of public EG&S, it has been estimated that a saving of 26% could be expected by the environmental agency if the price of carbon were to rise from \$0/t (no market) to \$12/t.

A full set of markets will reduce environmental costs to Government...and

Avoid unwanted outcomes

Some environmental goods, such as water quantity, tend to be negatively correlated with vegetation-related EG&S. Although the pilot was conducted in a region that is not a recognised catchment for irrigation water, the implications of incomplete markets for EG&S are clear.

National accounts are constructed with information revealed from transactions. Where transactions between those willing to pay for environmental goods and services and those willing to supply EG&S can be facilitated by creating markets, there is scope to include the environment in national accounts. Once markets for EG&S have been created, information about the flow of EG&S can be observed directly from transactions facilitated through auctions of conservation contracts, tradeable emissions permits and offset markets. From this information it is possible to include the contribution to gross domestic product (GDP) made through investment in environmental management.

Environmental accounts can be constructed if markets for EG&S can be created

The contribution of EG&S to GDP can be determined

Estimates of the stock of environmental assets can be made from the scientific processes used to inform market participants. This information is represented in physical rather than financial values and cannot, therefore, be included in the inventory component of national accounts. These data can be employed to populate satellite accounts that portray the status of key environmental stocks.

Satellite accounts can be based on biophysical data

The rewards from completing a set of environmental accounts are substantial. This would provide society with a comprehensive picture of the status of the environment; the impact of public funds allocated to the environment; and information about supply prices. This information will assist policy makers and the public to make better choices.

Environmental accounts would dramatically improve environmental management.

1. Introduction

In most countries, the landscape has been damaged by:

- the clearing of native vegetation
- the introduction of exotic plant and animal species
- the increased disturbance of soils associated with crop and pasture activities; and
- the increased use of artificial fertilisers and pesticides.

These changes:

- cause degradation of rivers and streams by contributing to the nutrient, salt and sediment loads in surface and groundwater systems;
- increase accessions to groundwater systems leading to dry-land salinity; and
- adversely influence populations of aquatic and terrestrial flora and fauna.

The United Nations Intergovernmental Panel on Climate Change identified land-use change and fossil fuel use as the two important human-induced influences on climate change and the environment.

Even though the consequences of land-use change in both human and environmental terms seem to be large relative to the value of production from land, fixing the problem has proven difficult. The main obstacle is that individuals own and manage land in their private interest without reference to the impact these decisions might have on others or on the environment. In response, many environmental agencies have invested in landscape planning, legislation to control land use, or simple incentive programs, such as fixed-price grants.

These schemes have had limited success because of two problems. First, landholders face other incentives, such as the profit motive, that are not aligned with those of environmental agencies. Secondly, landholders are often physically remote from environmental agencies, making it difficult and costly to monitor and enforce conservation actions once they have been established.

Advances in economics and science suggest that new approaches to environmental policy are now generally available. This report provides a blueprint for incorporating environmental management into the economic system in which private landholders operate.

2. The Landscape and the Environment

The landscape is a complex system of interacting domains including: surface and sub-surface hydrology, terrestrial and aquatic biodiversity, carbon and water quality.

As a result of landscape change, each of these environmental domains experience change with cause (land use or management change) and effect (the impact on the environment), separated by space and time.

The landscape in much of Australia has been significantly altered in the 250 years of European settlement. Figures 2.1 and 2.2 illustrate the major changes in the Victorian landscape that have occurred since European settlement. From these maps it can be seen that on the 70% of land that is privately owned, there has been significant clearing of land with the landscape changing from open forest, woodland and grassland (the pre-European state) to mixed crop and grazing with small pockets of remnant vegetation.

2.1 Landscape Change and Environmental Impacts: Avon-Richardson Catchment

Detailed analysis of the environmental impact of landscape change has been completed for the Avon-Richardson sub-catchment in Victoria (see Figure 2.3).

Figures 2.4 and 2.5 illustrate changes in landscape from pre-European to the current landscape. In the subsequent 250 years, 52% of the land area was cleared and is currently allocated to cropping; 37% to grazing; 6% to trees; and 5% to urban or infrastructure uses.

Using biophysical models (Beverly 2005) and ecological estimation techniques (Parkes 2003) it has been possible to estimate the impact of landscape changes on several domains of the environment including: terrestrial habitat, stream flow, water quality and carbon sequestration.

Stream flow – As reported in Table 2.1, this analysis suggests that in the pre-European landscape, stream flow, measured in gigalitres (GL), was estimated to be approximately 3.5 times lower than today. As reflected in relative standard error (RSE) estimates, stream flow per annum is now more variable (RSE 71% of mean) compared with stream flow in the pre-European landscape (RSE 62% of mean).

These results arise because deep-rooted vegetation (native trees) intercepts both surface and sub-surface flows through transpiration, thereby reducing mean stream flow and its variability.

Figure 2.1: The pre-European landscape

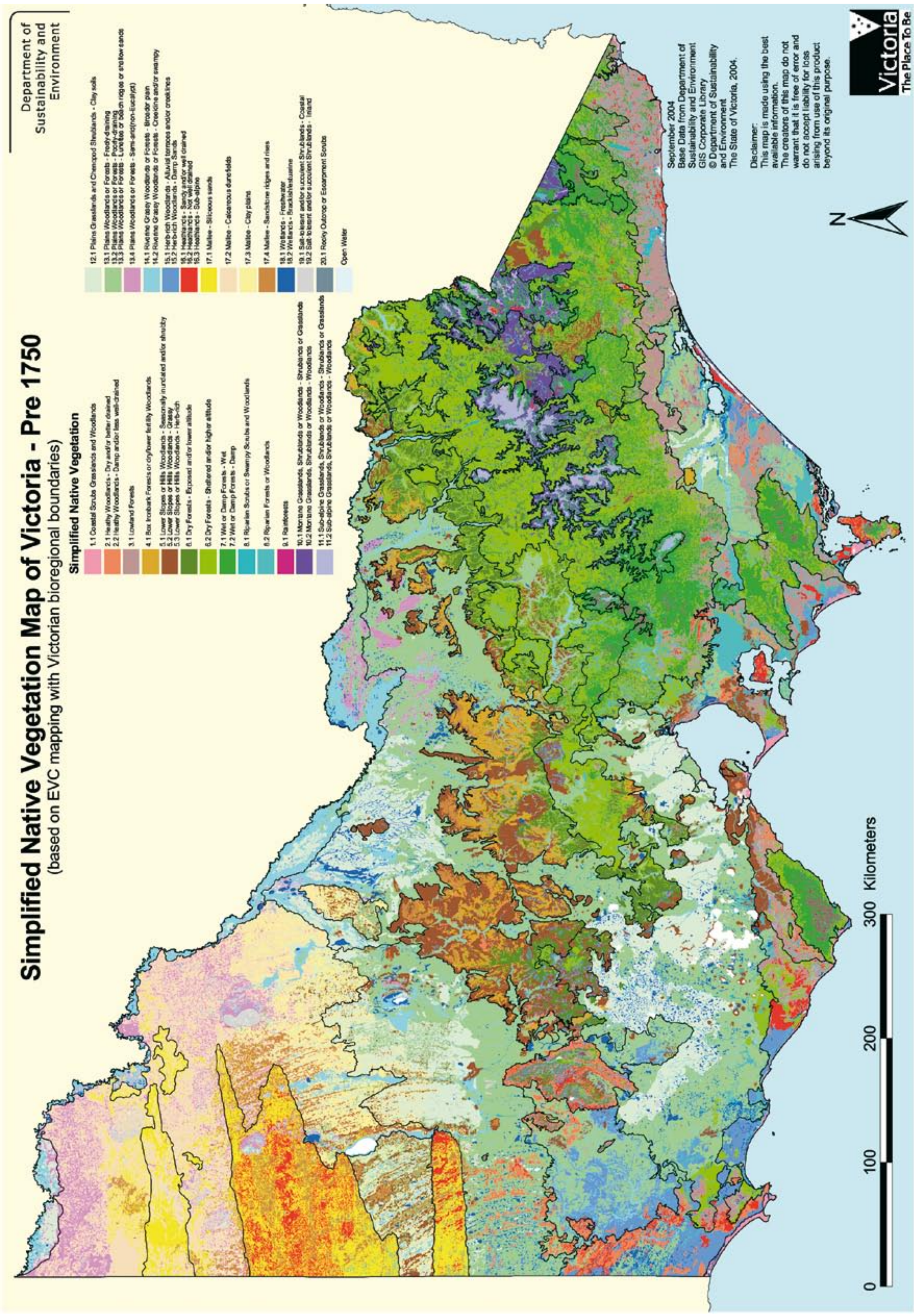
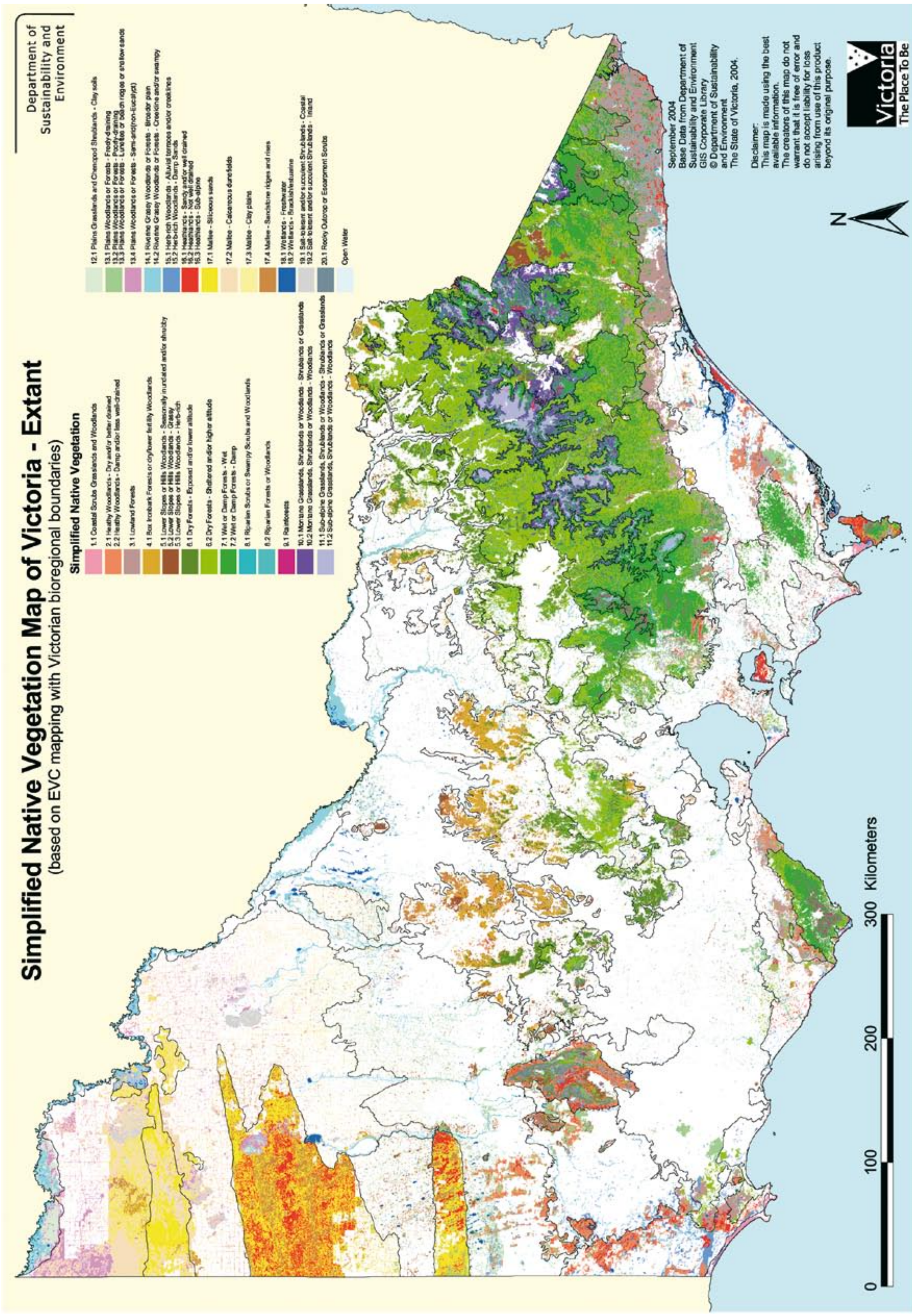


Figure 2.2: The current landscape



Area of land subject to high water tables – Dry-land salinity occurs when water tables rise, bringing salts to the root-zone of plants. In the pre-European landscape, the area of land not subject to dry-land salinity (denoted by a depth-to-water-table of greater than 0.8m) has been estimated at 370,938ha.

In the modified landscape native vegetation, which is generally deep-rooted, perennial vegetation, has been replaced with largely annual, shallow-rooted vegetation (e.g. cereals). These changes in vegetation have increased the area of land subject to dry-land salinity by 723ha. This represents only a 0.1% change in the area of land potentially degraded because of dry-land salinity (measured at 0.8m).

Terrestrial biodiversity – The stock of habitat, as measured in habitat hectares (see Parkes 2003), is estimated to have fallen from 370,000 to 14,000 habitat hectares. Land clearing and degradation of native vegetation through the introduction of pests, weeds and grazing by sheep and cattle have reduced the stock of habitat to only 4% of the pre-European stock.

Carbon – The stock of above-ground carbon in the current landscape has been estimated at 78.2MT. This compares with 103.9MT for the pre-European landscape. The amount of carbon stored above-ground is estimated to be more variable under the current landscape (RSE 33%) compared with the pre-European landscape (RSE 17%).

Water quality – Water quality, measured as the tonnes of salt exported to waterways, has been estimated at 2,190t/p.a. for the pre-European landscape. Under the current landscape, water quality is estimated to decline dramatically with 53,460t of salt exported.

Figure 2.3: The Avon-Richardson sub-catchment

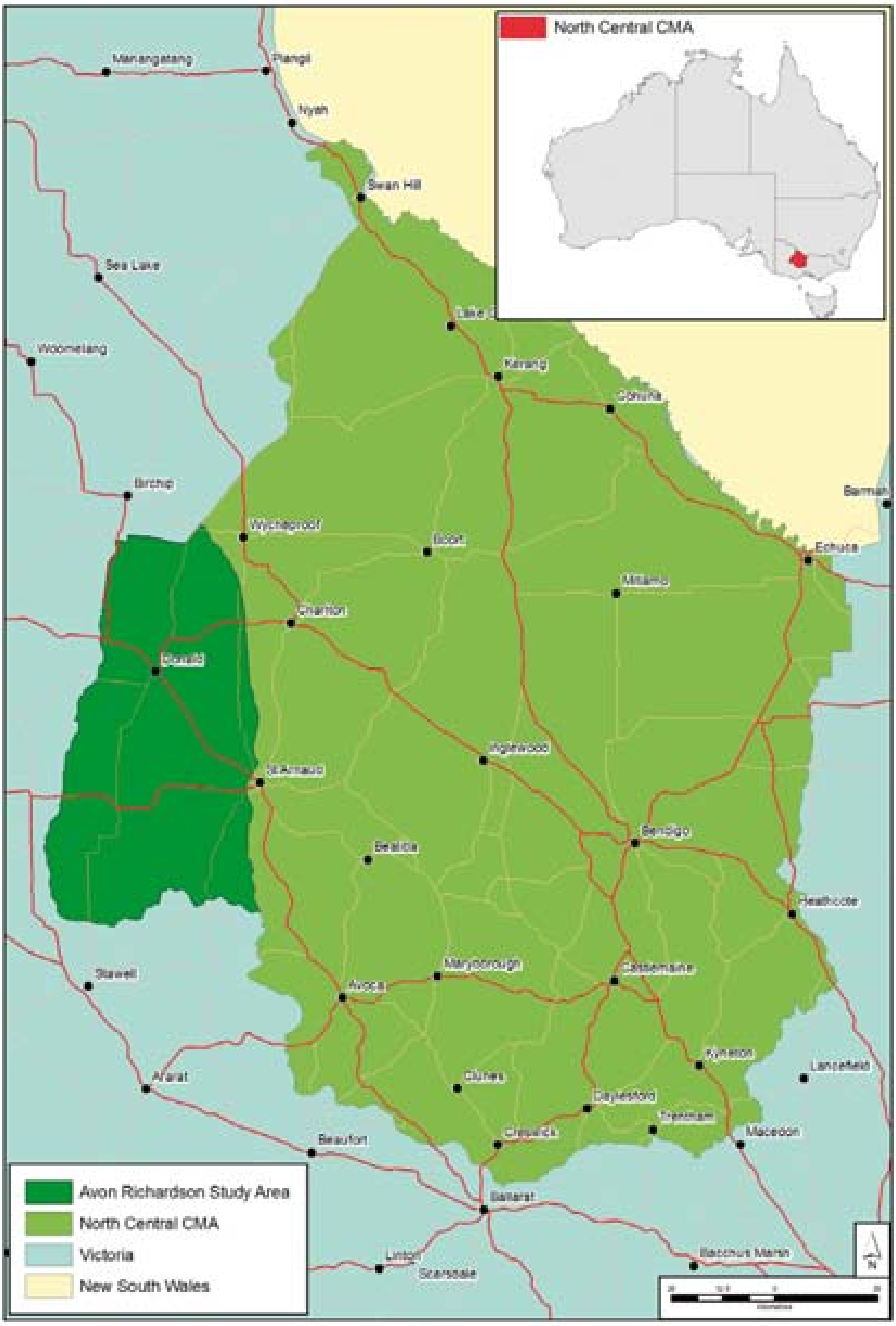


Figure 2.4: The pre-European landscape: Avon-Richardson catchment

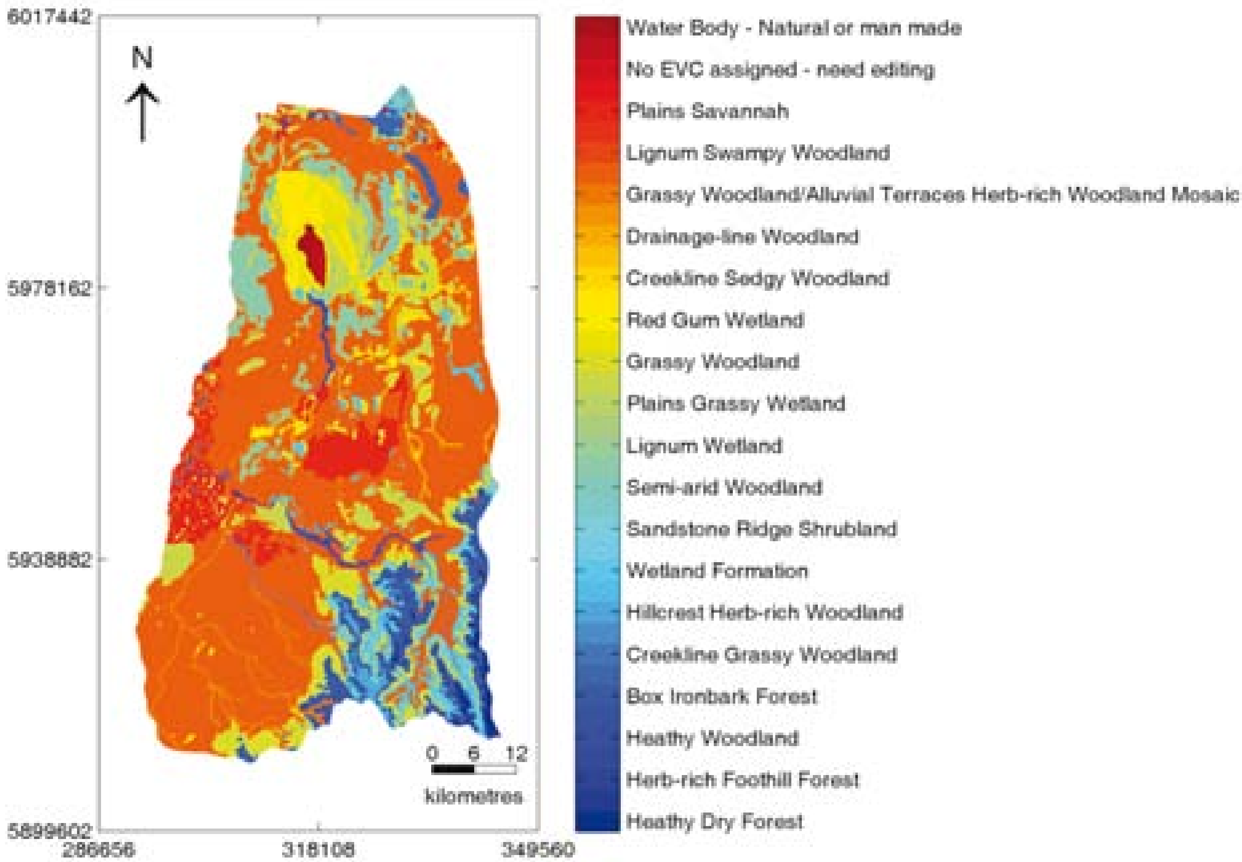
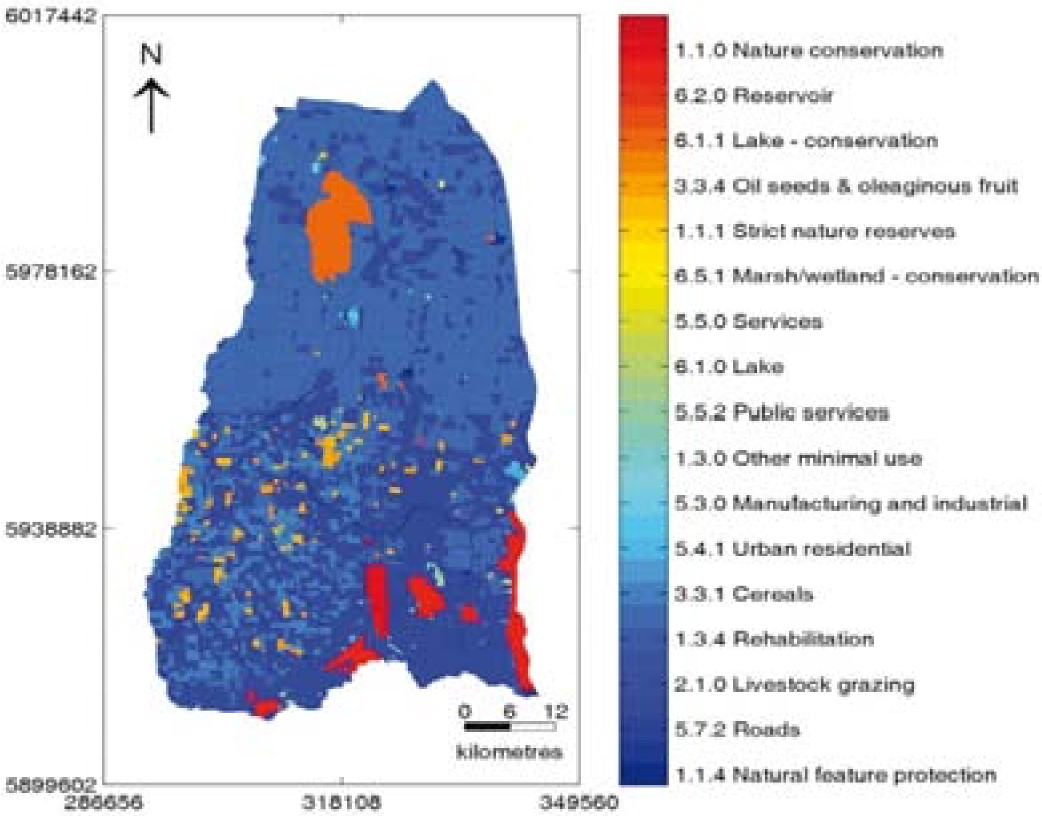


Table 2.1: Comparison of changes in environmental stocks from land-use change

	Pre-European landscape	**Current landscape**	**% Change**
Annual stream flow (GL) Mean, *(Standard error)*	18.9 GL *(62%)*	66.8 GL *(71%)*	353 %
Area of land with groundwater → 0.8m Mean, *(Standard error)*	370,938 ha (na)	370,215 ha (na)	0.1 %
Habitat (habitat hectares) Mean, *(Standard error)*	370,000 (na)	14,000 (na)	96 %
Carbon sequestered (Million tonnes) Mean, *(Standard error)*	103.9 MT *(17%)*	78.2 Mt *(33%)*	-25 %
Water quality – export of salt to streams (tonnes/annum)	2190	53,460	2,441%

Figure 2.5: The current landscape: Avon-Richardson catchment



2.1.1 Intervention type – Landscapes have been altered in a variety of ways since European settlement. In this section a range of different landscape modifications are analysed with respect to the impact on the environment. Table 2.2 reports the impact on:

- saturated area of land (defined as less than 1m depth to water table);
- stream flow; and
- water quality arising from different landscape modifications, including:
  - retention of native vegetation (pre-European landscape)
  - plantations of trees
  - pastures with deep-rooted species, such as lucerne
  - annual pastures, crops etc.

From Table 2.2 it can be seen that all land uses cause the area of saturated land to increase beyond that estimated for the pre-European landscape. The largest increase in the area of saturated land, from 112 to 2,268ha, occurs when land is converted to cropping or grazing activities. Activities with deep-rooted species, including lucerne or trees, tend to generate moderate increases in saturated land area.

Changes to stream flow follow a similar pattern with cropping or grazing causing the largest increase in mean annual stream flow and the deep-rooted perennials causing smaller increases.

The estimated impact on the variability of stream flow is also of interest. All land-use changes tend to increase both mean stream flow and the variability of stream flow from year-to-year. The greatest increase in variability (measured by the standard deviation as a percentage of the mean) has been recorded for lucerne in the cropping zone and native pasture on the slopes.

Water quality, measured as salt exported to waterways, declines most under a cropping or grazing landscape with 87,650t of salt exported per annum compared with 2,190t under the pre-European landscape. Landscapes that minimise accessions to ground water systems tend to moderate salt exports although these remain above those estimated for the natural landscape.

2.1.2 Location of intervention – The location of interventions in the landscape significantly affects the environmental goods and services (EG&S) generated. Figures 2.6, 2.7, 2.8 and 2.9 illustrate the environmental impacts of systematic changes in parts of the landscape from current back to pre-European landscapes.

These figures show that there are heterogeneous environmental impacts on all domains of the environment.

Figure 2.6 indicates that changing vegetation from annual (crops) to deep-rooted perennial trees (native vegetation) in some locations causes significant reduction in expected stream flow, while in other locations there is little detectable impact on stream flow.

As shown in Figures 2.7 and 2.8, a similar conclusion can be drawn with respect to the area of land subject to rising water tables. Figure 2.8, for example, shows that intervention in different locations (each intervention is a 25ha change to native vegetation) causes variable change in the area of land subject to rising water tables (2m). As indicated in the legend, intervention in some locations causes water tables to rise (within 2m) on only 1ha of land, while in other locations, the same intervention will cause the area of land subject to a 2m water table to rise by up to 46ha. Figure 2.9 illustrates the heterogeneous impact of changing the landscape on carbon sequestration.

These results suggest that the location of intervention will be a critical factor in the success of policy mechanisms intended to improve the environmental outcomes from the landscape.

2.1.3 Joint supply – Each intervention in the landscape generates a unique bundle of environmental services which are jointly supplied. Based on a random sample of landscape interventions across the entire catchment, it has been estimated that 73% of sites generated more than two environmental goods and services (EG&S). At the whole of catchment scale, Table 2.3 shows that there are generally low correlations between the different EG&S generated. From this table it can be seen that there are both positive and negative correlations evident between different environmental domains. For example, carbon sequestration is weakly correlated with water quality in streams (aquatic function), but has a negative correlation with terrestrial biodiversity.

Table 2.2: The impact of intervention type on the environment

Impact on the environment	**Saturated area (ha) defined as less than 1 m depth to watertable**	**Stream flow (GL) Mean (SE)**	**Water quality Mean (Tonnes Salt)**
Pre-European landscape	112	19 (63)	2,190
Current land use	1,518	67 (71)	53,460

Revegetation – trees in all agricultural land on slopes → 5 degrees	1,466	70(68)	48,200
Revegetation – 40 m buffer strip adjacent to streams	1,296	63(73)	44,500
Grazing/cropping	2,268	85 (57)	87,650
Adoption of three years lucerne in the cropping phase and native pastures on slopes → 10 degrees	1,178	56 (84)	21,900

Table 2.3: Correlation matrix: whole of catchment

	Aquatic function	**Carbon**	**Saline land**	**Water quality**	**Terrestrial biodiversity**
Aquatic function	1				
Carbon	0.17	1			
Saline land	0.16	0.06	1		
BLP	0.03	-0.07	-0.09	1	
Terrestrial biodiversity	0.09	-0.06	-0.17	0.64	1

2.1.4 Stochastic outcomes – Even if the causal relationships between landholder actions and biological outcomes were well understood and able to be modelled, the environment remains subject to a range of stochastic, exogenously-determined influences such as weather, pest and weed incursions. For example, the quantity of carbon sequestered, the volume of stream flow and habitat stock depend on the amount and distribution of rainfall.

Sergerson (1988) represents non-point-source pollution as an ambient level that can be represented as a probability function that is conditional on the abatement practice. The nature of the probability function is determined by the interaction between exogenous variables, such as rainfall, radiation, temperature; the biophysical processes relevant to each domain of the environment; and land use and management practice.

The objective of abatement policy in this context is to shift the probability distribution function by influencing control variables such as land use, so that the new distribution dominates the old one in the sense of first-order stochastic dominance (see Figure 2.10).

In doing so the environmental agency has raised the probability of meeting some ambient tolerance level. Sergerson (1988) notes that when there is a stochastic rather than deterministic relationship between an individual and the environment, the actions of a single landholder cannot be inferred from observed environmental stocks. Figures 2.11 and 2.12 illustrate the stochastic nature of stream flow and show that land-use change has changed the nature of the distribution of annual stream flow.

Under current land use, there is a much broader distribution of stream flow because of changes in surface and sub-surface partitioning of water. This partitioning is due to changes in the characteristics of vegetation and changes in water use arising from the predominance of shallow-rooted plant species in the contemporary landscape.

Figure 2.6: Impact on stream flow of changing the land use from current to pre-European land use

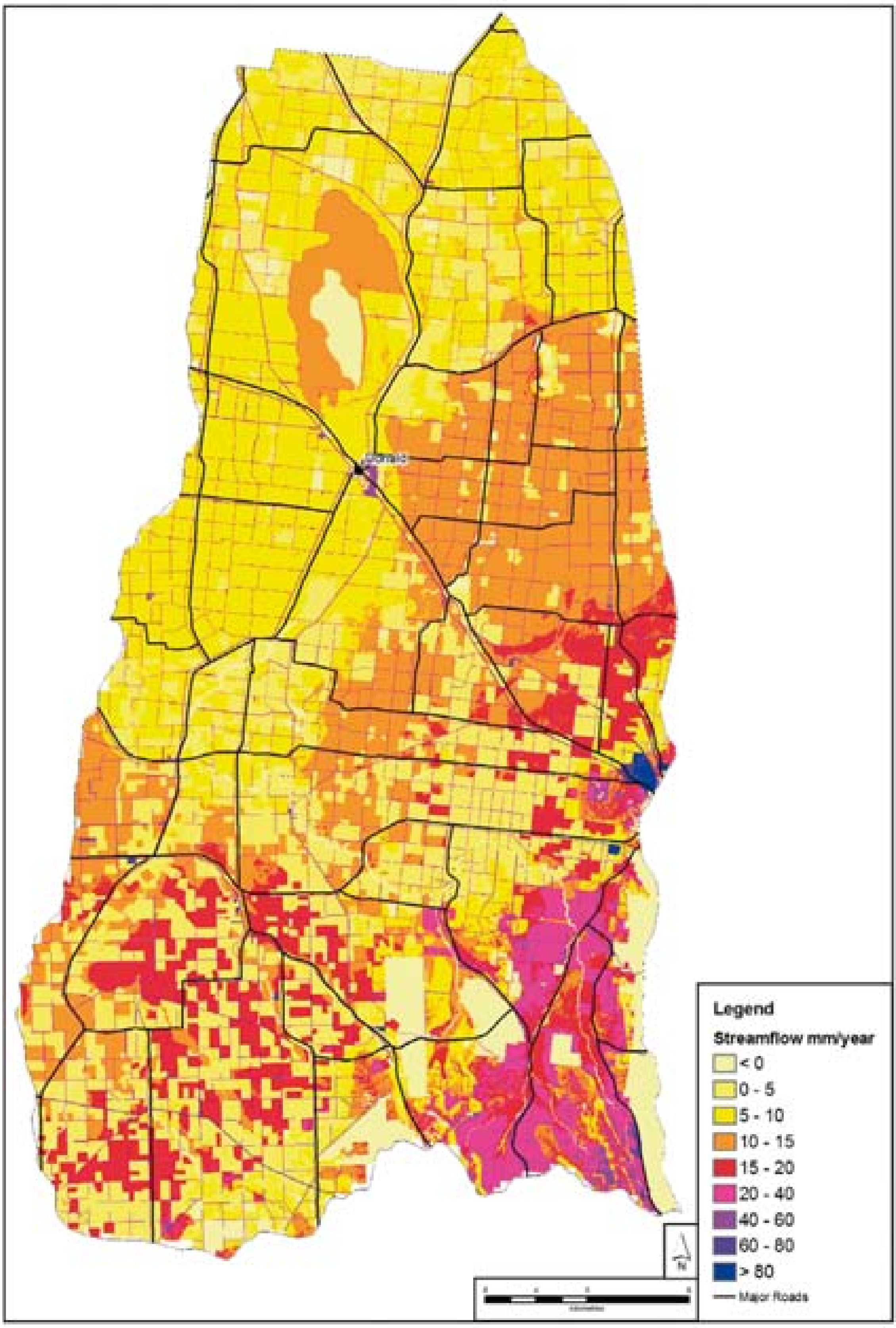


Figure 2.7: Impact on saturated area (0.5m) of changing the land use from current to pre-European land use

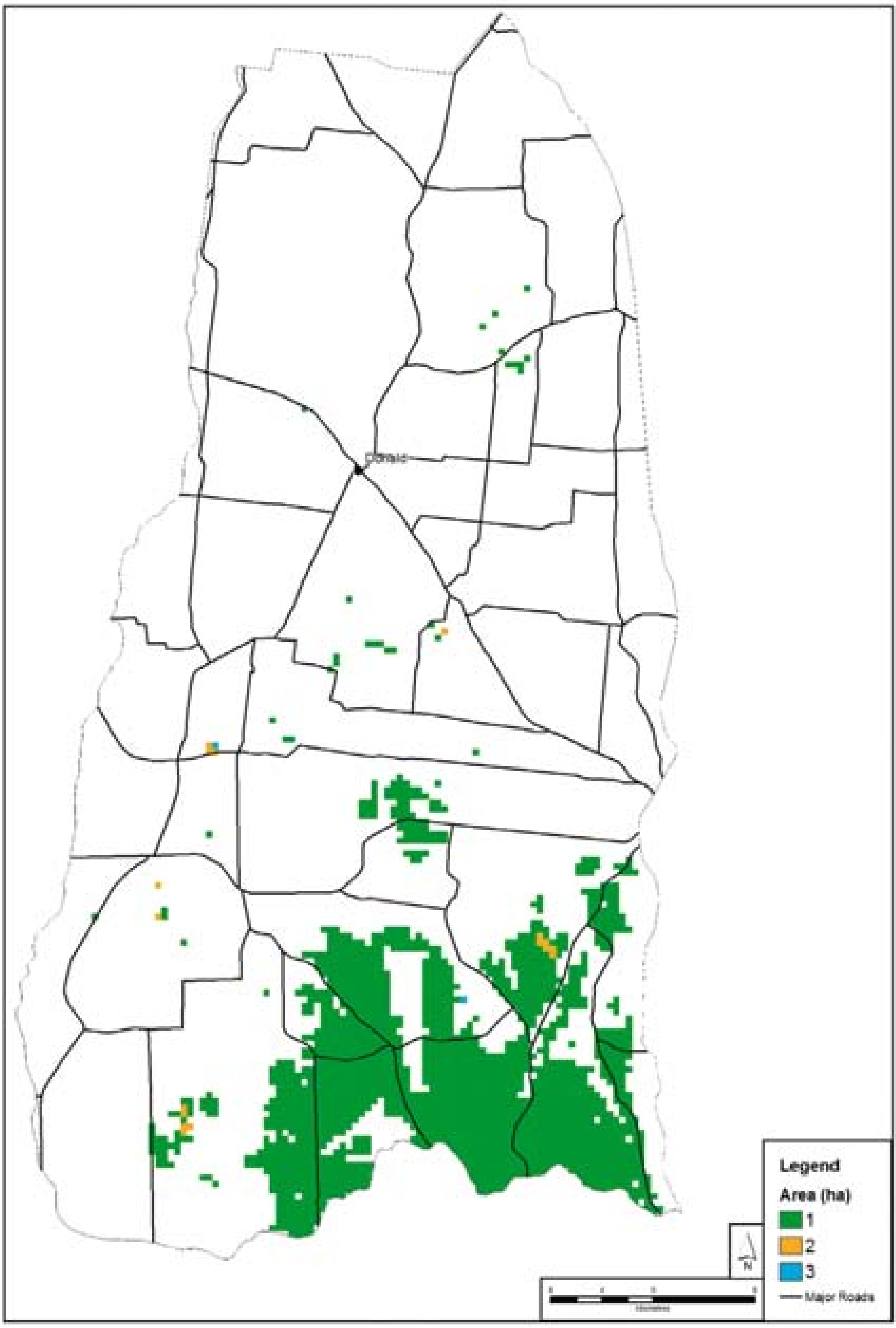


Figure 2.8: Impact on saturated area (2m) of changing the land use from current to pre-European land use

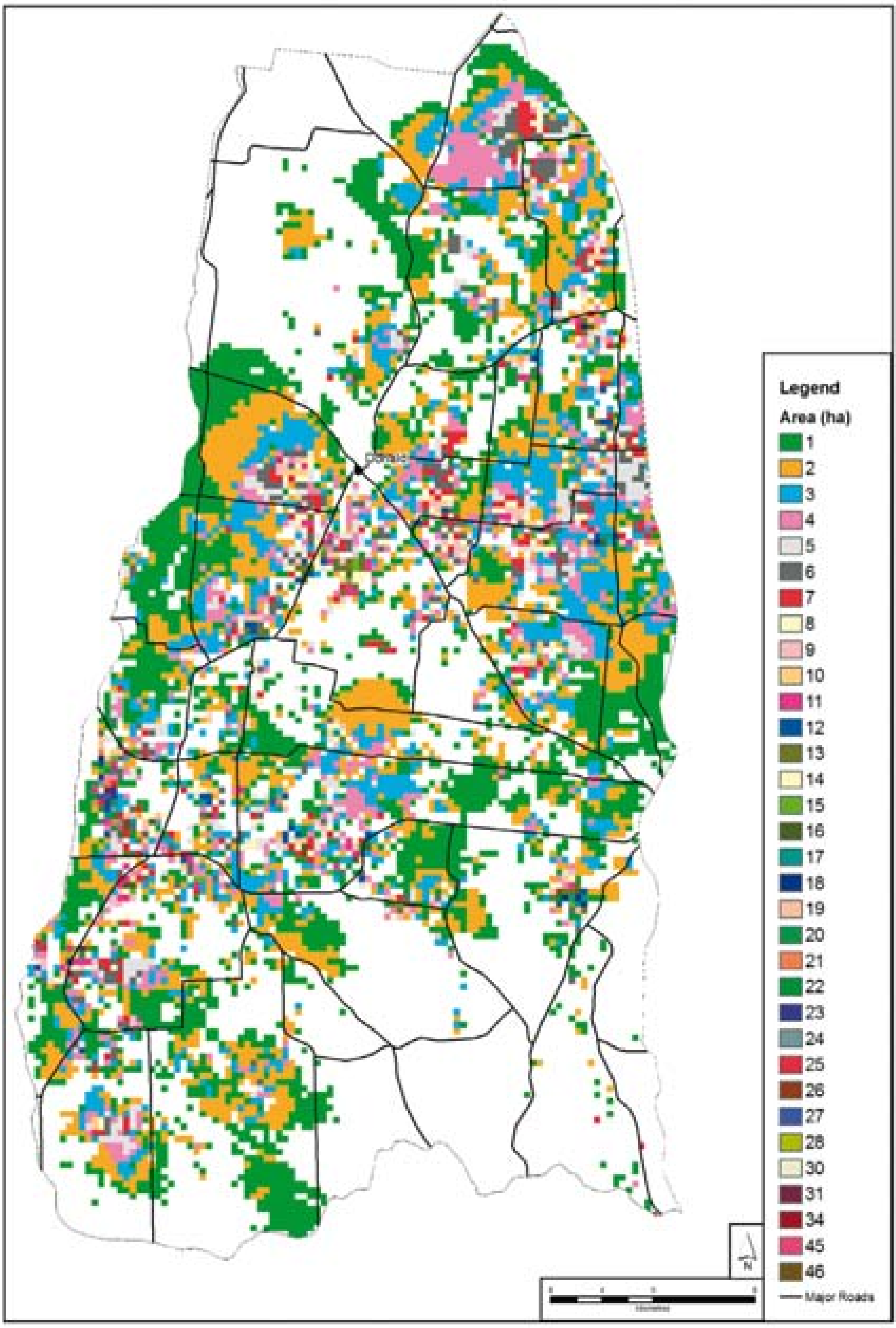


Figure 2.9: Impact on carbon sequestration (above ground) of changing the land use from current to pre-European landscape

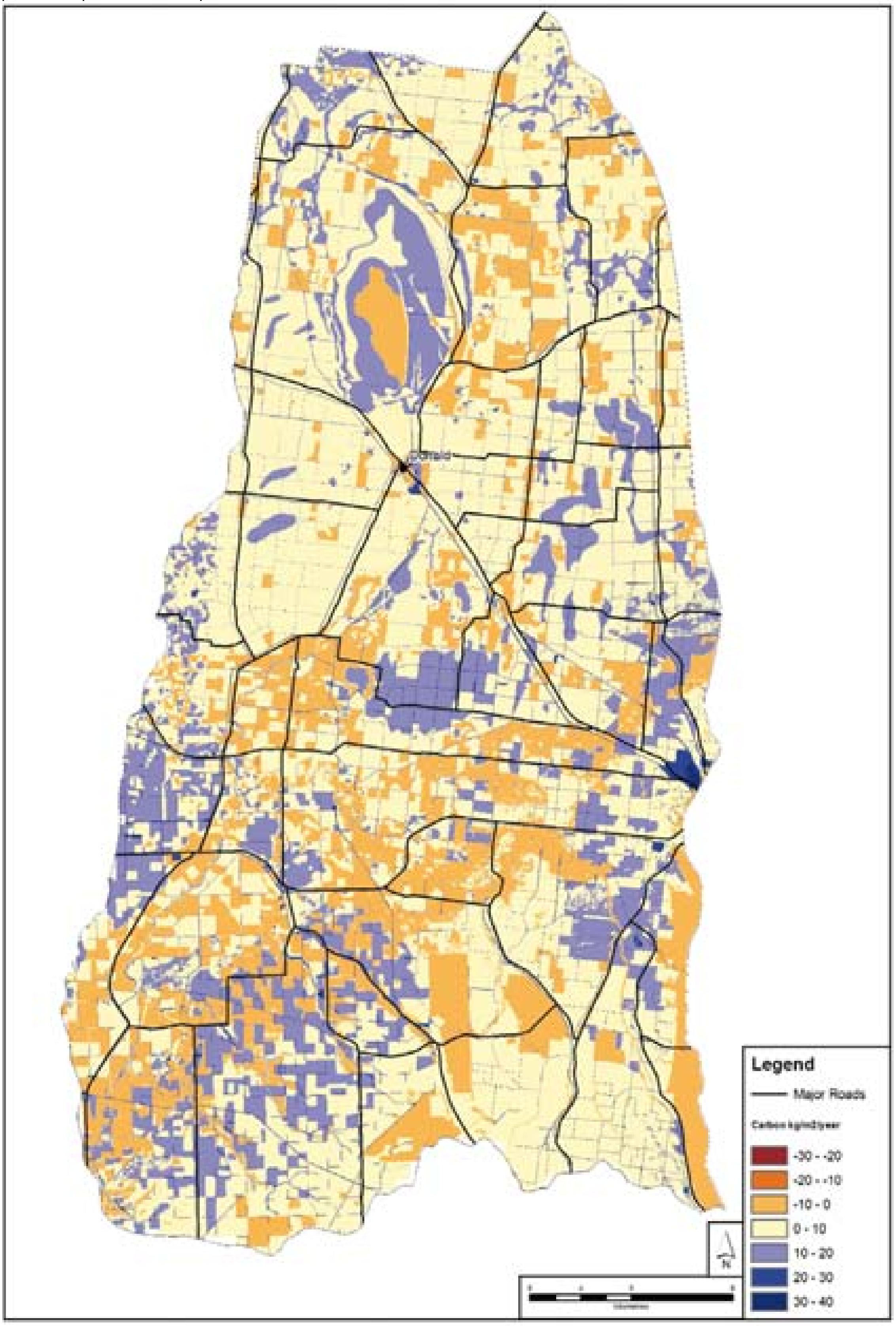
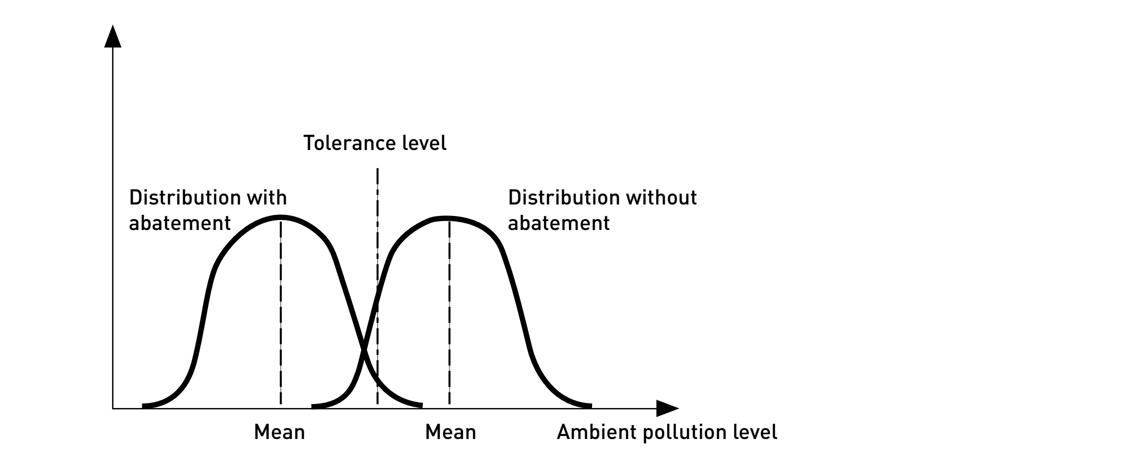


Figure 2.10: Environmental impact



Source: (Sergerson 1988)

Figure 2.11: Distribution of mean annual stream flow – pre-European landscape (mm/yr)

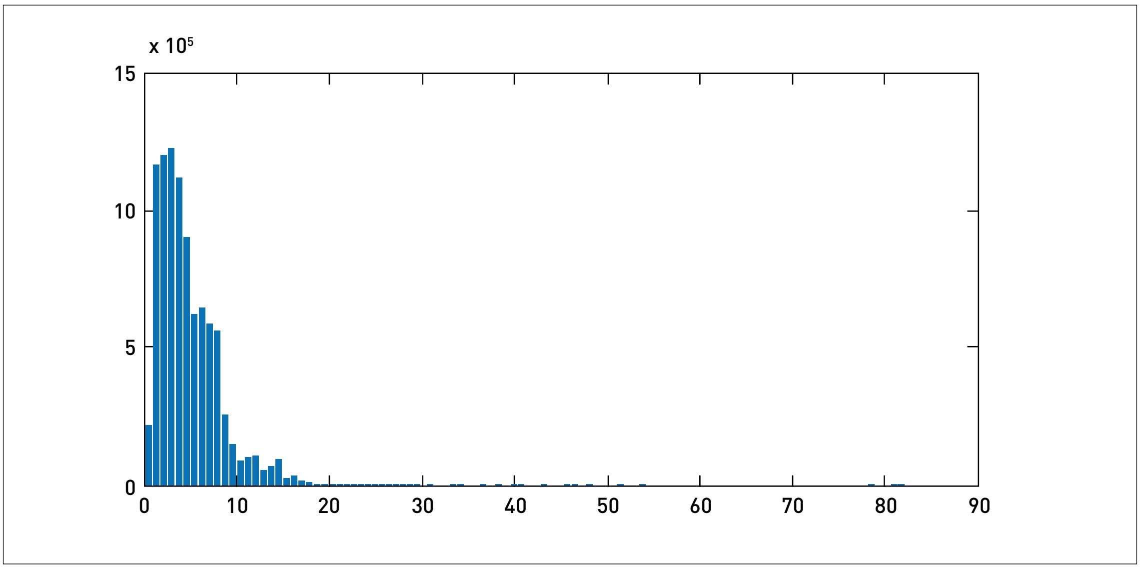
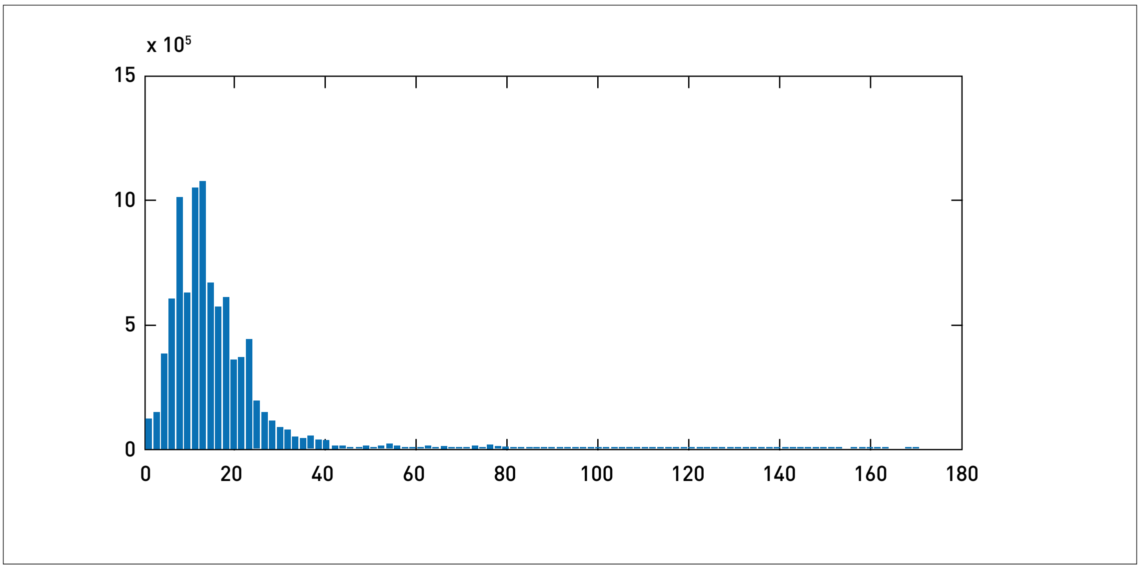


Figure 2.12: Distribution of mean annual stream flow – current land use (mm/yr)



Figures 2.13 and 2.14 illustrate the distribution of carbon sequestration in the pre-European and current landscapes. Again these diagrams show that the mean and shape of the distribution has changed significantly.

Figure 2.13: Distribution of mean annual carbon – pre-European landscape (kg/m2/yr)

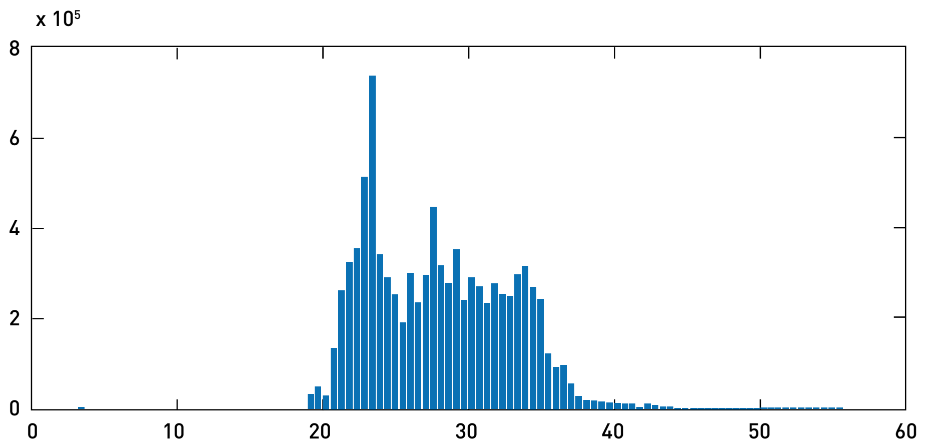
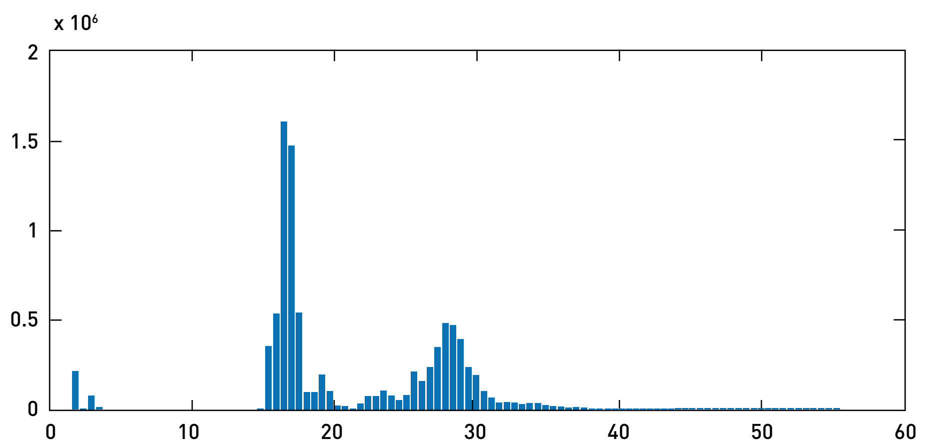


Figure 2.14: Distribution of mean annual carbon – current practice (kg/m2/yr)



2.1.5 Site synergies and non-convexities, long time scales – The final observation about the environmental goods and services (EG&S) generated from land use is that some domains display synergies and non-convexities. Site synergies refer to the observation that individual sites in a wildlife corridor have a value when part of a corridor that is greater than the individual site in isolation. In these cases, it can be argued that the actions of one individual could become interdependent with the actions of others.

Non-convexities refer to the situation where benefits are sometimes produced in lumps that are non-divisible. For example, governments require an outcome from investment, such as a functioning corridor, before any benefits can be derived. In the landscape, a certain quantum of change may be required to generate any benefits at all.

Finally, there are often long times scales involved in generating EG&S. In some land use systems, the interval between land-use change and environmental impact can be relatively short. For example, a decision not to remove vegetation can have immediate benefits on the EG&S.

Removal of stock from native vegetation, for example, can generate significant benefits in one decade. Recreating native vegetation on cleared land could, however, take much longer to generate equivalent EG&S. Similarly, planting trees in some parts of the landscape can generate groundwater impacts within 50 years, while in other parts the time interval between cause and effect could be 200 years.

3. An Economic Framework

Landholders are economic agents; they:

- have specific goals, objectives and risk preferences;
- have command over a unique set of resources; and
- hold information about costs, profit margins and production possibilities.

In effect, each landholder is the person who holds more knowledge about their land, resources and financial situation than anybody else. In some cases, they employ their resources and legal rights over their land, capital, labour, materials etc. to generate commodities.

In other cases, landholders might employ these resources to generate services such as recreation.

In either case, markets are the institution employed in Western economies to facilitate transactions between buyers and sellers of goods and services. It is through this institution that landholders use their private information (e.g. the costs of producing commodities), combine it with information from others (e.g. the profits from processing and selling goods derived from commodities), and make decisions about how to allocate resources between their alternative uses (commodity production or recreation in the case above).

Markets are the institution that resolve differences in the values of buyers and sellers of goods and services and in so doing, maximise the value created through these transactions.

It is clear from the previous section that landholders could also combine resources in ways that supply environmental goods and services (EG&S). Landholders could nurture areas of native vegetation, strategically introduce trees back into the landscape, or grow deep-rooted crops and pastures.

Markets for many of these EG&S have not evolved and land-use decisions tend to be made without consideration of the returns that might be available from the production of EG&S. This missing markets/institutions problem tends to distort land-use decisions toward commodities and against the production of EG&S. A second important consequence of missing environmental markets is that the environmental value creation process does not exist.

The economic problem then is for governments and philanthropic or non-profit organisations to design new institutions (institutions embed incentives) that reward private landholders for producing EG&S such that each landholder efficiently allocates resources to generate optimal mixes of commodities and EG&S, and value is created through transactions in EG&S.

This problem is further complicated because the production function that describes the way inputs are transformed into environmental outcomes is extremely complex. It has been shown that cause and effect are separated by space and time through buffered systems. The set of EG&S produced depends on the type of intervention; the location of intervention; and whether they are jointly supplied and subject to stochastic influences.

The first step in designing the institutions needed to correct the 'missing environmental market' problem is to diagnose the precise reasons why markets for these goods and services have not evolved naturally.

Once these reasons are well understood, it may be possible to identify ways of overcoming impediments with purpose-built institutions that facilitate transactions between those that want to procure environmental outcomes and those able to supply these goods and services. There are both demand- and supply-side perspectives to be considered.

3.1 The Demand-side Problem

It is widely understood that markets for EG&S fail because some of the information needed to facilitate transactions is not available. Specifically, information about 'willingness to pay' for additional units of environmental goods and services is not known.

Typically, markets provide a means for buyers of goods and services to reveal information about willingness to pay. When consumers make decisions about how much to spend or save and how to apportion expenditure between alternatives, such as food, shoes and CDs, these decisions are contingent on knowledge about how an additional unit of these goods and services improves wellbeing.

We understand, at least by intuition, the pleasure and pain associated with too many CDs and too little food. Unfortunately, the same mental processes are much more difficult when the goods and services being considered include habitat and water quality.

These goods and services have public-good attributes such that they are not able to be owned by any one individual (non-appropriable) and the benefits they provide can be enjoyed without restriction (non-rival). As a result of these attributes, public goods are not bought and sold in markets and hence information about our 'willingness to pay' for additional units is not revealed. Without this information it is difficult to determine how much effort should be invested in improving the environment.

It has also proven difficult to find a surrogate method of revealing information about willingness to pay for public goods because in the words of Laffont (2002), "the mechanism used for collective decisions must solve the incentive problem of acquiring the private information that agents have about their preferences for public goods".

3.2 The Supply-side Problem

Information about willingness to pay for additional units of environmental services represents only one part of the information puzzle relevant to EG&S. To allocate resources efficiently, information about the cost of procuring additional units of environment will also be required.

As noted in Section 2, the costs associated with employing land, labour and capital resources to produce environmental outcomes are better known by landholders (it is private information) and unit costs of producing EG&S are specific to each area of land (heterogeneous supply costs). Information about supply prices is not known by government or other agents interested in procuring EG&S and landholders have an incentive not to reveal this information.

Asymmetric distribution of information is recognised as one of the causes of market failure (Akerlof 1970) in many domains of the economy and mechanisms will be needed to reveal relevant information if resources are to be allocated efficiently.

As Laffont and Martimort (2002) note, supply-side problems arise when the *principal* delegates responsibility for the supply of goods and services to an *agent*. In these situations, information is asymmetrically distributed because the act of delegation creates an information advantage to the agent.

In the environmental context, it is clear that landholders (the agents able to supply EG&S from private land) have an information advantage over government (the principal) because it is landholders who have detailed information about the costs associated with modifying land use. In these circumstances, it is expected that governments (the uninformed party) will be at a disadvantage in commercial transactions with landholders.

Economic theory suggests that there are in fact three types of information problems that cause markets for EG&S to fail. Asymmetric information can cause problems prior to the transaction because some information is hidden from one relevant party. This is referred to as *hidden information* and causes *adverse selection* (the wrong suppliers are selected and so scarce resources are spent on higher cost suppliers).

These information problems can be so severe that transactions do not occur. The second information problem occurs because it is not possible to observe the actions of those who have been delegated to provide some good or service. This is called *hidden actions* (also referred to as *moral hazard*). In some cases moral hazard problems will be so severe that the value of a transaction is dissipated by the monitoring costs.

Resolving adverse selection and moral hazard problems imposes costs on the principal but if not addressed will reduce economic efficiency in the procurement of EG&S. Finally, markets become inefficient or in the extreme, fail, where synergies and non-convexity problems exist. All of these problems must be addressed before there can be efficient supply of EG&S.

A number of papers including: Wu (1996); Xepapadeas (1991); Fraser (2002); Latacz-Lohmann and Van der Hamsvoort (1997); Moxey (1999); and Choe (1998) have framed the private land–environment problem in this economic framework.

The principal (a purchaser of EG&S, e.g. government) delegates the task of environmental management to those who own and manage land (the agent) through contractual arrangements. In this institutional setting property rights are not exchanged (as is the case with commodity markets or tradeable emissions schemes), instead contracts are used to modify existing property rights for the purpose of achieving environmental outcomes.

A formal representation of this problem can be found in Laffont (2002) and Anthon (2006). The agent A undertakes investment $(I_{t,l})$ (t denotes the type of investment and l the location of investment) which generates a change in the state of the environment S. Environmental states can be represented as $S(I_{i,j}, e)$ where e is a random variable and $\partial S / \partial I \geq 0$. Landholders could invest $\overline{I}$ (high) or $\underline{I}$ (low), generating a new state of the environment defined as a probability function F(S). For simplicity, only two states are considered: S^L (low state) and S^H (high state) which characterise the new probability function. Only a fraction of landholders v have a high probability $\overline{\alpha}_i$ of achieving the high state S^H from $\overline{I}$ while the remainder $(1-v)$ will have a lower probability $\underline{\alpha}_i$ of achieving S^H from $\overline{I}$. For the same investment, landholders may also generate S^L with a probability of $(1-\overline{\alpha}_1)$ or $(1-\underline{\alpha}_1)$. Some landholders making a low investment $\underline{I}$ will achieve S^H with a probability of $\overline{\alpha}_0$ and $\underline{\alpha}_0$ according to type or will generate S^L with probability $(1-\overline{\alpha}_0)$ and $(1-\underline{\alpha}_0)$ according to type.

Expected social welfare can be denoted by:

$$W = (1-v)[\underline{\alpha}_0(V^H - \lambda \underline{t}^H) + (1-\underline{\alpha}_0)(V^L - \lambda \underline{t}^L) - \underline{I}] + v[\overline{\alpha}_1(V^H - \lambda \overline{t}^H) + (1-\overline{\alpha}_1)(V^L - \lambda \overline{t}^L) - \overline{I}]$$

that represents the expected net social benefit of the environmental goods and services (V) after accounting for transfers (t) to landholders to reward investment and the social cost of public funds (λ).

3.2.1 Adverse selection – Under incomplete information, a first-best solution is not possible because agents have some market power that derives from the information they hold about their costs and technology. As long as the principal insists on a level of output of EG&S from the inefficient type (i.e. high-cost provider), the principal must give up a positive rent to the efficient agent who can mimic an inefficient agent with respect to marginal cost. Following Anthon (2006) and Laffont (2002), the incentive compatibility constraints in the pure adverse selection problem are:

$$\overline{\alpha}_1 \overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \overline{\alpha}_0 \underline{t}^H + (1-\overline{\alpha}_0)\underline{t}^L - \underline{I}.$$

$$\underline{\alpha}_0 \underline{t}^H + (1-\underline{\alpha}_0)\underline{t}^L - \underline{I} \geq \underline{\alpha}_1 \overline{t}^H + (1-\underline{\alpha}_1)\overline{t}^L - \overline{I}$$

The high-probability agent must be rewarded for the high state but the low-probability agent must not be rewarded for the high state as this would give the high-probability agent an incentive to pass as a low-probability agent $\underline{t}^H \leq t^L$. If the low state is achieved payment cannot be higher than for the high state as this would give perverse incentives (i.e. $\underline{t}^H = \underline{t}^L$). The participation constraint under the incomplete information scenario then becomes:

$$E(\overline{\pi}) = \overline{\alpha}_1 \overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \geq 0 \qquad \overline{PC}$$

$$E(\pi) = t - I = 0 \qquad PC$$

This reduces the incentive constraints to: $\overline{\alpha}_1 \overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \underline{t} - \underline{I} = 0$; and

$$\overline{\alpha}_1 \overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \underline{t} - \underline{I} = 0$$

$$0 = \underline{t} - \underline{I} \geq \underline{\alpha}_1 \overline{t}^H + (1-\underline{\alpha}_1)\overline{t}^L - \overline{I}$$

The adverse selection constraints become:

$$\overline{\alpha}_1 \overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \underline{t} - \underline{I} = 0$$

$$0 = \underline{t} - \underline{I} \geq \underline{\alpha}_1 \overline{t}^H + (1-\underline{\alpha}_1)\overline{t}^L - \overline{I}$$

This suggests that the expected payment to the high–probability agent has to be larger or equal to the investment $\bar{I}$. In this case, the principal will need to pay more than opportunity costs for the high-probability agent to participate but the expected payout to the low-probability agent posing as the other agent has to be smaller than $\bar{I}$. Where the agent takes all of the risk, the optimal contract for the higher type will be to pay zero if the low state is achieved, and a payment higher than the investment if the high state occurs. Alternatively, if the principal takes all the risk, the optimal contract is to pay the same transfer whatever the final state.

There are three policy mechanisms that can be considered to deal with hidden information:

- *Menu of contracts* – While a menu of contracts approach has been employed for adverse selection in insurance markets, there have been no known applications of this approach in the environmental procurement field. Ferraro (2005) notes that designing a menu of contracts that is incentive compatible and satisfies participation constraints while maximising the environmental authority's objective function requires "knowledge about the distribution of landowner types and sophisticated calculations by conservation practitioners".
- *Costly to fake signals* – A second approach to manage adverse selection is to gather information on observable landowner attributes that are correlated with opportunity costs and to use these attributes to establish contract prices. Ferraro (2005) notes that this approach is common in US agri-environmental schemes where posted contract prices differ to reflect soil type, distance to roads and markets, habitat type and other variables that are correlated with opportunity cost but which are impossible or costly to fake.
- *Auction* – Auctions are a set of rules and processes that harness competition for the purpose of revealing an agent's type, i.e. whether they are low-cost or high-cost suppliers. Auctions are used to allocate conservation contracts in the Conservation Reserve Program (US), for biodiversity conservation in Australia (BushTender), and in Germany (Holm-Muller 2004).

Each approach aims to reveal landholder type and each comes at a cost because the conservation agency must invest in information revelation processes and a system of rewards to landholders to reveal private information.

Importantly, the principal will be required to pay landholders a rate above their true opportunity cost to encourage revelation of this information. This is referred to as an information rent that accrues to landholders because private information about their 'true' opportunity cost has conveyed some degree of market power.

The choice of which of these three mechanisms to employ reduces to a comparison of transaction costs, information rents and distortions associated with the supply of environmental services for the three alternatives, e.g. a menu of contracts, signals and auction.

There are fundamental differences between an auction, a menu of contracts approach and the costly fake signal approaches. Information asymmetry between the conservation agency and the landholder is addressed through competition in the case of an auction, through self-selection in the case of the menu of contracts, and through correlation with observable attributes in the signalling approach.

There are several information advantages of an auction over alternative methods of dealing with adverse selection. Unlike the menu of screening contracts, auctions do not require the conservation agency to specify the distribution of landholders' types (Ferraro 2005). Landholders reveal this distribution through their bids. Whereas auctions use competitive bidding to reduce the attractiveness of low-cost landholders claiming to be high cost, screening contracts accomplishes this goal by specifying a low level of environmental services from contracts aimed at high-cost landowners. For this approach, contracts will need to be designed to ensure that the inefficient type gets no rent, but the efficient type gets the information rent above opportunity cost. This is a difficult design problem that would rely on detailed a priori information about participants.

There are a number of factors that suggest an auction will reduce transaction costs involved in the procurement of EG&S from private landholders. Latacz-Lohmann (2005) identifies the information management advantages of an auction compared with the alternatives.

A well-designed auction facilitates revelation of specific information from the different players. Bidding is a discovery process where prices are determined through a decentralised process which takes into account the information from a range of sources. The environmental agency can design the rules (which EG&S are demanded and how they are measured) under which the competing bids are evaluated and the landholder, who is the better-informed party, provides information about the cost of changing land use.

Auctions can also sequence and combine information from different sources, including scientists, so that the principal obtains relevant information on which to allocate contracts. Where heterogeneous environmental outcomes are assumed (as demonstrated in Section 2); auctioning conservation contracts to landholders will require the use of complex models that convert land-use change into estimates of environmental change.

Provided these information problems can be managed, auctions compare favourably with a menu of contracts approach where the principal is required to make the first move by offering a menu of contracts with pre determined characteristics. Increasing the number of contracts offered to accommodate different types will raise transaction costs because some of the information needed will be hidden from the principal. There will be similarly onerous transaction costs associated with increasing the information needed to reduce information asymmetry with the signalling approach.

The disadvantages of auctions as a means of dealing with adverse selection in the case of conservation contracts include: the need for a large pool of bidders to induce competition; the additional costs of administering an auction; and certain types of auctions, such as those dealing with package problems, can involve complex bidding processes, although it is not clear whether these will be more complex than screening contracts.

There are many, often conflicting, design choices to be made in selecting the auction format for conservation programs on private land. While the revenue equivalence theorem suggests that all auction formats (English, Dutch, First-price sealed-bid, Vickrey) will generate the same revenue on average, this is under a set of standard assumptions[1].

If the assumptions behind this theorem do not hold, particular auction formats may prove superior. The characteristics of the environment noted in Section 2, including the existence of multi-item bundles of outcomes, joint supply, site synergies, stochastic outcomes and threshold effects, will also influence auction design. Latacz-Lohmann (2005) identifies several additional factors that need to be considered with environmental procurement auctions including: the repeated nature of conservation auctions; fixed-target and fixed-budget objectives; efficiency versus cost-effectiveness objectives; different payment formats (e.g. uniform price or price discriminating); and a range of information management options with respect to bidders (see Cason *et al* 2003).

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[1] The auction sells a single item; independent private values; the seller does not know individual valuations but assumes that these values are drawn randomly from a probability distribution that is known; bidders know their own valuations and the probability distribution of other bidders, but not those of other individual bidders; symmetric bidding; competitive bidding – no collusion (see Latacz-Lohman (2005))

3.2.2 Moral hazard – Moral hazard occurs when there is uncertainty in the way that the inputs of agents (disutility for the agent) translate into outcomes (the objective of the principal). This uncertainty arises because:

- the principal is interested in the result (in this case the environmental outcomes), but the agent may not be;
- the principal is not directly interested in effort exerted by the agent but the agent is because effort translates to additional costs; and
- there is a connection between increased effort and increased outcomes (see Macho-Stadler 2001).

Laffont (2002) notes that uncertainty of supply "is central to the contractual design problem with respect to moral hazard. The principal wants to induce the agent to high effort despite the impossibility of directly conditioning the agent's reward on his action".

In the pure moral hazard case (no heterogeneity between agents) the investments made by landholders are non-verifiable, but the principal will prefer high investments in the production of EG&S. The expected social welfare can be expressed as:

$$W = \alpha_1(V^H - \lambda t^H) + (1-\alpha_1)(V^L - \lambda t^L) - \bar{I}$$

As for the adverse selection case, the participation constraint is:

$$\alpha_1 t^H + (1-\alpha_1)t^L - \bar{I} \geq 0 \qquad \text{(PC)}$$

and an additional incentive constraint for moral hazard is added to ensure that the expected return to the high investment type has to be larger than the expected return of the low investment type:

$$\alpha_1 t^H + (1-\alpha_1)t^L - \bar{I} \geq \alpha_0 t^H + (1-\alpha_0)t^L - \underline{I}.$$

This is rewritten as:

$$(\alpha_1 - \alpha_0)t^H + (\alpha_1 - \alpha_0)t^L - \Delta I \geq 0 \qquad \text{(MH)}$$

where $\Delta I = \bar{I} - \underline{I}$

This suggests that there is a limited set of contracts that comply with participation and incentive constraints. In the case of pure moral hazard, where the agent carries all of the risk, the optimal contract is to pay zero if a low state occurs and a payment higher than the investment if the high state occurs. Where the risk is shared between the principal and agent, the optimal contract is not to cover the total cost of the agent in the low state and to give the agent a bonus in the high state.

There are a number of examples of environmental programs that have employed contractual arrangements with landholders to procure non-point-source EG&S including the Conservation Reserve Program (CRP) in the US; the Nature 2000 program as it is applied in several member countries of the European Union (Denmark, the UK and France); Australia (Stoneham 2003); and Germany (Holm-Muller 2004).

Some of these programs allocate contracts without reference to adverse selection (EU countries), however, the CRP, Australian and German auctions of conservation contracts identify landholder type.

3.2.3 Synergies – The final class of problem that prevents markets from operating efficiently occurs when the value of one action or investment is influenced by the actions or investments of others. For example, aquaculture sites are more valuable if conveniently located close to other sites and mobile phone spectrum is more valuable if it is combined with other bandwidths to create the networks needed by mobile phone companies.

Similarly, the value of some interventions in the landscape will depend on the proximity to other interventions. This occurs with wildlife corridors where a number of contiguous sites will offer greater environmental value than an equivalent number of independent sites. Markets, unassisted, are not able to allocate resources efficiently where synergies exist. Innovations such as combinatorial auctions that allow market participants to assemble packages of items can be used to overcome synergy problems.

The reason that markets for EG&S are missing or inefficient is perhaps more complex than previously thought. While the public good attributes of the environment are prevalent, the lens of information economics exposes other attributes of the environment (adverse selection, moral hazard and synergies) that also contribute to market failure particularly on the supply-side.

Although the problem of revealing values for additional units of public goods remains, there is a body of economic literature that provides important insights into the supply-side problems identified. Principal-agent theory provides a robust framework in which this class of problems can be considered and solutions proposed.

Designing, testing and refining the institutions needed to achieve efficient and effective outcomes is therefore an important element of environmental policy design.

4. The mechanism design methodology

Roth's important paper (2002) observes that a methodology has been developing to assist economists to design policy mechanisms where markets or other institutions are missing or inefficient.

Beginning in the 1940s, but coming to the fore in the 1990s, this approach is called *Economic Design* and within that, *Mechanism Design* includes a set of methods (Milgrom 2004).

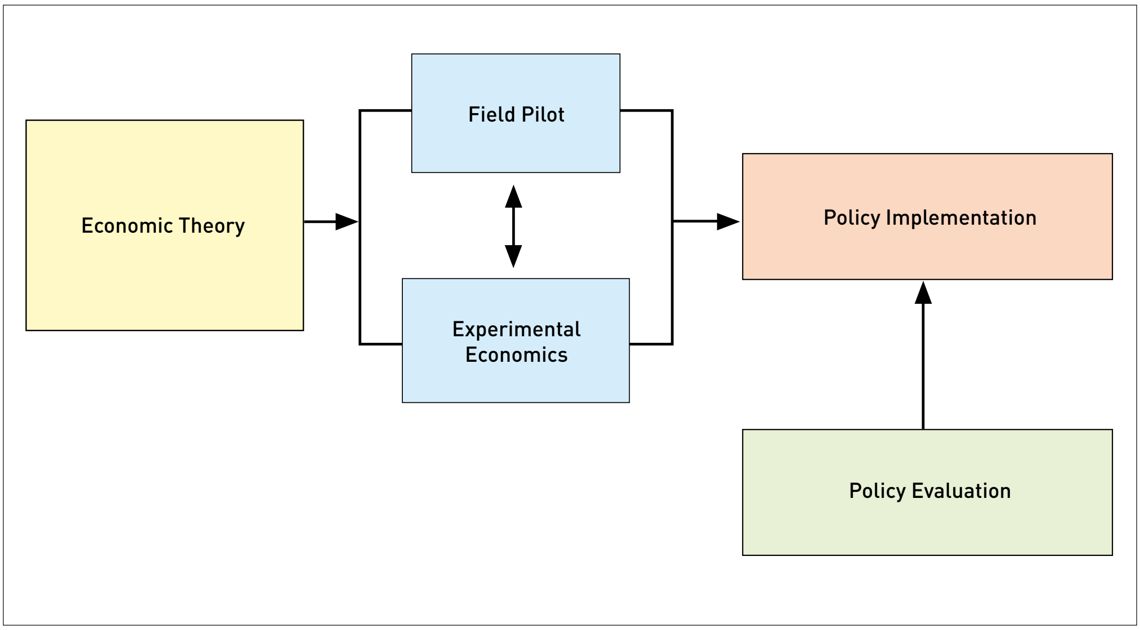
The mechanism design methodology provides policy makers with a systematic framework for understanding how the *environment* (the set of initial circumstances including the private tastes, knowledge and skills of economic agents) interacts with the *institution* (the rules of private property, allocation processes) for the purpose of completing *transactions*.

The mechanism design approach allows policy makers to analyse the alternative institutions that might be employed and to select the most efficient policy to achieve these outcomes. The policy designer is often confronted with an environment of imperfect information where there is little or no prior experience to draw on and each new application needs to be specifically designed to accommodate the particular characteristics of the problem at hand.

Roth notes that mechanism design incorporates three key elements:

- *Economic theory* – the application of theoretical frameworks that show aspects relating to the exchange of goods and services, including analysis of market efficiency and the reasons that they may be inefficient or missing. This analysis can be used to design mechanisms that overcome impediments to transactions. Roth notes that this body of theory includes game theory and information economics.
- *Experimental economics and field pilots* – New tools and techniques, including economic experiments and field pilots, are now available to test and refine mechanisms and to demonstrate whether they are practical, efficient and effective. Experiments or field pilots are particularly useful where policy makers are faced with specific problems for which economic theory is unclear and there is no practical, relevant experience. Experimental economics is a technique that systematically examines elements of new policy mechanisms by engaging human subjects with financial incentives who are subject to systematic policy treatments. Results from experimental sessions are then analysed using statistical techniques to determine the likely economic efficiency and effectiveness of alternative policy mechanisms. Field pilots are used to demonstrate, refine and familiarise people with new policy mechanisms before they are implemented more widely.
- *New computational capabilities* – Roth notes that new computational capabilities can overcome certain impediments that have previously prevented some markets from evolving. This is particularly relevant for package problems where combinatorial auctions are conducted electronically and supported by algorithms that assist participants to formulate bids.

Figure 4.1 Illustrates the mechanism design process now being employed by economists



The seminal applications of this approach to policy design are:

- the Federal Communication Commission (FCC) auction of spectrum rights (McAfee and McMillan 1996);
- the allocation of airport landing rights (Plott 1981);
- the Sarbanes-Oxley Act of 2002 (SOX) USA trading rules for emissions trading (Cason and Plott 1994);
- the Regional Clean Air Incentives Market (RECLAIM) USA emissions trading (Cason 1998); and
- the National Resident Matching Program (NRMP) which is a labour clearing house such as the one through which doctors are allocated to hospitals (Roth 1997).

In these cases, economists designed mechanisms that allowed individuals and firms to engage in competitive and collaborative interactions and exchange rights. These artificial markets were designed in the laboratory, implemented in the real economy and have been shown to be successful policy mechanisms. They also provide important insights into the complexity of policy design and implementation.

In designing a policy instrument that is tailor-made to the problem being addressed, Bardsley (2003 AARES) explains that we may find ourselves with some different-looking mechanisms. He warns that mechanisms may look different in different situations; some may be similar to standard regulatory approaches, some to a standard auction, and others different to any of these.

Bardsley advises designers to let the mechanism design emerge from the situation at hand, the policy problem and the analysis performed.

5. Creating Markets for Environmental Goods and Services: Results and Application in the Field

This section reports on the performance of a set of institutions that has been designed to deal with the missing environmental markets associated with private land. A field pilot was employed to test whether efficient transactions can be facilitated between buyers and sellers of environmental goods and services (EG&S).

The pilot was designed in the context of the three key approaches noted above: diagnosis of the underlying causes of market failure (Sections 3.1 and 3.2); design of new institutions that specifically address adverse selection and moral hazard (Sections 3.2.1, 3.2.2 and 3.2.3); testing and refinement through the mechanism design approach (Section 4); and evaluation.

5.1 A Complete Set of Markets: a Blueprint for Environmental Policy

A field pilot was employed to examine the efficiency and effectiveness of an economic system that includes a more complete set of markets for EG&S. Figure 5.1 provides an overview of the institutions that embed the incentives and processes needed to engage private landholders in conservation of EG&S. As illustrated in the diagram, landholders are also subject to certain constraints imposed by legislation including those that relate to land clearing and maintenance of habitat. Within these constraints, landholders seek to maximise their individual wellbeing by producing commodities or other private goods and services.

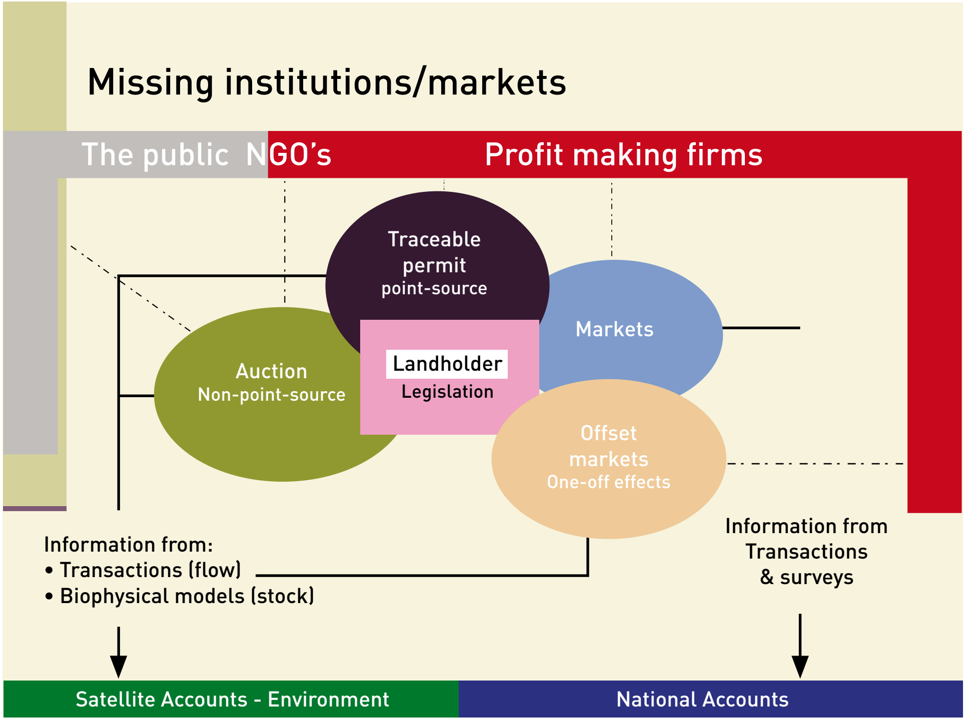
Markets are the primary institution employed by private landholders to engage with others for the purpose of completing the transactions needed to sell primary produce and to buy the relevant inputs. As noted earlier, these markets exist because they are the institutions that minimise transaction costs. Information from these transactions is observed by the Australian Bureau of Statistics and used to compile National Accounts, as illustrated on Figure 5.1.

The pilot reported in this paper explored the feasibility of introducing new institutions designed specifically to facilitate transactions between the landholder and other agents who have incentives to procure environmental goods and services. As illustrated in the diagram, these institutions fall into three broad categories:

- *Point-source* – Tradeable emissions permits, Pigovian taxes or hybrid systems (McKibbin and Wilcoxen 2002) are relevant to point-source problems;
- *Non-point-source* – Auctions of conservation contracts are suitable for non-point-source problems; and
- *Offsets* – Specialised markets for offsets will be needed to lower transaction costs.

Where these new institutions can be created and shown to efficiently resolve the adverse selection and moral hazard problems, this opens up the prospect of systematically observing transactions for the purpose of developing environmental accounts.

Figure 5.1: Missing markets for the environment: private land



5.2 The Pilot

A pilot was run to examine how the institutions illustrated in Figure 5.1 might work in practice and to observe how the existence of these institutions affects the investment and production patterns of landholders. In effect, landholders in the pilot were subjected to a 'complete' set of markets for private and public goods.

The pilot was run in two sub-catchments of Victoria, Australia: Avon-Richardson (370,000ha) and Cornella (47,000ha) as illustrated in Figure 2.3. At the time of the pilot, land use in the Avon-Richardson (Cornella) was 52% (53%) cropping; 37% (26%) grazing; 6% (20%) trees; and 5% (1%) urban or infrastructure. Annual rainfall for the pilot areas ranges from 450mm to 670mm per year. A fixed budget of A$400,000 was available for landholder payments.

Conservation contracts were employed to supply EG&S from private landholders. Some of the goods and services produced from these contracts could be purchased by private firms (such as those required to offset carbon emissionss) while others have public good attributes and are likely to be procured by an environmental agency on behalf of the public.

An important aspect of the pilot was the use of biophysical models to provide information about the EG&S that are expected to be generated from landholder intervention. Each participating landholder received a site visit where they were informed about the EG&S that could be expected from a range of investments.

In the pilot region, two forms of investment were common: revegetation of land that had been previously cleared, and restoration of habitat that had been degraded as a result of the impact of weeds, pests, stock and other influences. Within these two broad categories, many levels of investment were possible. The environmental benefit of each investment was estimated as the difference between the expected post-intervention state of the environment and the estimated initial state.

A metric, normalised against a benchmark of 'pre-European' condition, was employed to reflect the contribution that each intervention makes to the supply of EG&S. A composite index (the Environmental Benefits Index; EBI) was then constructed by summing the relative contribution made on each domain of the environment considered. The EBI is an additive index because EG&S have been shown to be jointly supplied (see Section 2).

The EBI does not reflect social preferences between different domains of the environment because of the theoretical difficulties briefly noted in Section 3.1. If information about willingness to pay for different environmental services were available it would be possible to weight one element (e.g. aquatic habitat) over another (e.g. terrestrial habitat) to reflect social preferences.

Landholders were informed about the environmental benefits expected from their investment, were informed about the distribution of environmental outcomes across all bidders, but were not informed about the environmental outcomes of other individuals. Landholders were then asked to formulate a bid or payment needed to complete the investments indicated.

In formulating bids, landholders were required to nominate the payment that would be required to change land from its current use to activities that produce EG&S. As noted in Section 3, theory suggests that the bid will include a participation payment and information rent. This suggests that profit-orientated landholders would require a payment to offset the costs associated with producing EG&S (e.g. the cost of materials such as fences, labour costs, etc); costs associated with profits foregone (e.g. the profit foregone from lighter stocking rates); and a rent associated with revealing private information.

The bidding strategy for landholders who have altruistic attitudes toward conservation will be different, particularly with respect to the information rent component noted above. The behaviour of altruistic participants in conservation programs with respect to the preferred auction format and optimal contract structure is an area that would benefit from further research.

The pilot was designed to represent an institutional setting where there is a complete set of markets for the goods and services derived from private land. Some of the funds for landholder payments are derived from emitters of carbon where sequestration of carbon is permitted and some funds are from government interested in procuring public goods (habitat). These sources of funds are combined by the landholder who, when formulating the bid, considers the expected return from carbon sequestration, based on a price of $12/t[2], and then determines the additional payment needed change land use.

An environmental authority receives the bids and ranks them on the basis of the price per unit of public EG&S generated. All EG&S (both public and private goods) were procured through one contract with each landholder. The marginal bid was identified at the budget constraint and contracts were offered to all bidders below this price.

After the contracts were signed, the landholder makes investment. An initial payment was made, outputs observed (in the case of carbon) and a state-contingent payment was made. Progress payments for the habitat component of the contract were based on compliance with an input schedule.

A sealed-bid, single-round, price-discriminating, budget-constrained auction was employed to deal with adverse selection for EG&S with public good attributes (see Stoneham 2003). Three changes were made to the allocation process to accommodate the more complex multiple-outcome problem. The first was to construct metrics for the public goods (habitat, water quality and salinity) as noted above.

2 The price of carbon was exogenously determined

The second change was the development and use of sophisticated biophysical models employed to estimate the expected translation of landholder investment into environmental outcomes. Wu and Skelton-Groth (2002) developed an empirical model to demonstrate the extent of fund misallocation when jointly produced environmental outcomes are ignored.

A simulation model was specifically developed to map landholder investment to expected environmental outcomes by linking one-dimensional farming system models capable of simulating pasture, crop and trees with a fully distributed three-dimensional groundwater model. The model simulates daily soil/water/plant interactions, overland flow processes, soil loss, carbon sequestration and water contribution to stream flow from both lateral flow (overland flow and interflow) and groundwater discharge (base flow to stream). The model develops both surface element network and a groundwater mesh based on unique combinations of spatial data layers.

Typically, the spatial data necessary to derive the surface network includes: soil, topography, land use and climate. The groundwater model required spatial data pertaining to aquifer stratigraphy, such as elevations of the top and basement of each aquifer, spatially-varying aquifer properties and river/drainage cadastral information. This capability allows for analysis of site-specific investment (down to 50m x 50m resolution) of any aggregation of sites. Simulations predict both the expected outcomes and information about the probability function from which any outcomes will be drawn.

Outputs include: soil/water balance (soil moisture, soil evaporation, transpiration, deep drainage, runoff, erosion); vegetation dynamics (crop/plantation yield, forest stem diameter, forest density, carbon accumulation); stream dynamics including stream flow, water quality and salt loads at a sub-catchment and catchment scale; and groundwater dynamics (depth to ground water, aquifer interactions, groundwater discharge to land surface and stream at a sub-catchment and catchment scale) (see Beverly 2005 and Eigenraam 2006).

The third change introduced was to inform bidders about the environmental goods and services offered by each landholder before bidding occurred. Using experimental economics Cason, Gangadharan et al (2003) conclude that withholding this information limits scope for landholders to extract information rents. Revealing this information could improve economic efficiency if price premiums form in the land market to reflect environmental scarcity. If this were to occur, landholders would have an incentive to investigate the environmental significance of their land and would change behaviour because of the financial rewards from conservation.

5.3 Bids in the auction

The auction received 54 bids. Figure 5.2 reports the frequency distribution of environmental benefit (EBI represents only the EG&S with public good attributes) estimated to be produced from each bid in the auction. Environmental Benefit Index (EBI) represents the quantity of public goods generated from each land-use change proposed by bidders.

Estimates of the environmental impact are derived from the visual assessment process developed by Parkes (2003) and landscape modelling developed by Beverly (2005). The average score for all sites assessed was 7,292 EBI units while the median was 1,001 EBI units. The distribution of tonnes of carbon sequestered from the actions proposed on each site, as illustrated in Figure 5.3, display similar heterogeneity.

These data illustrate the heterogeneous nature of environmental impacts resulting from land-use change as discussed in Section 2. The environmental benefits offered by each landholder are different because of location effects and because each landholder offers different types of intervention.

The auction also reveals the extent of heterogeneity with respect to the 'supply price'[3] for additional units of EBI (see Figure 5.4) and per hectare (see Figure 5.5).

Data from the auction not only reveal heterogeneous environmental impacts but the quantum of funds needed to complete conservation actions also varies from site-to-site. The distribution of bids is weakly bimodal, reflecting the higher cost and lower habitat gains from investments involving revegetation compared with habitat restoration. This result is consistent with earlier auctions (Stoneham 2003).

Figure 5.2: Distribution of environmental benefits (public goods only)

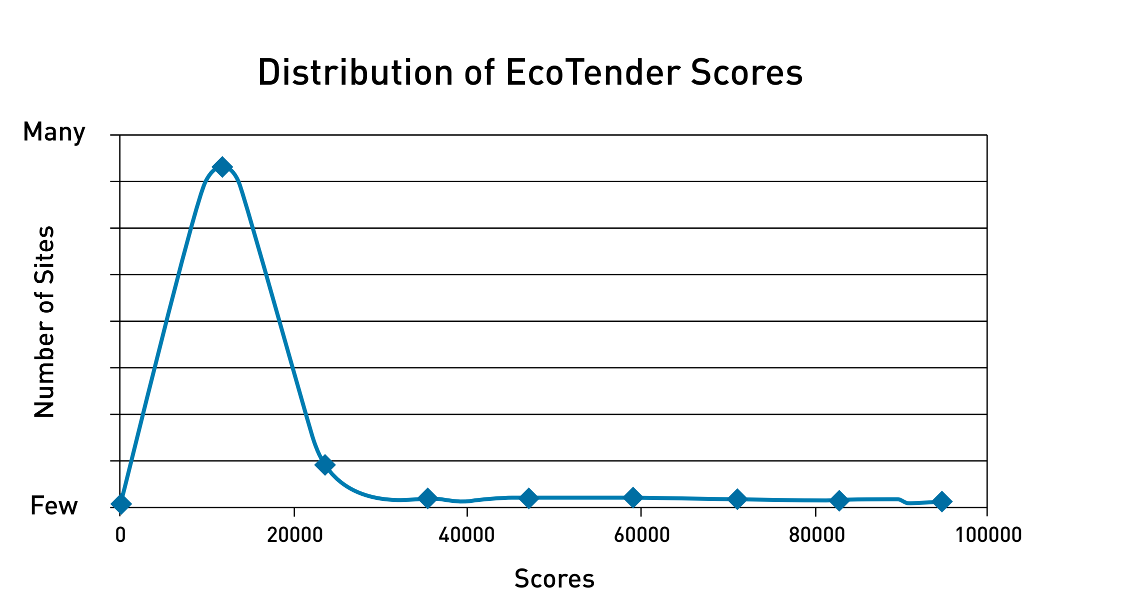
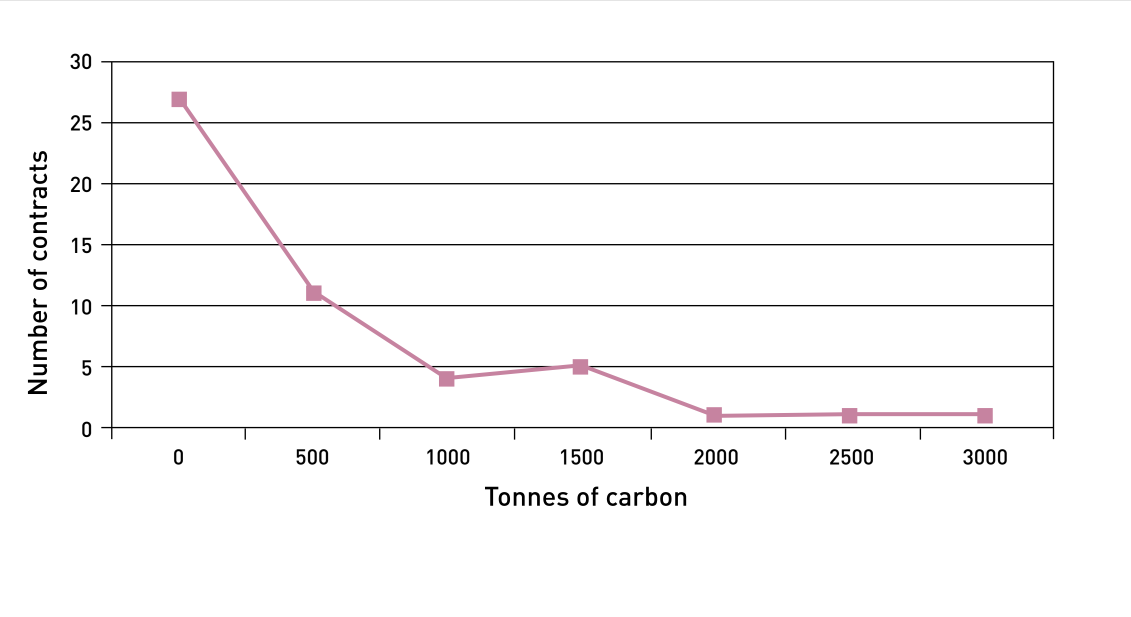


Figure 5.3: Distribution of carbon sequestration



3 The term 'supply price' is used recognising that there are information rents in landholder bids.

Figure 5.4: Distribution of bids expressed as a supply price per unit of EG&S

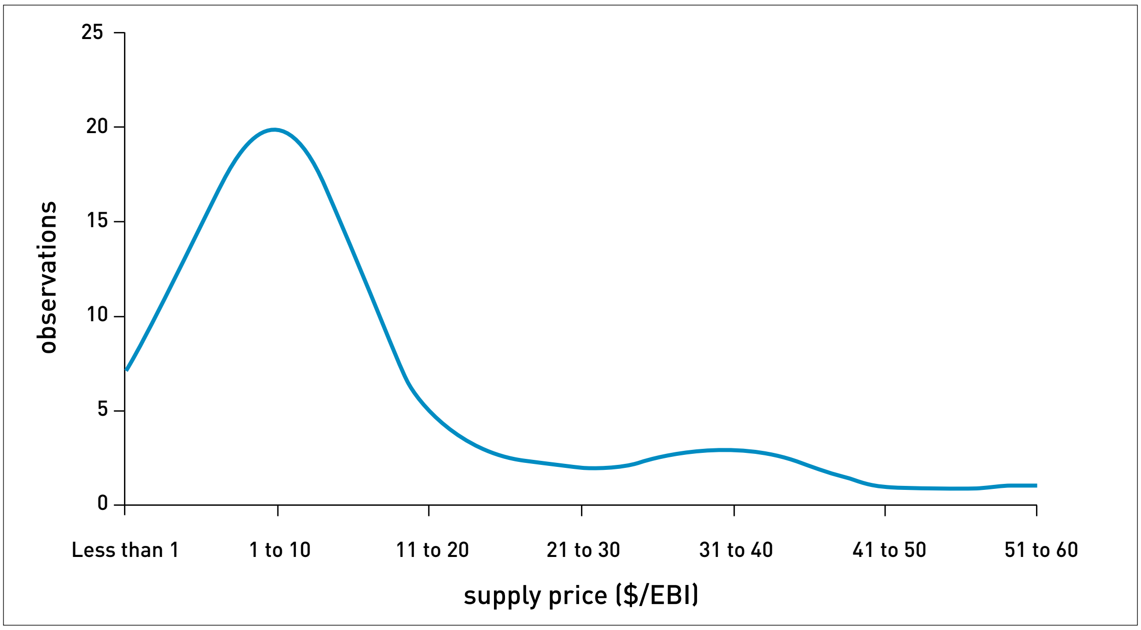
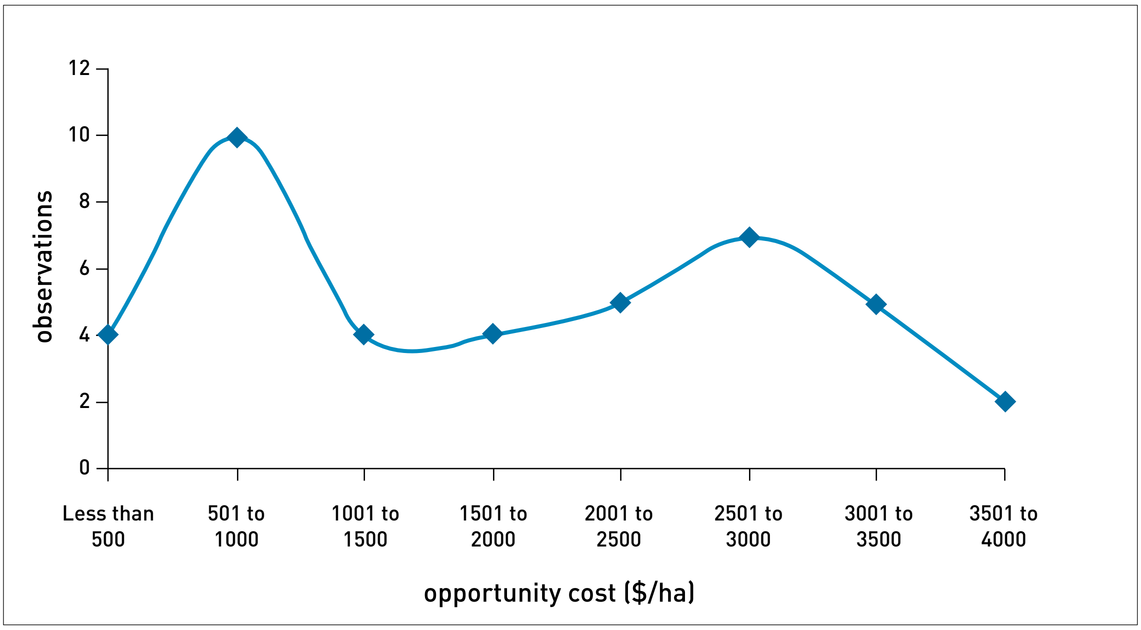


Figure 5.5: Distribution of bids expressed as a supply price per hectare



Within the budget constraint, a total of 357,186 EBI units were procured consisting of 277,595 units of habitat improvement, 25,056 units of water quality improvement and 5,755 units of salinity control. As noted above, these units are additive representing the relative movement from the current environmental status toward a pristine state (as defined by the pre-European landscape).

A total of 32 contracts were secured representing management agreements over 257ha of land. Figure 5.6 illustrates the contribution of each of the public goods represented in the EBI. This figure shows that terrestrial habitat makes up most of the total improvement in environmental status.

At the budget constraint, the marginal dollar invested by the environment authority translates into a 0.67% improvement in habitat, 0.08% improvement in water quality and 0.018% improvement in salinity. This suggests that investment in landscape change generates large changes in habitat improvement but relatively little improvement in salinity control.

This result can be largely explained by reference to Section 2 where it was reported that the current stock of habit represents only 4% of the pre-European state. This compares with the 0.1% change in the area of land subject to a water table of less than 0.8m.

A bid curve which ranks bids in order of bid prices is shown in Figure 5.7.

The characteristics of the bid curve (many low-cost bids but rising sharply thereafter) are consistent with the single outcome auctions run previously (Stoneham 2003). Available funds for the auction were allocated to contracts from low cost (left to right) until the budget was exhausted. At the budget constraint of A$401,000, a bid price of $18.26/EBI for the marginal unit of EG&S was observed. The highest bid received was $6,050/EBI.

The purpose of running an auction and ranking bids from low to high cost per unit of EG&S supplied is to deal with adverse selection (see Section 3.2.1). This process mimics the way markets allocate production activities to low-cost rather than high-cost suppliers of goods and services. In markets, each landholder has knowledge about the costs of production, acceptable risk-adjusted profit margins and can observe prices from the market. With this information, each landholder self-selects into or out of a supply contract.

In effect, low-cost suppliers select into supply contracts and high-cost suppliers select out of supply contracts. Markets, therefore, efficiently deal with adverse selection.

In the auction of conservation contracts, adverse selection is managed by ordering contracts from low-cost to high-cost and selecting those contracts that exhaust the environmental budget. It is noted that other auction formats could be employed, such as a uniform price auction, that operate more in-line with the self-selection process observed to occur in markets.

Many environmental programs do not specifically invest in revealing information about the quantity of EG&S generated. Instead, selection of participants occurs on an input basis, such as per metre of fencing or per hectare costs.

Figure 5.8 compares the bids received on a per hectare basis with the bids expressed per unit of environmental benefit. The important observation from these data is that the order of contract ranking would change dramatically if they were ranked on an input (per hectare basis) rather than on an output basis (per unit of EG&S).

Statistical analysis reveals that while bids expressed per hectare are positively correlated with bids expressed per unit of EG&S, the correlation coefficient is only 0.22. This means that a policy mechanism that selects participants on a per hectare basis would not deliver the best environmental outcomes. It would be less efficient because of adverse selection problems. Contracts would be awarded to many high-cost suppliers because they were ranked on inappropriate criteria.

The performance of the auction with respect to adverse selection was assessed by comparing the budget outlays required to procure a given quantum of EG&S with that required when contracts are selected at random from the bid population of participants as represented in Figure 5.9. This analysis revealed that a saving of 30% was achieved by employing an auction to reveal landholder type compared with an institution that did not invest in revealing landholder type.

Figure 5.6: Contribution of environmental goods and services to environmental benefit index

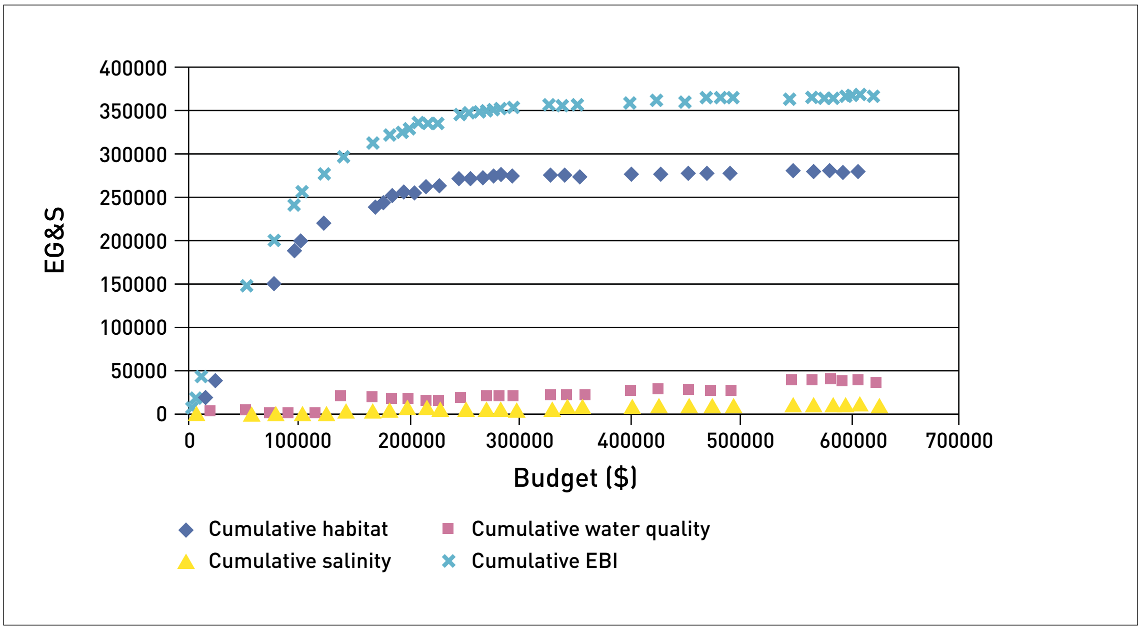


Figure 5.7: Bid curve

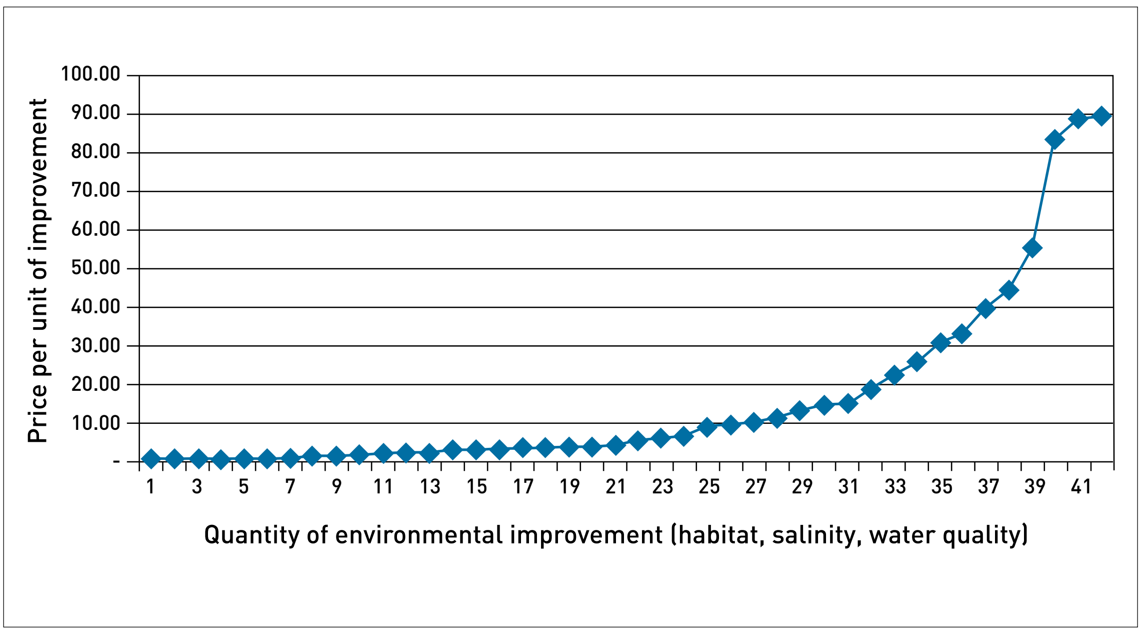


Figure 5.8: Comparison of bids per hectare and per unit of EG&S (EBI)

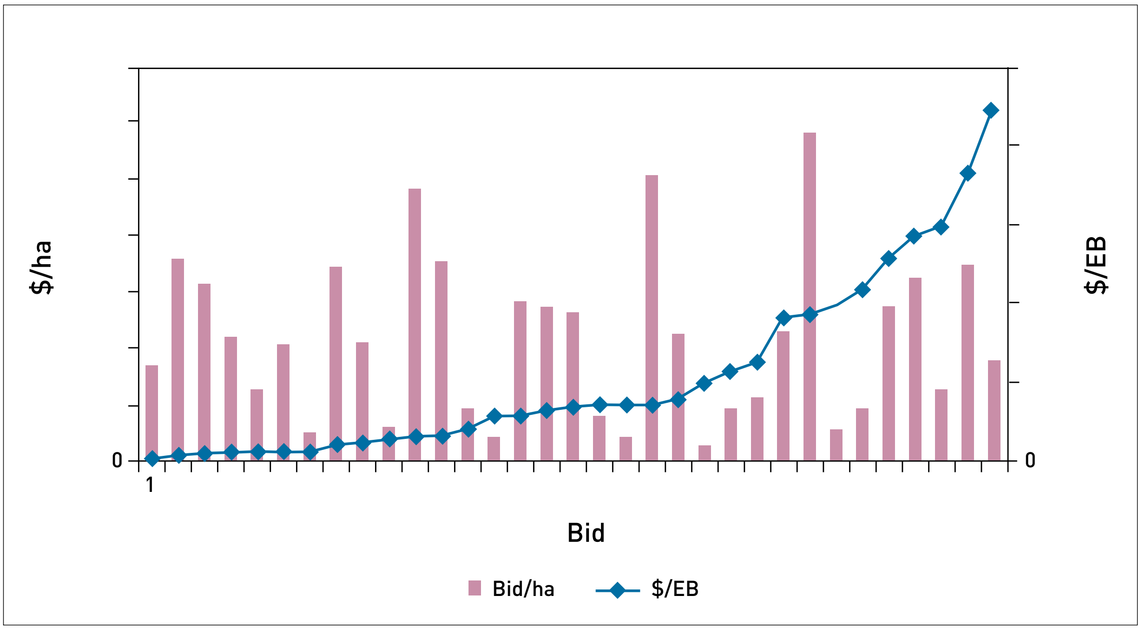
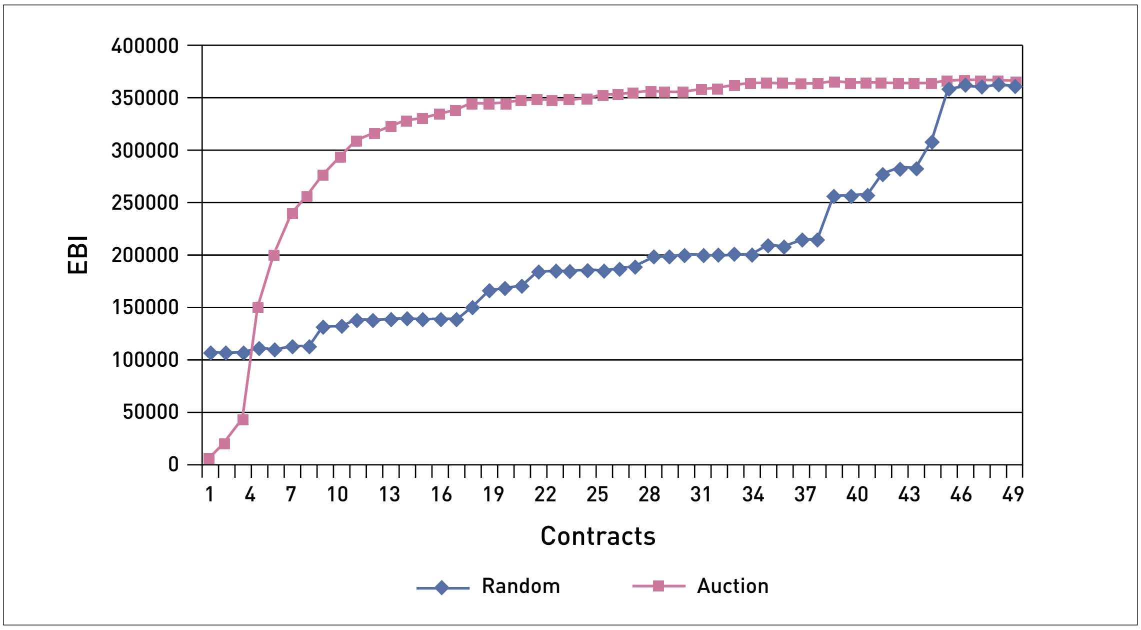


Figure 5.9: Economic efficiency – auction vs. random selection



As noted above, landholders were informed about the quantity of EG&S (EBI) their bid was expected to generate and how their environmental service compared with other bidders.

According to Cason *et al* (2003), this would encourage bidders with high levels of environment service to raise their bids to extract information rents. Analysis of the composition of bids reveals that landholders with low offer prices (per unit of environmental outcome: ($/EBI)), tended to have high levels of environmental service as shown in Figure 5.10.

Furthermore, the gross bid (in dollars) displays no trend across the entire range of offer prices ($/EBI). There may be several reasons for this observation. One reason is that the field pilot represents a one-shot game, whereas the experimental analysis conducted by Cason, Gangadharan *et al* involves repeated sessions. In the initial rounds of experimental economics sessions, it is commonly observed that bidders take several iterations of the market before bids reach equilibrium.

From this it can be concluded that given further experience and information from real-world auctions, fully informed landholders with higher levels of environmental benefits may raise their bids to capture more of the rents available. At the other end of the spectrum, those bidders with low environmental benefits would be constrained in lowering bids as individual participation constraints become binding.

As noted previously, EG&S are jointly supplied such that procurement of additional units of public goods also generates additional units of private EG&S. Carbon and water[4] are the two EG&S where tradeable permit markets could develop.

One objective of the field pilot was to expose landholders to a 'complete' set of missing markets for EG&S. Landholders were informed about the quantity of carbon likely to be sequestered from their investments and informed about a market clearing price for carbon ($12/t). They were then asked to nominate the additional payment required to change land use according to the management actions nominated in the contract. Figure 5.11 illustrates the quantity of carbon expected to be sequestered as additional EBI units (public goods) are procured.

For contracts that supply additional units of EBI at low cost (to the left) very little carbon is sequestered. These contracts generally involve regeneration of existing habitat and the carbon sequestered from these contracts is not admissible under Kyoto arrangements. Revegetation, on the other hand, is recognised under Kyoto protocols, generates lower habitat improvement (the major component of the EBI) but provides carbon sequestration. At the budget constraint, an estimated 11,768t of carbon is expected to be sequestered if the actions specified in the contracts were implemented.

If it is assumed that landholders' participation constraints hold irrespective of the source of revenue (carbon or public EG&S) and that contracts jointly supply EG&S, it can be shown that an increase in the price of carbon (exogenously determined) will reduce the funds required to procure public goods.

For a revenue-constrained auction, data reported in Table 5.1 show that as the clearing price of carbon rises, the number of contracts able to be funded from the environmental authority's fixed budget increases from 25 at $0/t to 41 at $20/t. These additional contracts only marginally increase the total quantity of public goods procured (EBI increases by 3% at a carbon price of $20/t) but there is a significant increase (191%) in the quantity of carbon generated. This result occurs because changes in the price of carbon precipitate reordering of the contracts from the environmental authority's perspective.

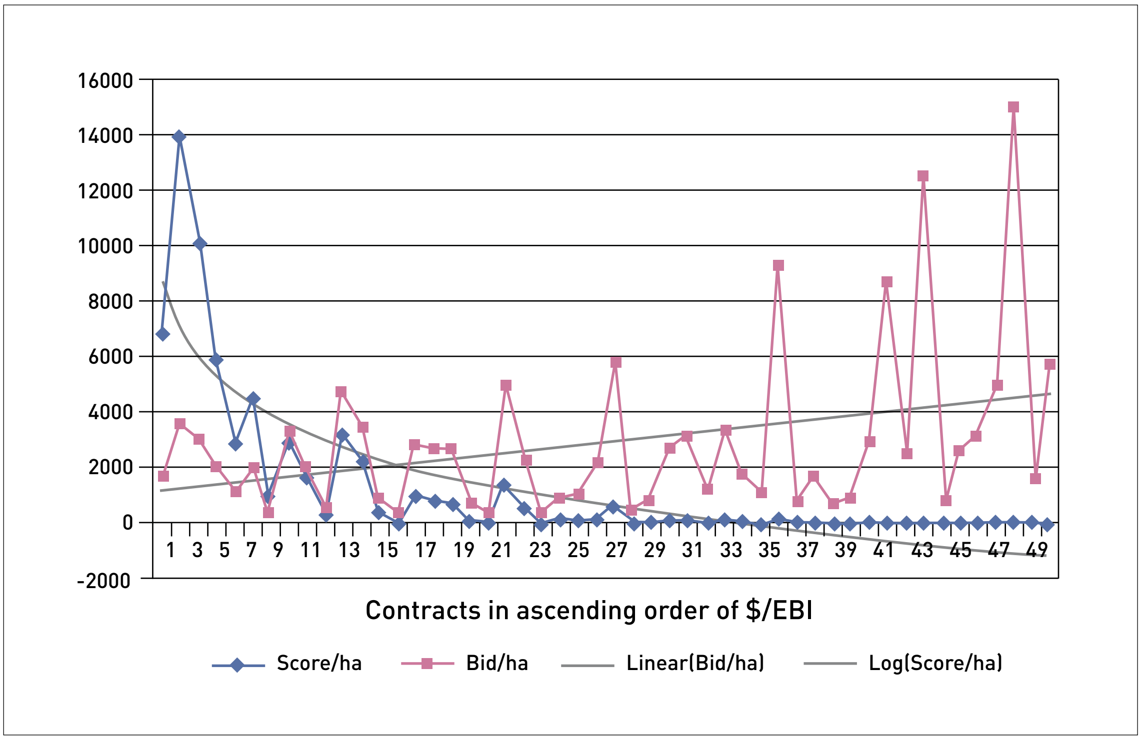
Given the participation constraint, the unit price of public EG&S ($/EBI) will change as the price of carbon changes and according to the mix of public (as measured by the EBI) and private EG&S (carbon) offered by individual bidders.

Table 5.2 indicates that in a quantity-constrained auction, the budget of the environmental agency required to procure public goods will be reduced as the price of carbon rises.

The public funds needed to procure a given quantity of public goods (EBI) have been estimated to fall from A$542,157 (at a price for carbon of $0/t) to $401,077 at $12/t and $302,657 at a carbon price of $20/t. This represents a saving of 26% and 44%, respectively, for the environmental authority.

4 In the Murray Darling Basin of Australia a market for irrigation water already exists.

Figure 5.10: Factors influencing bid price



5.11: Carbon sequestered per unit of public good production

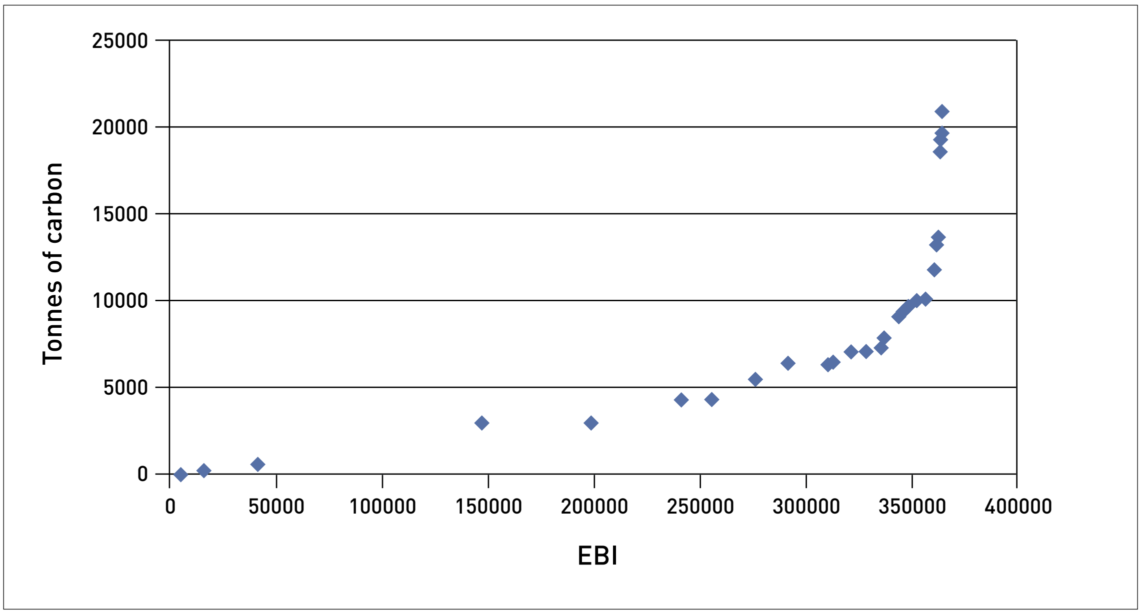


Table 5.1: The impact of changes in the price of carbon: revenue constrained auction

Price of carbon	**$0/t**	**$12/t**	**$20/t**
Total revenue required	$401,000	$401,000	$401,000
Number of contracts	25	34	41
Additional public goods (% increase in EBI units)	353191	360755 (2%)	364272 (3%)
Sequestration of carbon (tonnes of carbon)	10,078	11,768 (117%)	19,317 (191%)

Table 5.2: The impact of changes in the price of carbon: quantity-constrained auction

Price of carbon	**$0/t**	**$12/t**	**$20/t**
Public funds required	$542,157	$401,077	$302,657
Percentage saving	0%	26%	44%
Number of contracts	34	34	34
Public goods procured (EBI units)	360,755	360,755	360,755
Additional sequestration of carbon (% increase in tonnes of carbon)	0	0	0

6. National Accounts

In 1968, the United Nations introduced the System of National Accounts (SNA) as an internationally consistent approach to the measurement of economic activity within an economy. Information collated in national accounts is widely used to inform policy makers and researchers about the performance and characteristics of the economy. Central banks, for example, set monetary policy in the context of headline indicators including growth in gross domestic product (GDP), inflation and labour markets information.

It is widely recognised, however, that existing measures of national economic performance do not project a complete picture of economic or social wellbeing. While income and quality of life are clearly interrelated, it is clear that measures of national and per-capita income and employment statistics do not represent the full measure of human existence.

Robert Kennedy observed that GDP (one of the headline indicators of economic performance) fails to take account of "the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of public officials...It measures everything, in short, except that which makes life worthwhile".

Denison (1972) provides a discussion of the discrepancies between GDP and welfare and more recently Cobb (1995) and Layard (2005), among others, have observed a disconnection between income and happiness once a base level of income has been achieved.

Due to the shortcomings in the use of aggregate income as a measure of wellbeing, economists have attempted to expand the set of indicators employed to measure wellbeing including: inclusive wealth (Arrow 2004 and Pearson 2004); Gross National Happiness; and Headline Indicators (Patterson 2002) (see also Nordhaus 1973).

Similarly, the emerging realisation that human activity is dramatically changing the environment through processes such as global warming and competition between nature and humans for land has prompted interest in information about the status of the environment and the implications for current and future wellbeing.

Information provided in existing systems of national accounts is recognised as being inadequate with respect to the environment because it does not include the 'costs of environmental degradation and natural resource depletion, and non-market amenity values' and therefore could lead to 'misleading information on which to base decision making' (Harris 2002). As noted by Repetto (1988) 'a country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife to extinction, but measured income would rise steadily as these assets disappeared'.

The underlying problem, as Harris notes, is that the information upon which national accounts are constructed is defined by transactions that occur in markets and therefore, the boundaries of national accounts are determined by observed consumption and production activities.

Where markets for goods and services such as the environment are missing or poorly developed, these sectors will not enter national accounts even though they affect output, current and future income and wellbeing. A range of strategies has been proposed to address this problem including Natural Resource Accounting (NRA), 'green' GDP, Genuine Progress Indicators etc. In response to these considerations, the United Nations Statistical Division and the World Bank have coordinated international efforts to explore ways of augmenting the System of National Accounts (SNA) to include information about the environment and natural resources.

The System of Integrated Environmental and Economic Accounts (SEEA) has been developed to improve the way the environment is represented in national accounts and a number of countries have subsequently applied these principles at varying levels of complexity.

There remain many unresolved theoretical and practical issues associated with the measurement and use of indicators of aggregate economic performance. Some problems arise because concepts, such as income, have quite different meanings within accounting, economics and other social sciences. A range of measurement problems arise even within the SNA which are amplified when national accounting principles are expanded to sectors of the economy where markets do not exist.

6.1. The Environment and the System of National Accounts

National accounts provide a systematic, statistical framework for collecting, defining, presenting and comparing the economic activities of different countries in a consistent way.

The Australian System of National Accounts (ASNA) is based closely on the international standard, the *System of National Accounts, 1993* (SNA93). The national accounting framework consists of a set of balanced accounts using the principles of double entry accounting. These accounts are fully integrated in that there is a balance between the value of assets and liabilities at the beginning of an accounting period, the transactions and other economic events that occur during the accounting period, and the closing values of assets and liabilities.

National accounts are constructed by systematically recording information about the value of *stocks* held and the *flow* of goods and services. This involves defining *institution units, production and asset boundaries and accounting rules*. In general terms, stock accounts record the net change in wealth during an accounting period as a result of accumulation, depreciation and revaluation of assets. Information about stocks is derived from the opening and closing balance sheets of firms and organisations. Flow accounts measure transactions in the economy providing information used to derive measures of national income such as GDP.

The SNA measures both stocks (inventories) and flow (income) in monetary terms. For example, GDP measures the value added or income derived from the myriad of transactions that occur in the economy within a specified period of time. Figure 6.1 illustrates key concepts of value relevant to GDP.

Economists define value as the difference between willingness to pay (WTP) and willingness to supply (WTS) shown as the areas A + B. As illustrated in this figure, price distributes value added between consumers (area A) and producers (area B). This is often referred to as economic surplus or welfare.

Within the System of National Accounts, income (GDP) is measured as the area B defined as the market price for the good or service less the relevant costs of producing this good or service (shown as WTS).

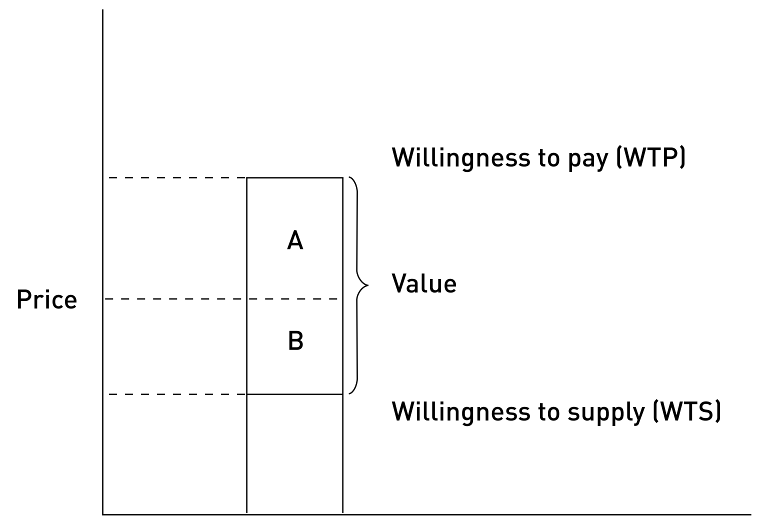
GDP can be measured in three ways: a) by observing consumer expenditure, gross investment and government purchases; b) by observing production in the economy avoiding double counting of intermediate goods; or c) by measuring income earned in production.

See Barro (1993) for a more detailed explanation of these methods of deriving GDP. The important observations about GDP are that value is created through transactions and that markets, the institution employed to facilitate transactions, determine price. In other words, markets provide the information used to construct national accounts. Similarly, measures of stocks or inventories in national accounts are valued at market rates.

During the 1980s, the United Nations Statistical Division (UNSD) and the World Bank coordinated efforts to modify the SNA to take greater account of the environment and natural resources.

In 1993, the System of Integrated Environmental and Economic Accounts (SEEA) was developed and applied in a number of countries. Harris and Fraser (2002) note three broad changes proposed through SEEA: segregating and elaborating all environmental-related flows and stocks within the SNA; expanding asset accounts beyond economic assets to include environmental assets; and detailing impacts on natural assets caused by production and consumption.

Figure 6.1: Value creation



In summary, the SEEA provides a framework in which to collect more information about the state of environmental and natural resource stocks but the missing market problem prevents full integration of the environment into measures of national income/wealth such as GDP. Instead, the SEEA utilises 'satellite' accounts that provide information about the environment and natural resources but are not fully integrated into the SNA. Several versions of the SEEA have been developed incorporating various valuation and measurement techniques needed to deal with the information problems that arise from missing environmental markets.

The most recent version (United Nations 2003) has been developed by The London Group as a detailed, harmonised and standardised approach to best-practice application of natural resource accounting techniques within the SNA framework. Included in the SEEA-2000 is the European System for Economic Information on the Environment (SERIEE) which defines environmental protection and expenditure classifications.

The emerging capabilities to harness competition and create new institutions that foster price discovery and efficiently allocate resources in sectors where markets do not exist, opens up the prospect of facilitating transactions between buyers and sellers of environmental goods and services. Where this is possible, new institutions could provide the information needed to include (or partially include) the environment into the existing System of National Accounts. In effect, the boundary of the market sector of the economy can be expanded to include sectors that have previously been excluded.

6.2 The Contribution of Environmental Activities to GDP

In this section, information generated from the pilot (discussed earlier in this report) is used to estimate the contribution that investment in the production of environmental goods and services (EG&S) makes to GDP.

This is possible because landholders in the pilot made land management decisions within a new set of institutions designed specifically to mimic the way markets discover prices and allocate resources. By employing this information revealed for EG&S, it is possible to construct relevant estimates of the contribution of investments in environmental conservation activities to GDP.

To illustrate this, consider an economy without the institutions needed for environmental management. In this economy, GDP will fall when private firms invest in conservation activities because some of the resources of landholders are diverted from producing commodities to the production of EG&S. For example, suppose a landholder excluded sheep from part of the farm to allow habitat to regenerate and support native flora and fauna.

In this case, GDP would fall because the landholder reduces sheep production and may also incur additional input costs arising from investment in exclusion fences, weed control and other activities needed to increase the production of EG&S. Because the additional EG&S produced are not valued in the current economic system, GDP will fall even though wellbeing may have increased.

Consider now an economy where new institutions such as auctions, tradeable permits and offset markets, have been specifically created to reward low-cost producers of EG&S, as was the case in the pilot reported in earlier sections of this report.

In this institutional setting, a landholder that wins a conservation contract in an auction receives an income stream from the production of EG&S. This contract requires the landholder to deploy some resources (land, labour and capital) that previously were dedicated to commodity production, to the production of EG&S. In this case, GDP will fall because of a reduction in sheep production but there will be an increase in GDP reflecting the value added from production of EG&S. As landholder bids reflect their participation constraint (see Section 3.2.1) the net change in GDP will always be positive. This can be illustrated empirically using data generated from the pilot.

Figure 6.2 reports the bids in the auction from landholders in the pilot (see Figure 5.7). These bids represent the amount that each landholder would need to be paid (in a competitive environment) to produce additional units of EG&S. Willingness to pay in this case is reflected in the budget provided for the pilot (BC) with B being the value of the marginal bid (A$14.81/EBI)[5]. Value added (the contribution to GDP from production of EG&S) according to SNA conventions will then be equal to the area ABD. This area represents the difference between the gross value of environmental production (ABCO, $5.3m in the pilot), less the value of intermediate goods revealed through the costs embodied in the bids (DBCO, $0.358m in the pilot).

The contribution to GDP from investment in environmental production/conservation in the pilot is therefore $4.942m (area ABD). The bid curve in this case is assumed to approximate the supply curve although it is known that bidders will require an information rent to participate in an auction (see Laffont 2002).

The same principles can be applied to estimate GDP when a tradeable emissionss permit or offset market is created. In the case of an offset market, legislation will be required forcing

5 In a price-discriminating auction, depicted in Figure 6.2, this will be the price where the budget constraint (the total funds made available from society for the auction) intersects the bid curve. In a uniform-price auction the marginal price will occur where the auction budget is exhausted when all bidders are paid the same price. Under a given set of assumptions, these two values will equate according to the revenue equivalence theory.

developers who destroy native vegetation to procure an offset. This requirement creates the incentive for buyers and sellers to transact.

In a well-designed offset market, buyers will reveal willingness to pay for offsets, sellers will reveal willingness to supply and processes will be introduced to overcome the various impediments to transactions including scale issues, package problems and matching requirements. A well-designed offset market will efficiently allocate development and offset activities and reveal prices, therefore providing the information needed for national accounts. In Figure 6.3, Q1 represents the cap on exploitation of the environment in an offset market. The price of offsets will form at between B and C depending on the rules of convergence introduced in the offset market.

Where these rules allow sellers to capture the entire economic surplus, price would settle at A and the measure of value added (GDP) can be represented as ABQ10 (gross value) less intermediate goods (costs) DCQ10. GDP is therefore the area ABCD. Where convergence rules divided this surplus, a price between B and C would be revealed and value added could be measured as the surplus below this price.

6.3 Including Environmental Stocks in National Accounts

As noted above, the SNA requires that inventories be included in national accounts at market valuations. Establishing a monetary value for environmental stocks such as flora and fauna, clean air and clean water etc seems problematic.

Figure 6.2 Bid curve and ontribution to GDP from investment in conservation: Avon-Richardson sub-catchment

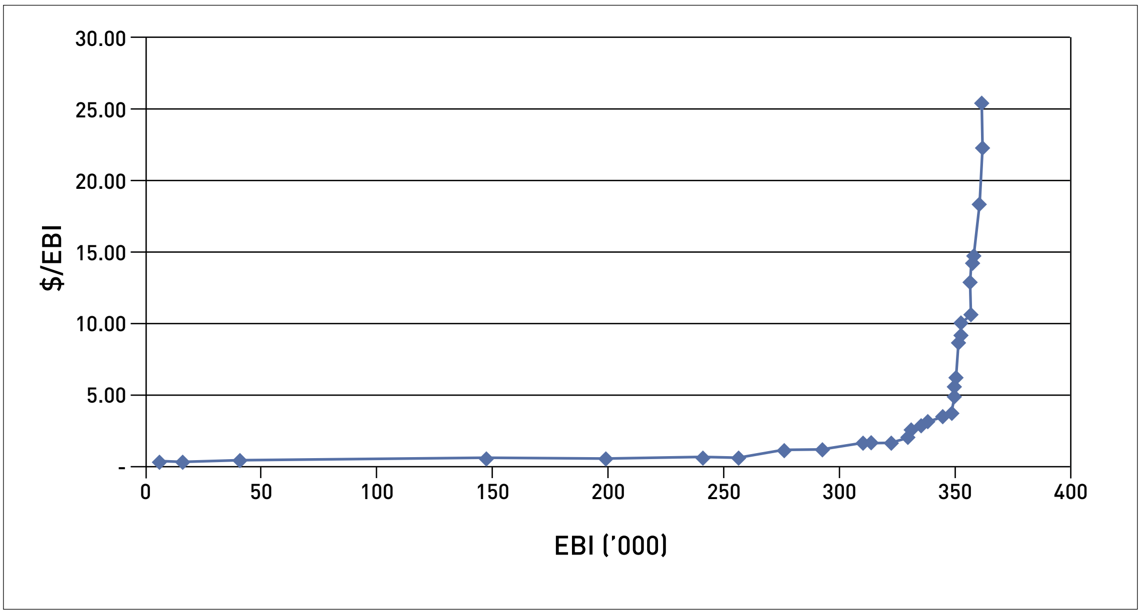
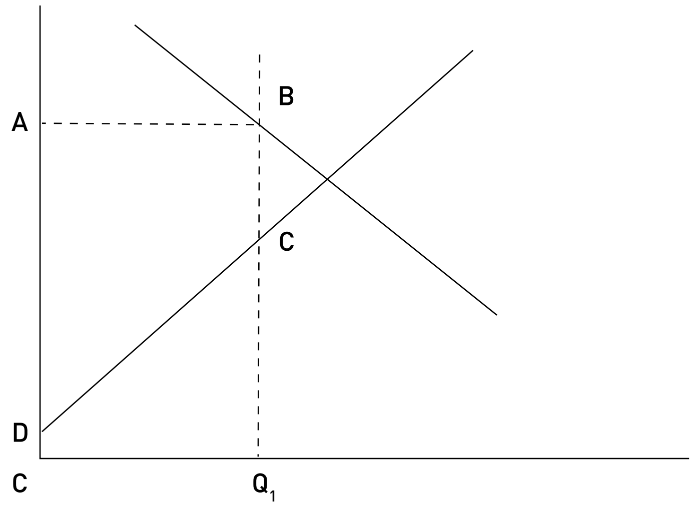


Figure 6.3: The contribution to GDP from investment in emissions control and offsets



These stocks have public good attributes with ill-defined property rights, suggesting that it will be impossible to establish realistic market values for these stocks. It has been possible, however, to greatly improve information about the physical status of these stocks because of the development of biophysical modelling needed to support the new institutions employed in the pilot (see Section 2). It seems appropriate then to construct satellite accounts as detailed in the SEEA to describe the physical status of relevant environmental stocks.

The data presented in Table 2.1 of this report provide information that could be added to a 'land account', 'water account' or 'carbon account' that might be constructed under a set of SEEA satellite accounts. For example, the land account could be augmented with information about the area of native vegetation, the type of vegetation and a measure of the quality of this vegetation measured as habitat hectares.

Table 2.1 indicates that the stock of habitat measured in quality adjusted terms (habitat hectares) has declined to only 4% of the pre-European stock. Similarly, information about the area of land subject to dry-land salinity could be added to the land account. In this case the area of land adversely affected by dry-land salinity has been estimated to have declined by only 0.1% compared with the stock in pre-European times.

The water account and carbon account could also be augmented to include information available about stream flow and water quality as presented in Table 2.1.

Information in these satellite accounts can then be used to depict a more complete picture of environmental stocks, providing improved information about how the production and conservation activities interact and the extent of degradation of important environmental stocks.

Inclusion of environmental production and conservation activities in estimates of GDP and the addition of information about changes in the physical stocks of environmental assets would significantly add to public information about the environment.

7. Summary and Conclusions

The way land is employed and managed has a significant impact on the environment. Based on analysis of one region, it has been shown that landscape change reduces environmental amenity and increases the variability of services provided.

It has been estimated that changes in the landscape over the last 200 years have: significantly increased the volume and variability of stream flow; reduced the quality of water in rivers and stream; increased the area of dry-land salinity marginally; reduced the amount of carbon sequestered in the landscape; and caused a large decrease in the stock of terrestrial habitat.

Analysis using biophysical models suggests that degradation of the environment can be reversed if private landholders invest in land use and management change.

Two observations can be made about the way these investments transform into environmental outcomes. The first is the *heterogeneous* nature of the environment with respect to: land use; type of intervention/action; location of intervention/action; and the timing of outcomes. The second is that environmental outcomes are probabilistic rather than deterministic because of the stochastic influences of weather, pests and other threatening processes.

While private landholders are rewarded for investment in commercial activities, such as commodity production, the economic system lacks incentives to reward investment in the environment. It is widely understood that markets fail because some domains of the environment display public good attributes and society lacks the mechanisms needed to make collective decisions about social preferences for public goods. Even if this information were available, it is now understood that information asymmetry on the supply-side also causes these markets to fail. Information problems are expressed as adverse selection, moral hazard, synergy and non-convexity problems.

If not addressed, these impediments prevent transactions from occurring between landholders able to competitively supply environmental goods and services (EG&S) and firms or organisations willing to pay for EG&S.

The pilot reported in this paper recognised that most investments in land-use change/management generate multiple environmental outcomes. Some of these EG&S (e.g. carbon and irrigation water) are able to be sold to private firms through tradeable emissions markets while others have public good attributes (water quality, habitat and groundwater accession).

Where public goods exist, it is not possible to define property rights or markets that trade these rights. In the pilot, landholders were exposed to an exogenously-determined price of carbon and an environmental agency was allocated a budget to procure EG&S with public good attributes.

In the case of tradeable permits, adverse selection is resolved through the market for permits and by auctioning conservation contracts in the case of EG&S that display public good attributes. Both of these institutions demand information about the quantum and quality of EG&S generated from changes in land use or land management. A substantial investment was needed prior to the pilot to develop biophysical models and biological information systems to meet specific information deficiencies. A single-round, sealed-bid, price-discriminating auction format was employed. Bidders were informed about the quantity of EG&S offered by their investments and their contribution relative to other bidders.

The pilot was designed to expose landholders to a complete set of markets for both commodities (these already exist) and EG&S.

The first observation to be made from the pilot is that transactions to supply EG&S were facilitated by the institutional framework developed. These transactions were made possible by designing and creating new institutions that reveal relevant information and process this information in ways that introduce competition into the environment sector, and by designing incentive-compatible supply contracts. These will be important elements of environmental programs that have an economic efficiency objective. When private landholders are exposed to these new institutions, they are required to make trade-offs between investment in commodity production and investment in supplying different classes of EG&S.

Due to the private and heterogeneous nature of information and incentives not to reveal this information, landholders - not central planning authorities - are best placed to make these trade-offs. It has been estimated from the pilot data (under a fixed outcome objective) that a 30% saving in the procurement budget could be made by auctioning conservation contracts to discover landholder 'type', compared with a mechanism that does not address adverse selection (e.g. a random draw).

This finding has important implications for the policy mechanisms employed in many countries for the purpose of procuring environmental outcomes from private landholders.

Planning and legislative solutions require all landholders, irrespective of whether they are high- or low-cost providers, to undertake investments in conservation.

Excluding problems that require full enrolment, centralised approaches will raise the cost and diminish economic efficiency of environmental programs. For the same reasons, other policy mechanisms such as fixed-price grants and simple incentive schemes will not be efficient, cost-effective or effective. Unless adverse selection is specifically addressed, it is landholders who hold market power in these transactions because they have private information about the cost of land-use change/management. The government environmental authority will come off second-best in this transaction. This outcome is predicted because of the 'market for lemons' problem, and a number of studies confirm that poorly designed environmental programs provide excessive information rents to landholders.

By investing in information systems (biophysical models) and new institutions the purchaser can reduce, but not eliminate, these information rents and so claw back some economic efficiency gains. As noted by Laffont (2002) there is some optimum where the marginal cost of further reducing information rents equates to the marginal efficiency gains.

The adverse selection problem is less important where landholders transact EG&S with private good attributes such as through a tradeable emissions permit scheme. In this institution landholders are price takers and will self-select into supply contracts according to type. Moral hazard is a more important design problem in this case than adverse selection.

Landholders in the auction were provided with full information about their absolute and relative provision of EG&S with public good characteristics. Previous experimental analysis suggests that this strategy would encourage landholders to raise bid prices. Analysis of bid data failed to detect any systematic rent-seeking behaviour by bidders. While this finding is at variance with the experimental results of Cason, Gangadharan *et al* (2003) the difference in behaviour may arise because the pilot involved a one-shot game compared with multiple rounds of the market experienced by bidders in the experimental situation.

The pilot provided some insights into the moral hazard problem relevant to the design of conservation contracts. Although economic theory clearly suggests that incentive-compatible contracts will involve the landholder sharing some of the risk involved in achieving environmental outcomes, this has proven difficult to achieve in practice. Four problems have been identified.

For some EG&S, such as water quality, the observed environmental outcome arises from the combined actions of a team of landholders. Different incentive structures will be needed to deal with the free-rider problem in this situation. A second problem arises because each investment by landholders has been shown to generate multiple outcomes. While a simple solution to this could be to pro-rata incentives according to the ratio of different EG&S generated, it is not clear whether the incentive effects of this approach are efficient. A third problem involves the long time scales (up to 200 years with groundwater systems) between investment and environmental outcome. Over such long time scales, the incentive effects of contracts will be lost. In this event, measures of outputs, such as tree growth, were used as the signal for incentive payments to landholders.

Biophysical modelling can assist in identifying appropriate output signals and the translation between outputs and outcomes. The final problem with contract design arises because in the initial periods of a contract, many landholders do not have technical knowledge about how inputs transform into environmental outcomes. While they are generally efficient at transforming inputs into commodities, they are often unfamiliar with the production of EG&S, at least in the early stages of the contract.

One proposed solution could be to define two stages of the contract, the first where landholders are provided with an incentive structure that rewards learning about environmental production and a second phase that includes incentive-compatible bonuses for outcomes. All of these contract design problems warrant more research.

The pilot also provided some insights into the way markets for different EG&S interact. Holding the participation constraint fixed, it has been shown that varying the price of carbon (an intersecting market because of the joint supply observation) has a significant effect on the allocation of land. The ranking of contracts changes markedly as the price of carbon is altered.

There are two important implications of this finding. The first is that there will be economic efficiency implications where some markets for some EG&S are missing. Environmental programs that do not take all EG&S into account could sponsor changes to the landscape that cause environmental decline. Tree planting schemes could arguably cause streams to dry-up, increasing the pressure on aquatic species and reducing the value of irrigation farmers' property rights for water. Where markets for some domains of the environment do not exist, it would seem appropriate to impose a tax or regulation to prevent unwanted environmental outcomes, but only as a second-best policy solution.

A second implication of the observed interaction between markets for different EG&S is that there are significant cost savings to be made by environmental authorities as a result of the multiple outcomes obtained from land-use change. Sequestering carbon, for example, automatically generates a bundle of EG&S with public good attributes. For a fixed outcome of public EG&S, it has been estimated that a saving of 26% could be expected by the environmental agency if the price of carbon were to rise from $0/t (no market) to $12/t.

Some environmental goods, such as water quantity, tend to be negatively correlated with vegetation-related EG&S. Even though the pilot was conducted in a region that is not a recognised catchment for irrigation water, the implications of incomplete markets for EG&S are clear. Where irrigators hold property rights for water, the interaction between landscape change and water markets will be profound. Current policy settings do not take account of this important problem.

Although the pilot focused on the supply-side, it does provide some information relevant to the demand-side of the market. For the pilot region, for example, it can be shown that at the margin, another dollar allocated to the environmental authority could provide: a) 37 units of habitat or one unit of salinity control; b) 4.5 units of water quality control or one unit of dry-land salinity; or c)

8.7 units of habitat or one unit of water quality improvement.

This information improves the 'information space' in which to improve elicited information about willingness to pay for additional units of the environment. It does not resolve the information and aggregation problems that persist on the demand-side of the market for EG&S.

Finally, the creation of markets for EG&S opens up the prospect of generating environmental accounts using the same principles that are employed to design national accounts. Although the basic structure of these accounts has been developed, a more systematic approach to data management in state environment agencies will be needed to fully populate these accounts.

It has been possible to develop estimates of the stock and flow of environmental goods using visual and modelling techniques. These estimates are informative in themselves, highlighting the severe decline in the stock of certain environmental goods. The stock of habitat, for example, has been estimated to decline to only 4% of pre-European stock while the area of saline land has only marginally increased.

The rewards to completing a set of environmental accounts are substantial. For the first time anywhere in the world, this will provide society with a comprehensive picture of the status of the environment (as it relates to private land); the impact of public funds allocated to the environment; and the price per unit of environmental outcomes. This information will assist policy makers and the public in general to make better choices.

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