

Quantifying Production-Environment Tradeoffs Associated with Grazing Land Management – A Case Example from the Australian Rangelands

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ABSTRACT

Contemporary Australian rangeland management is characterised by concurrent processes of a continuing intensification of land management practices and simplification of landscape ecological processes. This dual characteristic is associated with increasing levels of potential conflict between land management practices that promote improved economic performance of rangeland enterprises at the apparent expense of the ecological health of the landscape; and vice versa. A framework is described for making assessments of production and environmental tradeoffs for a range of rangeland management practices. Examples of the application of the framework are presented for 2 options, tree clearing and riparian fencing, respectively using case studies of a rangeland livestock enterprises located in 2 regions of Queensland.

Key words: Rangelands, economic-environmental tradeoffs, case studies

Introduction

A key, if not defining, feature of contemporary Australian rangeland livestock production is a continuing intensification of management. This is manifest in rangeland grazing enterprises reacting to a long-standing cost-price squeeze by striving to adopt technologies and practices that may raise their productivity through increased returns or reduced costs per animal or unit of land; and a general increase in the scale of operations (MacLeod and McIvor 2003). Examples include increased stocking rates, changes to animal nutrition, and grazing intensity. The economic study of this phenomenon has historically fallen within the domain of conventional production economics approaches to resource valuation and allocation (e.g. Workman 1986). However, this reliance on production economics to inform resource use decisions on rangeland enterprises may no longer be appropriate, given a second feature of contemporary range livestock production that has an ecological core; viz, the rapid simplification of the ecological structure of rangeland landscapes. This simplification particularly involves changes to the structure of the vegetation matrix through the removal or thinning of native tree and shrub layers, and the species composition and diversity of the herbage component (McIntyre and Barrett 1992). The emergent ecological characteristic of rangeland grazing landscapes has led to an increased interest in applying an ecological economics perspective to questions concerning appropriate rangeland resource management (e.g. Perrings and Walker 1997, Jones and Dowling 2005).

This dual character of increasing intensification-simplification of grazing landscapes, while delivering obvious and significant economic benefits to rangeland enterprises, has a prospective ecological downside. While the majority of Australian range landscapes are generally resistant and resilient to natural and management-induced pressures, there are definite ecological limits. For example excessive pressure on landscape resources (e.g. through overgrazing or excessive tree clearing) can lead to severe dysfunction in the way that they hold and utilise scarce resources (McIntyre *et al.* 2002) with adverse consequences for both the resources themselves and the continued ability to use them for economic purposes. These

include the future production of both traditional products (e.g. livestock and produce) and non-traditional products (e.g. biodiversity), which hold significant community values (e.g. Lockwood *et al.* 2000).

The forms of landscape dysfunction are many and varied, and an extensive literature usefully documents the recognised causes and scope (e.g. Harrington *et al.* 1984, Ludwig *et al.* 1997, McIntyre *et al.* 2002). Some landscape health problems that are relevant to rangelands landscapes would include:

- Declining productivity of native and sown pastures
- Reduced drought tolerance of pastures
- Soil structure decline and increased erosion
- Salination of land and water
- Tree decline at landscape scales
- Acidification of soils
- Loss of important plant and animal species; both locally and regionally
- Eutrophication of watercourses and lakes
- Encroachment and/or invasions of native and exotic weeds
- Loss of future land use options (e.g. eco-tourism, timber, bush foods)
- Loss of 'countryside' amenity values.

These problems are both systemic and deeply entrenched in Australian rangelands (NLWRA 2001). The key to achieving ecologically sustainable land management is for managers to stay within the limits required to maintain ecosystem function. However, as the key to maintaining a viable rangeland enterprise also involves the continuing adoption of productivity increasing management options, some balance in meeting these two objectives is required. Moreover, conflict may be inevitable and some hard decisions or tradeoffs will be needed between the production and environmental benefits and costs associated with a given opportunity for further intensification.

In this paper we draw on some insights from an ongoing program of research into sustainable rangeland management to explore both the nature and magnitude of potential tradeoffs between production and landscape resource health. This research initially involved the development of ecological principles and thresholds for landscape management and their prospective application to case studies of rangeland livestock enterprises. A prototype of a decision-making framework has recently been developed to identify potential economic and ecological impacts (positive and adverse) of a given management option and to place them in a transparent and consistent context. The main features of this framework are briefly described and 2 examples are offered of its application to hypothetical rangeland grazing enterprises.

Principles and thresholds for landscape design

In the mid-1990s CSIRO grazing lands research began to place increasing emphasis on identifying sustainable management systems that more fully integrated elements of landscape ecology and conservation biology. A set of landscape management principles was developed that relate to key elements of the landscape; including soils, pastures, trees, watercourses and wildlife habitat and migration corridors (McIntyre *et al.* 2000). These took a fairly wide-ranging view of landscape conservation to include elements of both resource and nature conservation; and include:

Resource conservation:

- maintaining pasture plants to ensure future production

- retaining sufficient trees in the landscape to avoid specific problems (e.g. salinity, insect control)
- protecting soil resources
- protecting the integrity of the rural landscape.

Nature conservation:

- maintaining a wide variety of plants and animals
- keeping landscape ecosystems healthy (including aquatic ecosystems)
- protecting future land use options
- protecting the amenity values of the rural landscape.

Thresholds for some of the ecological indicators were also defined, representing points beyond which significant impairment of ecological processes may occur. The key elements of the principles include:

10. Maintaining or re-establishing riparian buffers (40-100m wide), preferably fenced out and managed for controlled stock access
11. Retaining or re-establishing viable stands of vegetation (5-10ha) on all major land types
12. Managing grazing and fire regimes to retain high levels of ground cover (< 30% bare area), and a strong perennial grass structure (>70% of native pasture area)
13. Retaining minimum levels of tree cover across the landscape (30% woodland structure for grassy woodland)
14. Limiting intensive development activities (e.g. sown pastures, cultivation, fertiliser) to <30% total area, and maintaining vegetation or land use buffers between these intensive uses and areas of higher conservation value
15. Protection of vegetation on potential recharge areas where a salinity hazard exists
16. Linking vegetation patches across the landscape
17. Managing ecologically sensitive areas of the property (~10%) as dedicated conservation areas.

The principles were developed as an integrated set to exploit interrelationships between them. For example, re-vegetation of riparian zones will also increase the overall area of woodland cover on a property, and potentially raise the size of individual patches of vegetation. It may also impact on the area of intensive land use and provide specialised habitat for wildlife. Each of these impacts, in turn, is related to individual principles (i.e. 30% minimum woodland cover, viable patches of 5-10ha retained, 30% intensive development limits, and 10% dedicated wildlife habitat).

Application of the ecological principles

The economic scope for applying the ecological principles was explored through a case study of 4 rangeland grazing enterprises located in the sub-tropical woodlands of south-eastern Queensland (MacLeod and McIvor, in press). These enterprises varied between 950 and 10,500ha carrying 200 to 900 breeding cattle, and their landscapes included a mix of land uses and vegetation classes that ranged from fully sown pastures to limited tree clearing and full retention of the original native components. Detailed assessments were undertaken of the ecological health of the landscapes (incl. tree species density and health, soil type and condition, pasture species and condition, and potential quality of wildlife habitat) under the present management regimes. These were compared with an alternative conservation 'scenario' that was fully consistent with the principles and thresholds (Martin *et al.* 2000).

An assessment, based on a herd economic model, was conducted of both the 'present' and 'scenario' systems to determine the impact on production and profitability of the 4 case properties (MacLeod and McIvor 1998). Because these scenarios largely involved increasing

tree densities (e.g. salinity control, riparian buffers, representative vegetation communities, woodland cover) and restricting grazing access (e.g. timbered patches, riparian areas and dedicated conservation reserves), the main impact was to reduce the number of stock carried and projected turnoff rates.

The economic outcome was fairly adverse from a private landholder's viewpoint. For example, the mean carrying capacity across the 4 properties was reduced by 8-25%, and net profit was reduced by between 30-80% (MacLeod and McIvor, in press). The capital expenditure required to undertake the rehabilitation work (e.g. fencing, artificial waters and tree planting materials) was estimated to be \$65-\$120 per hectare. Not surprisingly, these sorts of projections were not likely to make the adoption of the full set of ecological principles particularly attractive for private individuals (Green and MacLeod 2002).

The projected result of non-economic outcomes is not unique to woodland grazing systems. For example, a similarly unpromising outlook has been predicted for restricting prescribed fire for pasture management to protect wildlife habitat in western New South Wales (MacLeod and Noble 1990), tree planting for salinity control in the cereal belt of Western Australia (Pannell 1999), and retention of native vegetation on crop-livestock farms in northern Victoria and southern New South Wales (Lockwood *et al.* 2000). This does not deny the positive contribution that the native vegetation is making to the profitability of the 4 case enterprises (especially as the main source of forage); or that retaining farm trees can hold potentially large social economic values (Miles *et al.* 1998). Rather, there is an urgent ecological imperative for preventing further losses of the tree and shrub components from the vegetation matrix or restoring them, but private range managers have little economic incentive for doing this.

Exploring production-environmental tradeoffs

In a strict sense the scenario-modelling exercise described before did not explore any trade-off between production and environmental outcomes. The full application of the ecological principles is heavily weighted to meeting a broad range of environmental objectives, regardless of whether they meet private or public interests and which party might stand to gain or lose. Therefore, the outcome as projected could be more accurately framed as a sacrifice of production to conservation outcomes. However, it was also recognised that a partial application of the principles may still be an acceptable option (MacLeod and McIvor, in press). In this case, a trade-off may apply because the extent to which the various elements of the principle set might be employed and the corresponding ecological and economic responses are variable. Moreover, a significant rationale for many of the individual principles and thresholds was centred on ensuring buffering safeguards and adherence to the precautionary principle (Wills 1997). Partial application has no real guarantee of providing this degree of sufficiency and it becomes more challenging to determine which elements of landscape health may be impacted by a particular management strategy and the magnitude of these impacts. A prototype assessment framework has been developed for this purpose (McIvor and MacLeod 2004); and the main structure is shown schematically in Figure 1.

The existing management of the property is initially defined, and then assessed in both financial and ecological terms. The economic assessment utilises a property scale economic model that can examine 11 management options; including pasture development and management, grazing management (including intensive grazing systems), production feeding, weed control, infrastructure development and tree replacement. The likely impacts of each activity on carrying capacity and animal performance are presented for the different land types on a property. These impacts are combined with the costs of the activities to assess changes to the financial performance of the property (i.e. gross margin, net profit, return to capital and capital value).

The ecological assessment is based on 8 attributes of ecological health in the landscape; 6 of which (soils and hydrology, pastures, weeds, feral animals, riparian areas and atmosphere) describe the maintenance of ecosystem function and stability, and the remaining 2 (native vegetation and habitat, and native animal populations) describe conservation of biodiversity. The specific components, attributes and indicators are listed in Table 1. The projected impacts of the 11 management activities on each of these 8 attributes are described on a scale from –3 (large negative impact) to +3 (large positive impact). The individual attribute scores can be aggregated into a general score, compared and an assessment then made of the nature and magnitude of any trade-offs involved.

If the trade-off at the end of the first round of the assessment process is not acceptable to the range manager, then a review is made of the possible management options to determine what is technically possible and what fits with property management. These can then be incorporated into a new management scenario, and the assessment of the ecological and financial impacts and tradeoffs is then repeated. This process would continue until either a compromise has been reached that is acceptable, or no feasible improvements can be made.

Applying the framework – case study examples of 2 options

The foregoing description of the assessment framework is necessarily abstract, and its component sub-modules are reasonably complex. This material is described and supported in considerably more detail elsewhere (McIvor and MacLeod 2004), and some feel for its practical application is now offered though 2 simple examples.

The application of the framework is illustrated with examples of 2 rangeland enterprises located, respectively, in the subtropical woodlands of south-eastern Queensland and the monsoonal grasslands on the Northern Territory. The first example involves an option to manipulate tree and shrub densities on the property by clearing trees to promote pasture growth. The second example covers an option to fence out and restrict grazing access to the riparian areas to prevent severe damage to the vegetation, soils and watercourses.

Description of the case study properties

Case 1. Subtropical woodlands - The majority of enterprises in the woodlands region are based on beef cattle grazing native or semi-improved pastures. Vegetation is dominated by eucalypt and acacia woodlands. The case study enterprise spans 7000ha comprised of 3 land types; including silver-leaved ironbark on granite (70% of area); narrow-leaved ironbark on clay (20%), and blue gum on alluvial cracking clay (10%). Approximately 50% of the blue gum area is riparian land. Tree clearing has previously been undertaken on 3900ha; of which 800ha is sown pasture. The property is a breeding, growing and fattening operation with a cattle herd of 1,530 adult equivalents (1 AE = 455 kg non-lactating cow), including 600 breeding cows. The main target for finished stock is north Asian markets, and the estimated capital value of this property is \$1.3 million.

Case 2. Monsoonal grasslands - The majority of enterprises in the grasslands region are also based on beef cattle grazing, but the pasture base is essentially native grasses with relatively few trees and shrubs in the vegetation matrix. There is little tree clearing or sown pasture development in the grasslands and none has been included in the hypothetical property. The average size of properties is also much larger, and the case study enterprise is 300,000ha and is also comprised of 3 land types; including Mitchell grass on cracking clay plains (30%), arid short grass on stony soils in hills (40%), and Spinifex on red soil plains (30%). The Mitchell grass land type includes a riparian area (5% of total) with a different mix of soil types and vegetation. The property is a breeding operation with a herd of 14,000 AE, including 6,500 breeders. The main target is for live animal exports to near Asian markets, and the estimated capital value is \$13.5 million.

The impacts of the 2 management options on production are described in terms of positive or negative effects on a number of animal production parameters – carrying capacity, liveweight gain, branding percentage and mortality rates. Baseline values for these parameters that are used in the model are presented in Table 2. These are translated into financial impacts through their effect on gross margins and profit; and the cost impacts incorporate both annual operating costs (including treatment reinforcement costs) and initial capital costs of implementing the options (Table 3).

The impact of the 2 management options on each of the environmental health attributes is based on an assessment of whether the impact is likely to be negative, nil or positive; and also if it is likely to be small, medium or large. In the absence of an adequate body of empirical information available to confidently model environmental impacts (i.e. similar to that used for determining financial impacts), “best bet” predictions are used to provide qualitative estimates following the general method of Barlow *et al.* (2003).

Example 1 – Tree clearing

Reducing plant competition for water and nutrients by clearing or thinning trees is one of most widely used management intensification practices in the sub-tropical grazing lands. The practice has also been identified as representing a major threat to biodiversity (McIntyre 2002). For the present example, it is assumed that 1,000ha of the silver-leaved ironbark land class will be cleared mechanically, pushed into fire rows and burned. After the tree clearing, the stocking rate on the cleared land increases from 8ha/AE to 4ha/AE, and total carrying capacity increases from the present 1,530 adult equivalents to 1,656 adult equivalents; but there is no assumed change to liveweight gain.

The projected economic and ecological outcomes for the tree clearing option are presented respectively in Tables 4 and 5. Tree clearing has a positive effect on all of the summary measures of economic performance (Table 4) with the investment of \$100,000 increasing turnover by 40 head and net profit by \$15,000 per year, a return of 15% on the additional capital outlay. Under the existing property management, the overall health rating is a small negative score (Table 5), due mainly to widespread clearing of the native vegetation and a decline in condition of riparian areas; although the soils and pastures are in generally good condition. The additional clearing further reduces the attributes for conservation of biodiversity. Some attributes of ecosystem function and stability also decline and the positive effects on pastures are insufficient to counteract these and the overall score for ecosystem function and stability decreases.

Therefore, a trade-off has been identified for this option between production and environmental health. The positive economic results (an additional net profit of \$15,000) demonstrate why tree clearing has been such a popular development option in the past. However the large negative environmental impacts (-10) are also indicative of the reason that major concerns have increasingly been expressed about the practice (McIntyre 2002).

Example 2 - Riparian fencing

Riparian areas and watercourses are often regarded as ‘keystone’ ecosystems holding some of the highest ecological values of the landscape (MacLeod 2002b). They are also commonly degraded by livestock and there has been a growing call to restrict grazing in these areas by fencing them out. For the second example, it is assumed that the riparian zone on the Mitchell grass land type will be fenced separately and grazing in this area reduced to 20% of the previous level. Assuming the riparian zone is 1 km wide (500 m on either side of the stream), then the 4,500 ha zone will be 45 km long requiring 90 km of fencing with gates at approximately 10 km intervals. With the reduction in grazing in the riparian zone, cattle numbers decrease by 300 to 13,700AE; but there are no changes to the cattle weight gains.

The projected economic and ecological outcomes for the fencing option are presented respectively in Tables 6 and 7. All of the economic financial impacts of fencing the riparian zone were negative (Table 6) due to the reduction in grazing without any compensating production responses. An additional expenditure of \$172,000 leads to a reduction in net profit of \$35,000. Overall, the property under existing management is assumed to have a small negative score (Table 7), due mainly to small deleterious effects of European land use on a number of attributes that are partially offset by the good condition of the soils and pastures. Although fencing *per se* has no environmental impacts, the reduction of grazing pressure in the riparian zone is predicted to improve most attributes and leads to a large improvement in overall ecological health.

For this example, a trade-off has also been projected between production and environmental health. In this case, pursuit of the management option favours environmental outcomes at the expense of economic returns. Although the fencing and reduced grazing pressure in the riparian zone is predicted to give large (+9) improvements in ecological health, it also reduces property net profit by \$35,000.

Some issues

The framework and its component economic and ecological sub-modules remain subject to further testing, development and refinement. Some issues that need to be considered as part of this evolution process are briefly canvassed in the following subsections.

Scale issues

Appropriate ‘scale’ is an important consideration for assessing tradeoffs between economic interests of rangeland enterprises and ecological consequences of intensification in production management. Many investment decisions that lead to intensified use of rangeland resources are made at the scale of individual managers exploring options for a component part of their holdings, and the ecological consequences might be manifest at that same scale or at higher levels of scale. For example, rangeland grazing enterprises are characteristically large scale (e.g. thousand of hectares) and many practices will have highly localised ecological impacts – such as establishment of water points leading to high concentrations of stock and consequent scalding, bogging or erosion around these points. These might be accompanied by an increased and localised incidence of predation and weed infestation resulting from the changed moisture availability and disturbance. However, in many cases, localised actions may also have impacts of a regional nature – such as impacts of local burning and clearing on the viability of regional wildlife populations; pollutant accession to watercourses impacting on downstream users; or pastoral activities reducing or eliminating the scope for multiple uses such as tourism, indigenous use etc. These wider scale impacts are not readily treated in the present framework – although the general logic of the trade-off assessment process would still apply.

Another consideration for scale that is important for assessing trade-offs, even at a highly localised scale of paddocks, is context and the site-specific nature of many landscape functional processes. For example, salinity outbreaks on toe slopes are typically hydrologically linked to the removal of critical numbers of trees in specific recharge zones (McIvor 2002). Tree removal *per se* in the immediate area will not necessarily lead to the problem, nor will replacement of an equal number of trees if the specific removal or augmentation sites are not spatially linked to the outbreak site. Sound decision making in these circumstances requires access to higher levels of technical detail than is incorporated within in the present framework.

The temporal imbalance between many economic responses and the manifestation of ecological consequences is also important. For example, the ‘here and now’ nature of the

chronically adverse terms of trade for rangeland livestock production will tend to make interventions that offer immediate production and profit gains more attractive than more conservative management options which might avoid an uncertain and prospectively adverse environmental outcome. The examples of tree clearing and riparian fencing illustrate this point well. The time taken for the real nature of the trade-off to be identified is prospectively medium or long term (habitat loss leading to diminished fauna populations, tree clearing and global climatic change) or uncertain (whether conservative management of riparian vegetation can actually restore damaged aquatic ecosystems). The present ecological assessment ratings would require modification to handle uncertain and time-bound outcomes for the major health indicators. Ignoring this may lead to some important aspects of the choice set being overlooked, leading to inaccurate assessments.

Multiple uses

The potential scope for conflicts between different prospective uses for rangeland resources is increasingly recognised; frequently involving different stakeholders with quite different values for various economic and ecological outcomes of range resource management. A critical issue for the present framework would be to institute an appropriate process for negotiating the nature of the tradeoffs and voting on prospective choices from the multiple perspectives. Some new innovations in the public choice domain, such as multi-criteria analysis and citizen's juries, might offer some scope for addressing this issue (e.g. Beinart and Nijkamp 1998, Smith and Wales 2000). The present framework remains targeted at single decision makers confronted by the various intensification options.

The present economic model would need to be modified and expanded to accommodate the multiple values and impacts of the choices that were being tested at these wider scales. Similarly, the impact ratings used to consider the ecological consequences of a particular land use decision may need to have different ratings and weightings depending on the diversity of stakeholders who might wish to participate in the choice process. Moreover, the priorities amongst different objectives will be influenced by the particular setting – choice decisions affecting land close to urban centres or iconic landmarks (e.g. Uluru) with very high biodiversity values and access opportunities might draw more interest and potential conflict than the same category of choice affecting a more remote area of lesser recognised value.

Starting position and differential outcomes

A key issue in this context is the fact that the nature and scope of the outcomes of a particular management choice are likely to be significantly influenced by the state of the resource at the time that the choice is being made. This might be illustrated using the case of a decision to increase stocking rates subsequent to an action to thin timber stands in a native grass dominated paddock that is comprised of two soil types of inherently different fertility. The final impact of this choice will be influenced by (i) the original stocking rate – high or conservative, (ii) the subsequent stocking rate – also high or conservative, (iii) the timber density before thinning commenced, (iv) the timber density after the event, (iv) the condition of the pasture before thinning – poor or good, and (v) which of the two soil types underlies the area being treated.

A worst case scenario of poor condition land of low inherent productivity being subject to extremely severe intensification will typically lead to limited economic gains and very severe ecological outcomes – for the opposite scenario, the tradeoffs might be less difficult to accommodate. To make an informed choice it would be important to have a realistic understanding of both the initial state and the potential transformation path that leads to the final modified state.

Thresholds and bottom lines

The notion of assessing 'trade-offs' can carry the sense of a continuous ability to substitute between economic and ecological outcomes associated with a given intensification choice. However, there is increasing recognition that the choice sets may be truncated by the presence of thresholds (discussed earlier) beyond which various dimensions of landscape function might become rapidly dysfunctional. For example, dieback may accelerate in some woodland communities once average tree densities fall below approximately one third of the undisturbed climax densities; and populations of some woodland bird species might also begin to disappear from local landscapes below a similar threshold (McIntyre 2002). These beyond-threshold shifts might be irreversible in either an economic or realistic temporal sense. There is also the possible existence of economic thresholds or bottom lines, such as minimum acceptable income or a necessary cash flow limit to service debt obligations.

The presence of both ecological and economic thresholds suggests that the choice set may be limited to an all or nothing option – perhaps warranting close adherence to the precautionary principle of deferred action pending better identification of the real choice sets and their outcomes that are actually confronting rangeland managers (MacLeod 2002a). While the present framework remains useful for assessing many typical intensification options, the presence of thresholds and irreversible consequences will still need to be recognised.

Different value metrics

Assessing trade-offs is necessarily about making choices, and this is made considerably easier when the outcomes can be ranked in terms of a common metric; and the choices involve close substitutes. Choices involving different metrics and less substitutability are typically more difficult. The economic implications of intensification choices are made easier by the common metrics of profit available to screen the various choice outcomes (such as for the 2 examples) and the wider experience with prospective outcomes allowing more confidence in their prediction. Ecological outcomes are inherently more difficult to predict with much precision, as most are complex and many remain non-fully expressed (e.g. salinity outbreaks post-tree removal) or are emergent properties of combined threatening processes (e.g. grazing x fire x tree removal). The use of rating scales in the present framework to assess the direction and magnitude of the ecological impacts from the various intensification options considered under the case studies is an attempt to provide some consistency. The combined choice between the projected economic and ecological outcomes becomes more difficult once the different metrics of profit and score ratings are mixed together. However, individuals do make such choices many times per day, often with little conscious thought using various implicit and explicit weightings and rules of thumb to explore and rank the choice options. Formal algorithms and procedures involving multiple criteria are available and are to be investigated, along with formal testing with range managers.

Response and choice

The management choice sets that can be presently handled within the assessment framework are quite wide-ranging. For example, beyond the 2 applications described before, it has been applied to 11 management options across 5 major rangeland regions (McIvor and MacLeod 2004). In all cases, both the economic and ecological responses are essentially determined by biophysical properties of the grazing enterprise and the environment in which its activities are conducted. In that sense, the models and framework in which they are incorporated present rangeland decision-makers with information that is largely value-neutral – although their response to this information is unlikely to be so.

What are acceptable or responsible trade-offs (choices) remains a personal judgement. The framework should be useful to assist rangeland managers to screen various options in a

consistent manner and to clarify the nature and scope of trade-offs between economic advantages and ecological consequences. There remains a critical role for communication of social values on various outcomes of contemporary management to minimise the scope of individuals accepting tradeoffs that may not be supported by the broader community interest.

Concluding remarks

The framework and the research process that has given rise to it are still in the initial stages of development and execution. Both the framework and its constituent models have been developed as a “proof of concept” tool. These will continue to undergo refinement as the CSIRO research program matures and additional empirical support is obtained for the linkages between management intensification activities and responses for the various ecological health attributes and indicators.

The management choice sets that can be presently handled within the assessment framework are quite wide-ranging (2 of which are presented here), and the economic and ecological responses are essentially determined by biophysical properties of the grazing enterprise and the market conditions. We hope that the framework will be useful for assisting private land managers to screen various options in a consistent manner and to clarify the nature and scope of trade-offs between economic advantages and ecological consequences.

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References

- Barlow, R., Ellis, N.J.S. and Mason, W.K. (2003) A practical framework to evaluate and report combined natural resource and production outcomes of agricultural research to livestock producers. *Australian Journal of Experimental Agriculture* 43, 745-754
- Beinat, E. and Nijkamp, P. (1998). *Multicriteria Evaluation in Land Use Management*. Kluwer Academic, Dordrecht.
- Green, J.L. and MacLeod, N.D. (2002). Barriers and opportunities for adoption. In: S. McIntyre, J.G. McIvor and K.M. Heard (Eds.) *Managing & Conserving Grassy Woodlands*. CSIRO Publishing, Melbourne. pp. 177-200.
- Harrington, G.N., Wilson, A.D., and Young, M.D. (1984). *Management of Australia's Rangelands*. CSIRO, Melbourne.
- Jones, R. and Dowling, P., 2005. Sustainability and economics of temperate perennial Australian grazing systems. *Agriculture, Ecosystems and Environment*, 106(4):313–416.
- Lockwood, M., Walpole, S. and Miles, C. (2000). *Economics of Remnant Native Vegetation Conservation On Private Property. Research Report 2/00, Johnstone Centre, Charles Sturt University, Albury.*
- Ludwig, J.A., Tongway, D.J., Freudenberg, D., Noble, J.C. and Hodgkinson, K.C. (1997). *Landscape Ecology: Function and Management*. CSIRO Publishing, Melbourne.
- MacLeod, N.D. (2002a). Principles for property planning. In: S. McIntyre, J.G. McIvor and K.M. Heard (Eds.) *Managing & Conserving Grassy Woodlands*. CSIRO Publishing, Melbourne. pp. 25-40.
- MacLeod, N.D. (2002b). Watercourse and riparian areas. In: (S. McIntyre, J.G. McIvor and K.M. Heard Eds.) *Managing & Conserving Grassy Woodlands*. CSIRO Publishing, Melbourne. pp. 143-76.
- MacLeod, N.D. and McIvor, J.G. (2005). Reconciling economic and ecological conflicts in the use of grazing lands. *Ecological Economics*. In press.
- MacLeod, N.D. and McIvor J.G. (1998) Managing grazed landscapes: Production and conservation tradeoffs in subtropical woodlands. In: J. Gooday (Ed.) *Proceedings of Bio-Economics Workshop, 22 January, Armidale, NSW, ABARE, Canberra*. pp. 51-63.
- MacLeod, N.D. and Noble, J.C. (1990). An economic evaluation of the impact of prescribed fire on pastoral leases in the eucalypt shrublands of southwestern New South Wales. *Environment International*. 17:151-62.

- McIntyre, S. (2002). Trees. In. S. McIntyre, J.G. McIvor and K.M. Heard (Eds.) *Managing & Conserving Grassy Woodlands*. CSIRO Publishing, Melbourne. pp. 79-110.
- McIntyre, S., and Barrett, G.W. (1992). Habitat variegation: An alternative to fragmentation. *Conservation Biology* 6(1):146-7.
- McIntyre, S, McIvor, J. G., and MacLeod, N. D. (2000). Principles for sustainable grazing in eucalypt woodlands: landscape-scale indicators and the search for thresholds. In. P.Hale, D. Moloney and P.Sattler (Eds.) *Management for Sustainable Ecosystems*, Centre Conservation Biology, University of Queensland, St. Lucia. pp. 92-100.
- McIvor, J.G. (2002). Soils. In. S. McIntyre, J.G. McIvor and K.M. Heard (Eds.) *Managing & Conserving Grassy Woodlands*. CSIRO Publishing, Melbourne. pp. 41-59.
- McIvor, J.G. and MacLeod, N.D. (2004). *Environmental and financial implications of changing land management in Australian rangelands. A report of a consultancy to the Department of Environment and Heritage, August 2004*. CSIRO Sustainable Ecosystems, Brisbane.
- Martin, T.G., Best, K.M., McIntyre, S., McIvor, J.G., and MacLeod, N.D. (2000). *Four grazing properties in S.E. Qld: Patterns of land use and ecological status*. CSIRO Tropical Agriculture Technical Memorandum No.5., Brisbane.
- Miles, C.A., Lockwood, M. and Walpole, S. (1998). Incentive Policies for Remnant Native Vegetation Conservation. *Johnstone Centre Research Report 108.*, Charles Sturt University, Albury.
- NLWRA 2001. *Australian Dryland Salinity Assessment 2000*, Environment Australia, Canberra.
- Pannell, D.J. (1999). Explaining Non-Adoption of Practices to Prevent Salinity in Western Australia: Implications for Policy. *SEA Working Paper 99/08*, Agricultural and Resource Economics, University of Western Australia, Nedlands.
- Perrings, C.A. and Walker, B.H., 1997. Biodiversity, resilience and the control of ecological-economic systems: The case of fire driven rangelands. *Ecological Economics*, 22(1):73–83.
- Smith, G. and Wales, C. 2000 Citizen Juries and Deliberative Democracy. *Political Studies* 48:51-65.
- Wills, I.R. (1997). *Economics and the Environment*. Allen & Unwin, Sydney.
- Workman, J.P. (1986). *Range Economics*. MacMillan, New York.

Table 1 Components, attributes and indicators of ecological health

Component A. Maintenance of ecosystem function and stability

Attribute 1. Soils and hydrology

- (a) Soil water supply (infiltration/runoff, leaching, rooting depth)
- (b) Physical properties (structure, surface crusting/sealing, bulk density)
- (c) Chemical properties (pH, organic matter, nutrient levels)
- (d) Biological activity (fauna, earthworms, microbial activity, litter)
- (e) Erosion (ground cover, soil movement/loss/accumulation, topsoil depth)
- (f) Dryland salinity (area, watertable depth, salt levels in soils and streams)

Attribute 2. Pastures (cover and composition, perennial grasses)

Attribute 3. Weeds (species, density/cover)

Attribute 4. Feral animals (species, density)

Attribute 5. Riparian areas

- (a) Water quality (physical, chemical, biological)
- (b) Stream health (vegetation, bank and bed stability, fish population)

Attribute 6. Atmosphere (greenhouse gas emissions)

Component B. Conservation of biodiversity

Attribute 7. Native vegetation and habitat

- (a) Area and proportion of original vegetation and habitat
- (b) Regional ecosystems (proportion, threatened)
- (c) Condition
- (d) Configuration
- (e) Structure/balance

Attribute 8. Native animal populations (size and viability)

Table 2 – Baseline animal production values for 2 case study properties.

<i>Case study 1. Sub-tropical woodlands</i>			
	Land type		
	Silver-leaved ironbark	Narrow-leaved ironbark	Blue gum
Carrying capacity (ha/AE)	8	10	5
Annual liveweight gain (kg)	140	100	150
Branding percentage (%)	80	same	same
Breeder mortality (%)	2	same	same
Steer mortality (%)	0.5	same	same

<i>Case study 2. Monsoonal grasslands</i>			
	Land type		
	Mitchell grass plains	Shortgrass hills	Spinifex plains
Carrying capacity (ha/AE)	12	20	200
Annual liveweight gain (kg)	140	130	100
Branding percentage (%)	65	same	same
Breeder mortality (%)	7	same	same
Steer mortality (%)	2	same	same

Table 3 – Capital and operating costs of tree management options.

	Tree clearing	Tree planting	Riparian fencing
	(\$/ha)	(\$/ha)	(\$/km)
Capital costs	100	1,000	2,600
Operating costs	5	10	130

Table 4 Economic assessment of tree clearing option

	Existing	Revised	Change
Total number of stock carried (AE)	1,531	1,658	+127
Total number of stock sold (Head)	492	532	+40
Property gross margin (\$'000)	254	274	+20
Property net profit (\$'000)	124	139	+15
Property return to capital (%)	4.7	5.0	+0.3
Property capital value (\$'000)	1,595	1,807	+212
Capital cost of management change (\$'000)	N/A	150	

Table 5 Ecological health assessment of tree clearing option

Attribute	Existing	Revised	Change
1. Soils and hydrology	+2	+3	+1
2. Pastures	+1	+3	+2
3. Weeds	-1	-2	-1
4. Feral animals	0	0	0
5. Riparian areas	-2	-3	-1
6. Atmosphere	-1	-4	-3
7. Native vegetation and habitat	-2	-4	-2
8. Native animal populations	-1	-2	-1
A. Ecosystem function and stability	-1	-3	-2
B. Conservation of biodiversity	-3	-6	-3
Total score	-4	-9	-5

Table 6 Economic assessment of riparian fencing option

Attribute	Existing	Revised	Change
Total number of stock carried (AE)	14,000	13,700	-300
Total number of stock sold (Head)	3,452	3,377	-75
Property gross margin (\$'000)	1,431	1,396	-35
Property net profit (\$'000)	805	770	-35
Property return to capital (%)	5.6	5.3	-0.3
Property capital value (\$'000)	13,545	13,569	+24
Capital cost of management change (\$'000)	N/A	172	

Table 7 Ecological health assessment of riparian fencing option

Attribute	Existing	Revised	Change
1. Soils and hydrology	+2	+3	+1
2. Pastures	+1	+2	+1
3. Weeds	-1	0	+1
4. Feral animals	0	0	0
5. Riparian areas	-1	+1	+2
6. Atmosphere	-1	0	+1
7. Native vegetation and habitat	-1	+1	+2
8. Native animal populations	-1	0	+1
A. Ecosystem function and stability	0	+6	+6
B. Conservation of biodiversity	-2	+1	+3
Total score	-2	+7	+9