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Economics of deep-rooted perennials in western Australia

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Abstract

Much of the hoped-for success of deep-rooted perennials in reducing the eventual extent of dryland salinity in Australia will depend on the farm-level economic performance of the available perennial-based farming systems. A diverse range of factors contributes to this economic performance, including short-term production-related issues, dynamic factors, sustainability factors, risk factors and whole-farm factors. Although some examples of profitable perennial-based farming systems can be identified, they are limited to particular niches in particular regions, which tend to be higher rainfall regions. For the great majority of land that is at risk of salinisation, no profitable perennial plant options are currently available. The benefits of perennials for on-farm salinity prevention are likely to be of secondary importance in determining their economic attractiveness to farmers. A case study is presented for lucerne (*Medicago sativa* L.) in the southern region of Western Australia. Lucerne appears likely to be profitable in suitable environments, even without considering salinity-related benefits. However, further improvements to its economic performance are needed if it is to be adopted voluntarily on a scale that would address the bigger, catchment-level problems such as river salinity and flooding risk. Policy implications of these findings are discussed.

Keywords: Salinity; Economics; Woody perennials; Lucerne (*Medicago sativa*); Western Australia

1. Introduction

Recognition of the growing problem of dryland salinity in Australia (Ghassemi et al., 1995; Ferdowsian et al., 1996) has resulted in increased interest in the use of deep-rooted perennials as the primary means of reducing salinisation of farm land (e.g. Anon., 1996).

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Notwithstanding the breadth of scale of salinity impacts in some situations, the economic performance of these perennials at the individual farm level is very important because it is a prime driver of farmer decisions regarding adoption (Cary and Wilkinson, 1997; Lindner, 1987; Pannell, 1999; Sinden and King, 1990). The less profitable are the perennials, the more their adoption is inhibited by other complexities and difficulties (Pannell, 2001). In relation to farmer adoption of perennials, Pannell (2001) stated the following.

> Lack of awareness of salinity is probably not a major factor explaining slow and low adoption of the recommended practices. Rather, the major factors relate to the economic costs and benefits of current treatment options, the difficulties of trialling the options, long time scales, externalities, and social issues. This combination of factors means that the problem in many regions is extremely adverse to rapid adoption, probably more so than for any other agricultural issue in Australia. In other words, farmer reluctance to adopt the radical changes being recommended is completely understandable and, indeed, reasonable from the farmers' perspectives.

Undertaking high quality economic analyses of perennial plant-based enterprises is not straightforward. Complexities that may need to be considered include: interactions between perennials and traditional crops and pastures, benefits from prevention of land degradation, and the methods used to integrate the perennials into the farm system.

Our aims in this paper are (1) to review the issues involved in conducting economic analyses of deep-rooted perennials in crop–livestock-based farming systems of southern Australia and (2) to present results from a case study of lucerne in south-west Western Australia. We will first consider the different levels of economic analysis that are possible, and highlight the importance of conducting economic analyses at the farm level. Requirements of such farm-level analyses will be considered before presentation of results from a case study. Finally, implications of the paper for salinity policy will be outlined.

2. The need for a farm-level focus

Economic analyses of perennial plant enterprises may be conducted at different levels, with potentially different results.

- Field
- Whole farm
- Catchment
- Region

Catchment level and regional economic analyses are clearly much more difficult, and have been very rare (Van Bueren and Pannell, 1999). Most economic studies at these levels have focused on 'the cost of salinity' which is a concept of almost no practical value (Van Bueren and Pannell, 1999). One of the few examples of economic analyses of treatments at the catchment scale is the work of Greiner (1997).

In this paper, we focus on farm-level analyses. Pannell (1998) has argued that although catchment-level analyses are clearly desirable, analyses at the farm level can also make important contributions, even for dryland salinity. Reasons include the following.

1. Notwithstanding the reality of catchment processes (especially water-related) beyond farm boundaries, and the undoubted value of group-based extension, final decision making still rests with individual farmers. For resource conservation practices, as for others, private financial considerations are key drivers of management decisions. Individual farm models provide useful information about economic incentives facing farmers.
2. Even where the model is used to provide direct support to policy makers who are concerned with aggregate rather than individual effects, individual farm models can contribute in a number of ways. These include providing information about the costs of reducing land degradation, and the likely responses of farmers to potential policies.
3. In some situations, the central concerns are not with spillover effects, but with poor decision making due to poor information. In these cases, individual farm models are appropriate.
4. Even where spill-over effects exist, they may not be substantial enough to make a difference if they were factored into farmer decision making.

Pannell et al. (2001) outline six reasons why spill-over effects from dryland salinity are less important in Australia than commonly perceived.

1. For a proportion of the landscape, little groundwater moves across farm boundaries. Hydrological flow systems are localised in many situations.
2. Even in regional flow systems, it can be possible for treatments to be effective locally, at least temporarily. This is relevant to landscapes with low slopes and low transmissivity of soils, such as the wheatbelt of Western Australia.
3. In key Australian landscapes, damage to key rivers, will continue for many years (centuries in some cases) even if large-scale revegetation programs are implemented (Hatton and Salama, 1999). Therefore, spillover costs will be high irrespective of localised decisions.
4. As the process of farm consolidation and enlargement continues, it is increasingly likely that discharge and recharge sites occur within the same farm. In other words, fewer farmers are suffering from saline discharge that originated outside their own farm.
5. Discounting of future benefits and costs is necessary to allow valid comparison of economic impacts occurring at different times. Given the slowness of some key off-site benefits from perennial plants, discounting causes the significance of these benefits in present day terms to be small.
6. Given the adverse economics of currently-available perennial plant systems (particularly in drier regions), the optimal balance between the costs and benefits of salinity prevention may involve very little prevention or abatement of salinity, even when off-site benefits are considered.

This set of issues requires us to rethink the salinity problem. Combined with the evidence about farmer adoption of new practices, they bring to the forefront the on-farm economics of perennial plants. If perennials are not profitable at the individual farm level, it is extremely unlikely that Australia will be successful in preventing the forecast dramatic increase in dryland salinity (e.g. Ferdowsian et al., 1996; Murray-Darling Basin Ministerial Council, 1999).

Recent hydrological modelling for Western Australia and South Australia has strongly reinforced this conclusion. George et al. (1999b) modelled a number of catchments and found that the area of land needing to be revegetated to prevent salinisation of land generally exceeded the area of land threatened with salinisation, sometimes by big margins. Similarly, Hajkowicz and Young (2000) report results from modelling of Wanilla Catchment (Lower Eyre Peninsula, South Australia) by Stauffacher et al. (2000). Their estimates are that revegetating 50% or more of land in the catchment with deep-rooted perennials will reduce the forecast level of saline land in 20 years time by only a few percent. Clearly, for such a revegetation strategy to be viable, the perennial plant systems must be almost as profitable as the agricultural enterprises they displace. Hajkowicz and Young (2000) concluded that the revegetation strategies modeled by Stauffacher et al. (2000) would have benefit:cost ratios of approximately 0.5, with the best option not exceeding 0.7, even when broader community benefits were factored in.

3. Economics of perennials at the farm level

Pannell (1995) described the factors that contribute to the economic benefits and costs of legumes in the farming system. He grouped them into short-term profit factors, dynamic factors, sustainability factors, risk factors and whole-farm factors. Clearly, the same set of issues will apply to perennials such as lucerne.

Pannell (1995) drew a number of general conclusions about the economics of legumes in southern Australia, including the following.

- In most circumstances, the optimal farm plan includes a mix of cereals, legume crops and pastures.
- It is important to recognise soil types and target activities accordingly.
- Although legumes can make a valuable contribution to profit, if grown in the wrong rotations or on the wrong soil types they can actually decrease profits.

These conclusions would also apply to perennials. They indicate that no single perennial plant, even if highly successful, is likely to dominate farmland use in most regions. This is because of a combination of factors, including soil type diversity, constraints on availability of machinery and labour, and risk considerations. It will be important to identify circumstances (regions/soil types) in which any new perennial is or is not profitable.

In considering perennials, sustainability factors are of particular interest. Reductions in salinity, water logging and, for woody perennials, wind erosion are all potential benefits. There is a tendency among scientists for too much emphasis to be placed on these aspects, to the neglect of more direct determinants of profitability. For example, Fig. 1 illustrates the extent to which the required level of direct profit from a perennial can be reduced as

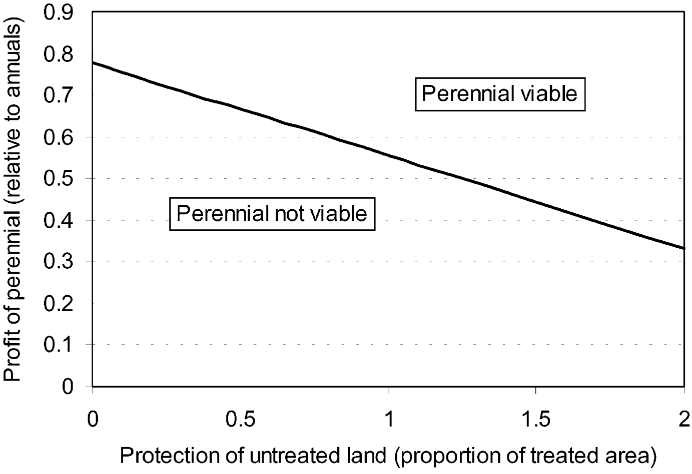

Fig. 1. Trade off between direct profitability and benefits from salinity prevention in calculating required net benefits of a perennial.

the area of additional land protected from salinity is increased. In preparing this figure, the following assumptions were made.

- The farmer's planning horizon is 20 years.
- The farmer's real discount rate is 10%.
- 'Treated' land is land on which the perennial is established. 'Protected untreated' land is additional land that is protected from salinisation.
- All of the land in question would become salinised after 10 years if left in annual-based systems.
- If the perennial is established immediately, it permanently protects from salinity all the land on which it is established.
- It may also protect an additional area of land, expressed in Fig. 1 as a proportion of the area of treated land.
- The net profitability of production from salinised land is 20% of the profitability of non-saline land.

Given this set of assumptions, the graph shows how much direct profit would be required from the perennial to justify their inclusion, from a narrow financial perspective. If no additional untreated land is protected, the perennial would need to generate profits at least 78% as large as the traditional agricultural enterprise grown on the land in question. As the area of protected untreated land increases, the perennial can be justified with a lower requirement for direct profit.

The figure shows that even if a large area of additional land is protected from salinity, the perennial enterprise must still generate a net profit to be financially attractive. For example, if 100 ha of trees were to protect 300 ha of land in total (the area under trees plus an additional 200 ha), the trees would still be required to generate net profits 33% as large as those of the annual-based enterprise. It would not be sufficient for the perennial to 'break even' in the sense of generating benefits that offset their establishment and input costs.

In reality, the required profit is likely to be at least 70% of the annual system's profit. George et al. (1999a) show that the proportion of additional land protected by perennials is much smaller than previously expected by many.

A number of studies into the farm-level economics of perennials have been conducted in Western Australia. Herbert (1999) conducted analyses of a range of salinity treatment strategies (including perennials) for the Fence Road sub-catchment of the Blackwood catchment. Despite adopting assumptions that were favourable to the perennials, he found that most strategies had low benefit:cost ratios. Herbert did not calculate the economic benefits due to salinity prevention, but Fig. 1 reveals that these benefits are likely to be relatively small in any case. In most cases, the direct economic benefits of a perennial will be much more important than the indirect benefits due to salinity prevention.

On the other hand, there are positive results available for some situations.

- One option assessed by Herbert (1999) had a benefit:cost ratio >2. On deep, low fertility sandy soils, the benefits of tagasaste trees (*Chamaecytisus proliferus* var. *palmensis*) grown in close belts, with alleys planted to serradella and perennial grasses, was found to be positive under assumptions that resulted in a gross margin of US\$29 ha^{-1} (US\$1 = AU\$1.7, June 2000). This represented an increase of US\$21 ha^{-1} over current practice on this soil type.
- Tasmanian blue gums (*Eucalyptus globulus*) in south-west Western Australia are profitable in the right environments, with suitable soils and rainfall (Burdass et al., 1998).
- Oil mallees may become profitable for farms located within the transport limits of processing plants/power generators, for which a pilot plant is currently in the planning phase (Cooper, 1999). This cautiously positive outlook is supported by analyses by Herbert (2000) for Western Australia.
- The perennial pasture plant, lucerne (*Medicago sativa*), appears to be currently profitable in suitable environments (soil type and rainfall) in southwestern Australia. This will be examined in detail in Section 4.

Despite these positive signs, we would acknowledge that the positive results apply to particular niches in particular regions, which tend to be higher rainfall regions. For the majority of land that is at risk of dryland salinity, no profitable perennial plant options are currently available. Further research and industry development is required to redress this deficiency.

4. Case study

This case study provides a detailed economic analysis of lucerne, the deep-rooted perennial which is currently considered the most promising in this region of southwestern Australia. We consider not just the direct costs and benefits of lucerne, but also its role in the rotational farming system practiced in the region, its impacts on other enterprises, and the influence of soil type on its role and economic performance. The study captures whole-farm influences of lucerne on feed availability and machinery usage, as well as its production levels at different times of the year and in different phases of the rotation. We provide a more detailed and comprehensive representation of the integrated production system than other studies of perennials cited above.

4.1. Background

In recent years, Western Australian farmers have shown increasing interest in the potential for lucerne pasture as a means of reducing recharge of the water table. This is particularly so in the southern regions of the state, where there is a relatively high frequency of summer rainfall and where there is a history of lucerne production (Bee and Laslett, 2002). Lucerne appears to be substantially more effective at preventing recharge than traditional annual crops and pastures (Latta and Blacklow, 1998; Latta et al., 2002; Ward et al., 2002).

Lucerne research in Western Australia has examined the effects of lucerne on soil fertility and subsequent change in cereal yield and grain protein. Nitrogen fixation by lucerne has been found to be similar to annual legumes, and yields and grain protein levels in the following cereal crops have increased in some cases (Latta et al., 2002).

An advantage of lucerne over annual pasture species is its ability to provide good quality feed to stock at times when feed quality is most limiting. Typically, in Mediterranean-type environments feed quality deteriorates in late summer and autumn such that growers are required either to provide costly feed supplements or to reduce stock numbers. This is one of the main factors determining the value of the stock enterprise in the agricultural region of Western Australia.

While lucerne has shown potential to provide out of season grazing for stock, its economic value depends also on the cost of providing this feed. Establishment costs of lucerne are high relative to other pastures and there is also a risk of establishment failure (Bee and Laslett, 2002).

4.1.1. Description of the farming system

This study focuses on the southern agricultural region of Western Australia, in particular an area known as the ‘South Coast Sandplain’. The South Coast Sandplain extends from east of Esperance to the Kalgan River east of Albany (Fig. 2) and up to 100 km from the coast. The region has a Mediterranean-type climate. Around two-thirds of annual rainfall occurs between May and October, followed by summer drought from December to March. Annual rainfall decreases rapidly with increasing distance from the coast, ranging from over 700 mm at the coast to 300 mm around 100–150 km from the coast. Soils have developed from tertiary marine sediments and are predominantly sandy with poor nutrient status, yet these soils can be very productive with the addition of chemical fertilisers.

Most farms include a mix of crop and livestock enterprises with the majority of income coming from the crop enterprises. A range of cereals, pulses and oilseed crops are grown. Livestock production comprises mainly wool and meat from sheep, with a small proportion of growers producing cattle. Most pasture is a mixed sward of self-regenerating annuals that include grasses, herbs and legumes. The seasonal pattern of

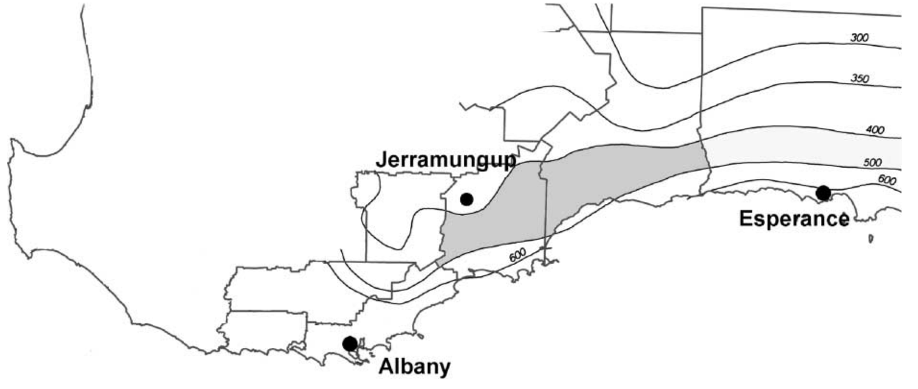

Fig. 2. South Coast region of Western Australia. Shire boundaries and rainfall isohyets relevant to the South Coast Model are shown. Shaded areas show Fitzgerald (in the west) and Esperance (in the east) sub-regions represented by the model.

growth of annual pasture species affects the cost of meat and wool production. Pasture quality is highest early in the growing season when growth rates are slow. Growth rates are highest in spring prior to senescence, at which point the quality and availability declines gradually through physical deterioration and leaching of nutrients. Availability of annual pasture is most limiting just prior to and immediately after the 'opening rains' that signal the commencement of crop sowing. It is, therefore, often necessary to supplement the feed supply with grain during this 'feed gap' period. The feed gap constrains the size and profitability of livestock enterprises.

Average farm size is approximately 2000 ha of which approximately 400 ha is non-arable. Farm operations are highly mechanised and family members supply most of the labour required on-farm. During seeding and harvesting of crops, casual labour may be hired. Specialist contractors undertake some of the sheep operations such as shearing.

4.1.2. Overview of model of an 'integrated dryland agricultural system' (MIDAS)

MIDAS is a mathematical programming model which describes biological, physical, technical and managerial aspects of the farming system. It models the inter-year production influences of crop-pasture sequences and the intra-year interdependencies between enterprises. Average production data is used in a year-in-year-out framework, so year-to-year variability (risk) in production and the dynamics of shifting resources between enterprises are not represented. The model selects resource use to maximise profit, subject to managerial, resource and environmental constraints.

Versions of MIDAS for the 'Eastern Wheatbelt' and the 'Great Southern' regions of Western Australia have been described in detail by Morrison et al. (1986), Kingwell and Pannell (1987) and Morrison and Young (1991). The South Coast (SCM) version of MIDAS, used here, has a similar structure to the Great Southern (GSM) model. The main differences between the two models are that SCM includes a greater number of rotations and land management units (LMUs). Values of production parameters such as pasture

Table 1
Description of the land management units represented in the South Coast Model

LMU[a]	Description	Production P7–P10[b] ($t\ ha^{-1}$)	Arable (%)	Area[c], Fitzgerald (ha)	Area[c], Esperance (ha)
1	Sandplain duplex (sand depth < 30 cm)	–	85	200	600
2	Sandplain duplex (sand depth = 30–80 cm)	0.95	95	200	800
3	Deep sand (sand depth > 80 cm)	0.65	60	100	400
4	Sandy loam duplex	–	90	300	0
5	Reddish brown loams	–	90	200	0
6	Red clay loams and clays	–	80	200	0
7	Grey loams and clays	0.75	90	600	0
8	Saline soils	–	15	200	200

[a] Land management unit.
[b] Lucerne production for Period 7 to Period 10 (late summer to autumn).
[c] Assumed areas of each land management unit in two different sub-regions.

production, crop yields and inputs costs are representative of a typical farm on the South Coast Sandplain, between the 400 and 500 mm rainfall isohyets (Fig. 2).

The SCM has over 1100 activity options (decision variables) including 24 crop-pasture rotation sequences for each of eight LMUs (which are described in Table 1). Production parameters include grain yield, grain quality, grain protein levels (in the case of wheat) and germination rates of pasture. Input costs include fertiliser, chemicals for weed and pest control, machinery costs, labour, crop insurance and seed costs.

The seasonal supply of pasture is described by partitioning the pasture sub-matrix into 10 periods. Periods 1–5 describe the rates of pasture growth at different times of the growing season. Growth rate is a function of the feed on offer to livestock at the end of each period. Feed not consumed in a given period is carried forward to the following period. Periods 6–10 cover summer and autumn in which the quality of availability of dry feed declines over time.

Other activities represent the followings.

- pasture consumption by sheep at different times of the year;
- availability of crop machinery at sowing and harvest time;
- yield penalties associated with delayed sowing;
- grazing of crop stubble by sheep;
- supplementary grain feeding during the feed gap;
- selling of sheep;
- selling of grain and wool and
- bi-monthly cashflow.

Risk is not represented in the model. The mathematical solution of the model identifies the farming system which maximises long-run expected profit. The strategy selected includes rotations for each LMU, sheep flock structure, selling times of sheep and grazing strategies.

4.1.3. Inclusion of lucerne in MIDAS

Production levels of lucerne assumed in the model were based on averaged trial data from sites in Western Australia during 1997–1999 (Latta, personal communication, 1999). It was assumed that during the normal growing season, lucerne pasture was a mixed sward of volunteer annual species and lucerne, and production levels were similar to annual pastures. In addition, unlike annual pastures, lucerne may provide green feed during summer. Average summer production levels based on trials are shown in Table 1. Higher than average summer rainfall during the period of the trials means that these estimates are unlikely to be achieved by farmers as a long-term average. Therefore, summer production was scaled by a factor of 0.4 to better reflect the researcher's view of likely production levels (Latta, personal communication, 1999). We assumed that lucerne provides rotational benefits for subsequent cereal crops (higher yields, lower nitrogen fertiliser requirements) similar to those observed following productive annual legume pastures.

Grain and wool prices used were those forecast for the next 3–5 years by Agriculture Western Australia (Wilkinson and Layman, personal communication, 2000): wheat ASW, US\$118 t^{-1}; barley malting grade I, US\$121 t^{-1}; canola, US\$194 t^{-1}; lupins, US\$112 t^{-1}; wool 21 μ greasy, US\$2.06 kg^{-1}. All prices are net of all selling costs, including transport. The establishment cost of lucerne was estimated to be US\$94 ha^{-1}. This varies substantially between farms, and does not take into account the risk of establishment failure, which incurs a cost of resowing.

Five new rotations were included in the model for three LMUs (2, 3 and 7). Each new rotation included a phase of lucerne followed by 1 or a number of years of crop:

- 4 years lucerne followed by wheat–canola–barley–legume–wheat;
- 4 years lucerne followed by wheat;
- 3 years lucerne followed by wheat–canola–wheat–barley;
- 3 years lucerne followed by wheat–barley and
- 3 years lucerne followed by wheat–canola.

The model was run for different combinations of wool price, grain prices, establishment costs, summer lucerne production and area of lucerne sown. The values tested for each of these factors are shown in Table 2. The analysis was repeated for two sub-regions, Fitzgerald (in the west) and Esperance (in the east).

Table 2
Values used for each factor examined in the sensitivity analysis

Factor examined	Value
Wool price (21 μ, US\$ kg^{-1} greasy net on farm[a])	1.47, 2.06, 2.65, 2.94
Wheat price (ASW, US\$ t^{-1} net on farm)	82, 94
Barley price (Malting grade I, US\$ t^{-1} net on farm)	85, 97
Canola price (US\$ t^{-1} net on farm)	159, 176
Lupin price (US\$ t^{-1} net on farm)	79, 91
Establishment costs (US\$ ha^{-1})	59, 94
Production of lucerne during periods P7–P10 (% of measured)	40, 100
Area of lucerne sown (ha)	50, 100, 150, 200, 250, 300, 350, 400, 450, 500

[a] 'Net on farm' means all charges and tolls have been deducted including transport to receival point.

Table 3
Summary of MIDAS model results, based on assumption of low cost of lucerne establishment (US\$59 ha^{-1}) and lower wheat price (US\$82 t^{-1})

Wool price (US\$ kg^{-1} greasy net on farm)	Summer lucerne production[a] (% of measured)	Area of lucerne (ha)	Change in profit per ha of lucerne (US\$)	Stocking rate[b] (sheep ha^{-1} winter pasture)
Fitzgerald region				
2.06	40	230	13	6.9
	100	230	18	7.6
2.94	40	315	21	7.8
	100	315	32	9.9
Esperance region				
2.06	40	0	0	4.1
	100	138	2	6.0
2.94	40	323	6	7.1
	100	412	17	8.1

[a] Production of lucerne during periods P7–P10 (% of measured).
[b] Stocking rate is expressed as dry-sheep-equivalents per hectare. Compare with rate of 4–5 without lucerne.

4.2. Results and discussion

4.2.1. Economic value of lucerne

Results in this section are based solely on direct financial benefits and costs of the alternative enterprises, without accounting for the salinity-related benefits of lucerne. At wool and grain prices expected in the medium term and based on the lower level of summer feed production, lucerne increased farm profit in the Fitzgerald sub-region, but not in the Esperance region (Table 3). The primary reason for this difference is that Esperance included none of LMU 7, on which lucerne performs well.

The rotation selected for LMU 7 in Fitzgerald includes a 3-year phase of lucerne followed by wheat, canola, wheat and barley. On the 600 ha of LMU 7 on the model farm, it is profitable to grow 230 ha of lucerne on average (15% of the arable area of the farm). Including lucerne on LMU 2 is equally profitable to the current optimal rotation, but only if small areas are grown.

A reason for lucerne's inclusion on LMU 7 is that available grain legume crops are relatively unsuitable on the heavy soils of this LMU. Lucerne provides a fertility boost that is otherwise only available at a greater income sacrifice.

A second and more important reason is that lucerne provides good quality summer feed at costs competitive with other feed sources such as grain supplements. It thereby enables the stocking rate of the farm (sheep per ha of winter pasture) to be profitably increased above the level of 4–5 sheep ha^{-1} which is viable without lucerne (Table 3). Additional income results from higher wool and meat sales while input costs increase to a smaller extent. Table 3 also shows that the profitability of lucerne is very dependent on the level of summer production.

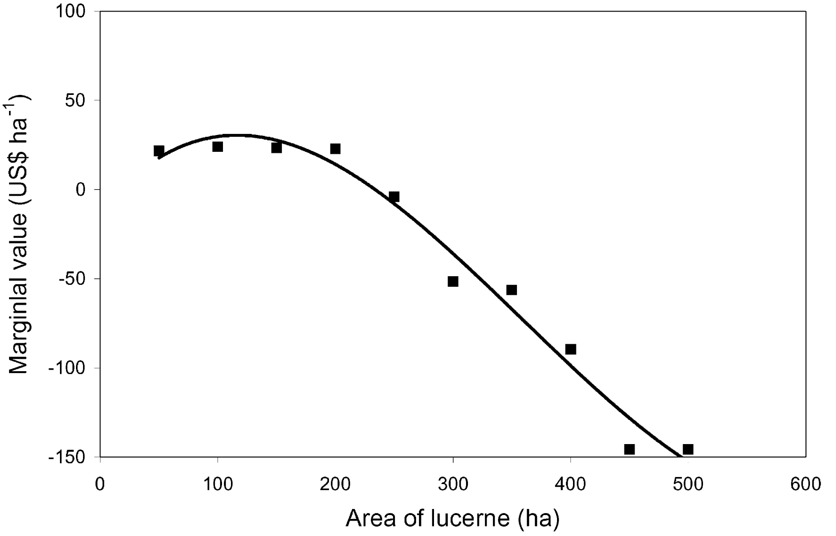

Fig. 3. Marginal value of lucerne in Fitzgerald (wool US\$2.06 kg^{-1}).

However, profits do not continue to increase with larger areas of lucerne due to the 'law of diminishing marginal returns'. This is demonstrated in Fig. 3, which shows for one illustrative scenario the marginal increase in profit per lucerne hectare at different areas of lucerne. The optimal area of lucerne is where the addition to profit resulting from a marginal increase in area is zero, which, in this example, occurs when there are 230 ha grown annually. At areas >230 ha establishing additional lucerne area reduces profit.

The declining marginal value of lucerne occurs for two main reasons. Firstly, to further increase the area of lucerne requires adoption of either less profitable rotations that include a greater proportion of lucerne or additional lucerne being grown on a less suitable LMU. For example, in Fig. 3, lucerne has been established on LMU 2 to increase the area above 230 ha. Establishing lucerne on LMU 2 is less profitable than on LMU 7, so much so in this example that profit falls. Secondly, lucerne provides feed at a time when it is relatively scarce. As more lucerne is grown, good quality feed becomes less scarce and other factors begin to limit the extent to which efficiency of livestock production can be improved. The contribution to profit resulting from a marginal increase in lucerne, hence is reduced as the area of lucerne increases.

4.2.2. Influence of grain prices, wool price and establishment costs on profitability

Optimal lucerne area is most sensitive to grain and wool prices and less sensitive to the cost of lucerne establishment, as these costs are spread over the length of the rotation. With more favourable market conditions (lower grain prices, wool price US\$2.94 kg^{-1} greasy and low establishment costs), the optimal area is around 150 ha higher than in Fig. 3, bringing lucerne to almost 25% of the arable area of the farm.

The optimal area of lucerne in the Esperance region is much more sensitive to market conditions. Curve A in Fig. 4 (corresponding to the last line of results in Table 3) shows

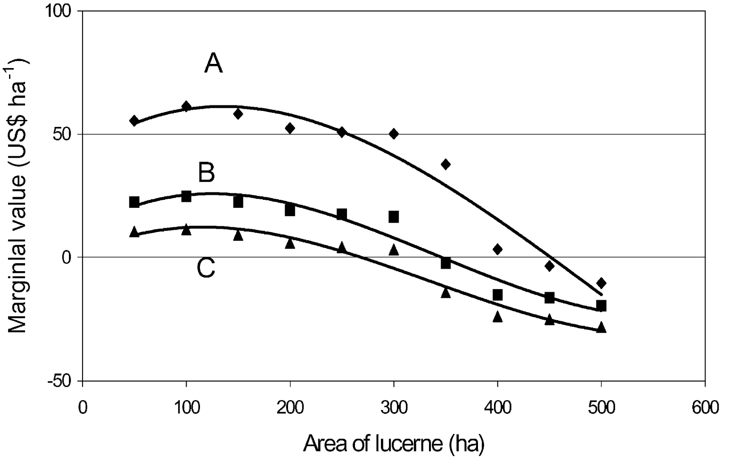

Fig. 4. Marginal value of lucerne in Esperance, assuming wool US\$2.94 kg^{-1} (curve A: low grain prices, low establishment cost; curve B: high grain prices, low establishment cost; curve C: high grain prices, high establishment cost).

that with favourable conditions for lucerne, the optimal area is 412 ha—26% of the total arable area of the farm. An increase in grain prices leads to a reduction in the optimal lucerne area to around 350 ha (curve B in Fig. 4). Where grain prices and costs of establishment are both high the optimal area is 300 ha (curve C in Fig. 4). From this point, any adverse change, such as a reduction in the wool price to US\$2.65 kg^{-1}, would make lucerne unprofitable in the Esperance sub-region.

4.2.3. Impact of lucerne on the spread of salinity

Differences in the productive capacity between farms, the mix of LMUs, farmer management ability, personal preferences and commodity prices will mean more or less lucerne may be established on the South Coast, compared to that suggested by the above results. In addition, the benefit of reducing the depth of the water table has not been considered so far. As Fig. 1 showed (for a specific set of assumptions), benefits from salinity prevention may mean that the net returns to lucerne need only be around 80% of the next best enterprise. If the profitability of each lucerne rotation is increased to represent the value of salinity prevention as reflected in Fig. 1, the optimal area of lucerne is increased from 15% to just over 20% of the arable area. The optimal area of lucerne will be even greater where the economic climate is favourable to livestock. It is hoped that lucerne may provide an effective buffer to offset recharge from a number of subsequent years of crop. If it is fully effective in this, an average lucerne area of 20% per annum implies that approximately 40% of the farm land may have salinity prevented or at least delayed.

If risk considerations were modelled, there may be further enhancement of the attractiveness of lucerne. Anecdotal evidence indicates that lucerne production is less affected by below-average rainfall years than are annual crops and pastures.

Nevertheless, there are some causes for concern which would temper this relatively positive outlook. One concern is the results of modelling studies, such as Stauffacher et al. (2000), which indicate that in some catchments, planting more than 50% of the landscape to perennial species protects a relatively small area from salinisation.

Secondly, there are uncertainties regarding the effectiveness of the buffer created by lucerne in reducing recharge in the long term. Much of the recharge occurs after episodic rainfall events and the timing of such events relative to the lucerne phase of the rotation may be critical to the long-term effectiveness of a buffer (Tennant, personal communication, 2000).

Finally, even under the more optimistic scenarios modelled here, the proportion of land likely to be voluntarily sown to lucerne is insufficient to address catchment scale problems such as the flood risk and salinisation of natural waterways.

It is not possible to directly generalise these results to the whole agricultural region of Western Australia to attempt to estimate the likely area of lucerne in other regions. However, factors influencing the optimal level of adoption will be the same: the area of suitable soil types; the level of summer production; expected prices and establishment costs.

5. Implications for policy

The National Landcare Program (NLP) started with the premise that land degradation in agriculture could be solved by awareness-raising and education programs for farmers (Curtis and De Lacy, 1997; Vanclay, 1997). This paradigm has been the dominant force in Australia shaping policies for prevention of natural resource degradation in agriculture. The NLP approach has certainly raised awareness of perennials among farmers, but the level of adoption so far has been too small to prevent ongoing increases in the area of saline land.

There appears to be a belief in policy circles that if we can raise environmental awareness among them and inculcate a stewardship ethic, then even if economically-viable perennials do not exist, farmers will voluntarily make the sacrifices to adopt perennials. Pannell (2001) argued that such a view fails to take account of the level of sacrifice that is implicitly being expected of farmers—it is very substantial. Barr (1999) emphasised the inadequacies of relying on voluntarism and a stewardship ethic. He commented that, "There is a significant body of research that demonstrates that links between environmental beliefs and environmental behaviour are tenuous." (p. 134). He notes that the NLP involves only a minority of farmers (albeit a 'substantial' minority), and that, "It is probably unrealistic to expect any voluntary policy to achieve any greater degree of penetration of the farming community than has been achieved by Landcare." (p. 135). Perhaps even more importantly, the proposition that we should encourage farmers to adopt practices that are not in their own best interests raises ethical and moral questions.

The other ethical dimension of this question is that by continuing to neglect economic considerations in our Landcare and Integrated Catchment Management policies, our institutions are failing to act appropriately to prevent as much as they could of the potential area of dryland salinity. Most catchment plans have not been properly evaluated in terms of their likely economic benefits. In this situation, it is not surprising that farmers' commitment to implementation of the plan is difficult to maintain once they are faced with the reality of the time and expense involved.

It is clear that by far the most important need from salinity policy is to alter the financial incentives for adoption of perennial production systems. Persuasion, education and extension will remain inadequate while the available options are financially unattractive. A small minority of the public resources devoted to the salinity problem is now allocated to development of new, profitable perennial enterprises. Given the critical importance of this activity, it has been, and continues to be, grossly under-funded. It should be recognised that such development work is not certain to succeed, but without it we seem certain to fail to prevent serious future salinity problems.

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