Total Value Assessment of Tree Clearing for Developing Grazing Systems in Central Queensland

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Net benefits from clearing trees to develop pastures in central Queensland, Australia

Abstract

Tree clearing is widely practised in Queensland to develop exotic pastures to enhance pasture production and hence the financial gains. One of the major woodland community i.e. brigalow (*Acacia harpophylla*) was targeted for clearing in the early 1950s due to its fertile soils, and recently marginal communities such as Poplar box (*Eucalyptus populnea*) and Iron bark (*Eucalyptus melanophloia*) are also targeted for clearing. Net benefits from clearing woodlands to increase pasture production, hence cattle production, is questioned in this paper. Previous studies have emphasised the gains in pasture yield over <10-15 years of clearing, without considering any long term ecological effects. The questions are whether an increase in pasture production following clearing is sustainable over a long term (>15 yrs.) or whether such an increase is 'actually beneficial' and does not impose any adverse in-situ and ex-situ ecological effects on grazing systems?

The study is based on detailed ecological data on pasture production, soil properties (biological and physicochemical), litter production and nutrient recycling, and pasture plant diversity and diet quality. For this, three tree communities i.e. *A. harpophylla, E. melanophloia* and *E. populnea* were selected in central Queensland. There were three different ages of clearing i.e. 5 yr, 11-13 yr and 33 yr for each of the tree community. Comparisons were made for paired plots between cleared and uncleared (intact) woodlands across 3 age groups of clearing. The results indicate that pasture production increases post-clearing, but then declines over the longer term (more than 30 years). A bioeconomic model applied to develop scenarios for pasture production over the 50 years of time frame of clearing, also suggested a decline in pasture yield with age of clearing based on the yearly average increase estimated from the old (30 years) to 50 years of age clearing. Although, the cleared pastures could be economically beneficially as predicted in bioeconomic model, however, it is difficult to predict how the change in ecosystem functions in old pastures (> 30 years of clearing), by implication, affect pasture yield. The opportunity cost of clearing to achieve production gains in terms of loss of ecosystem functions and their implication for future production gains, are discussed.

Key words: Tree clearing, pasture production, livestock production, ecological benefits.

1. Introduction

Tree felling, tree clearing and deforestation to develop productive agricultural systems are significant issues of concern for the global community. Worldwide, deforestation rates have increased to 14.6 million ha per annum during the last decade (FAO 2001). Australia is at sixth rank with the rate of 564,800 ha clearing per year during 1990-2000. About 75 per cent of the total clearing in Australia occurred in Queensland (State of the Environment Advisory Council 1996). In Queensland, during 1999-2001, an average of 577,000 hectares were cleared each year, with 94% developed for the purposes of improving pastures (Department of Natural Resources and Mines 2003 and 2005).

Pastoralism is the main industry for Queensland, contributing about $3.8 billion in 2000-2001 to the total state economy (ABS 2001). Since the beginning of the last century until 1985, various governmental policies for settlement schemes and incentives encouraged clearing on a large scale to develop land for pastures and cropping (Boulter *et al.* 2000; Isbell 1962). The main reason for clearing is to increase productivity and hence the monetary benefits. In the process of developing 'productive' pasture systems, much of cleared area was sown to various exotic grasses especially buffel (*Cenchrus ciliaris* L.). These species performed well to capture the flux of nutrients available upon clearing. Due to large scale cultivation of a few exotic grasses, a monoculture set of pastures has been created on most of the cleared land. There is a general perception among the beef producers' community of Queensland that clearing trees followed by sowing to exotic grasses such as *C. ciliaris* leads to greater pasture productivity.

The approach to achieve greater monetary gains from 'developed' pastures is preferred to date. Most studies to date (Burrows 1993; Burrows *et al.* 1999; Scanlan and Burrows 1990; Scanlan 1991) have highlighted the production gains from clearing, though these gains were limited to <10 years of age of cleared pastures (Scanlan 2002).

Recently, there has been increasing levels of control by the State Government over clearing activities (Rolfe 2000), culminating in controls on freehold land introduced in 2004. This placed a cap on the total area to be cleared, with all clearing activities to be completed by 2006. The debate over clearing has focused on production versus conservation outcomes, and it is unclear how economical it is to clear vegetation on more marginal soils, particularly when long term ecological impacts are considered (Rolfe 2000). It is also unclear whether clearing activities trigger changes in ecosystem functioning that could increase the risk of future production losses.

The research reported in this paper is aimed at identifying the productive (including financial returns from pastures) and ecological impacts of clearing over a longer time period in the central Queensland region. Three major woodland communities i.e. Brigalow scrubs (*Acacia harpophylla*), Box woodlands (*Eucalyptus populnea*) and Ironbark woodlands (*Eucalyptus melanophloia*) were selected on one property to quantify the impacts of clearing on pasture production, plant diversity, soil properties, and litter production. The impacts were measured over time at recent (<5 years), medium (11-13years) and old (>30 years)) age of cleared pastures in comparison to their uncleared (intact) woodland pastures for each tree community. The losses and benefits from clearing in pasture production are further used in a simple bio-economic model to assess the net benefits of clearing activities for each of the tree community.

The results provide information about the net private benefits of clearing over 50 years of time. Only the potential private costs of clearing activities are included in the analysis. The public costs of clearing activities associated with biodiversity loss, soil nutrient loss and nutrient loss through litter recycling are discussed. To assess the overall value of tree clearing activities to the community, the net private benefits of clearing activities are compared to the public costs resulting from the clearing activities.

2. The Central Queensland Case Study

Materials and methods

Paired sites of cleared and intact/uncleared woodlands for the three vegetation types were selected across three age groups of clearing i.e. recent (5 yr), medium (11-13 yr) and old (33 yr) on a property "Avocet" (30 km. south of Emerald) in central Queensland, Australia. There were total 18 sites in a factorial design of 3 tree communities x 3 time-since-clearing x 2 (paired) sites for each age of clearing. All the sites were selected on one property to have similar management practices.

Pasture yield and pasture species diversity

At the centre of the selected 1 ha area at each site, a fenced plot of 10 m x 10 m (an exclosure to exclude cattle) was established to determine pasture above-ground biomass and composition. A quadrat size of 1 m x 1 m, derived from the stable number of species per unit area based upon preliminary analysis was chosen. Measurements were taken from five randomly assigned quadrats located at different positions for March 2001, July 2001, November 2001 and March 2002. Plant samples from each quadrat were harvested just above-ground level, taken to the laboratory and dried at 60 ^{o}C for 48 hours to determine their biomass. The average quantity of pasture above-ground biomass for grazing was calculated over a 12 month period from these seasonal measurements. All types of plants in a quadrat were also identified to study the species composition.

Soil properties

Soil attributes are important indicators of ecosystem stability, as the changes in soil parameters directly impact on pasture production. In the experiment, 8 soil samples were taken per site from unfenced area (1 ha) in January 2002 using a hydraulic soil rig. All the samples of one site were bulked and processed for analysis. The samples were taken at different depths (0-5, 5-10, 10-20, 20-30 and 30-60 cm). Samples were analysed at the soil laboratories of Incitec Ltd (Brisbane) for soil organic carbon (SOC), soil pH_w and soil NO_3^-. To determine the microbial biomass of Carbon (SMB-C) and Nitrogen (SMB-N), samples were taken from the top 0-5 cm of soil in March 2002, and analysed using the chloroform fumigation extraction method (Vance *et al.*, 1987) at the Natural Resource Sciences Laboratories (Department of Natural Resources, Mines and Energy, Indooroopilly, Brisbane, Queensland). Further details of methods used are reported in Sangha (2003).

Litter production

Litter production determines the amount of nutrients being recycled and available for future plant growth. In the experiment, litter production was measured at four month intervals at unfenced sites using the paired-plot technique (Wiegert and Evans, 1964). On each occasion, three random quadrats of 1m x 1m were laid in three different directions. The average amount of litter produced over a year was computed from litter produced during different seasons.

Litter samples collected in March 2001 (without decomposition) from each site were thoroughly mixed, ground, and analysed for N (using CHN analyser) and P (using ICP).

Statistical analysis

Individual effects of tree clearing on pasture biomass and litter production were analysed using Genstat (2002, version 6). The residual maximum likelihood (REML) (Patterson and Thompson, 1971) method was used. The main effects for type of tree community and uncleared-cleared (recent, medium and old) treatments within each tree community were analysed. Models included the fixed effects of tree community and clearing treatments plus their interaction (community*cleared-uncleared), and the random effects of age since clearing. If the interaction between community and cleared-uncleared treatments was not significant for predicting changes in the dependant variables ($P<0.05$) then it was removed from the fixed model to test the main effects. The variance matrix derived from REML analysis was used to calculate approximate LSDs (least significant differences of means) at $P<0.05$. The means from REML analysis were used in presenting the results.

For soil properties, the REML procedure was also used to identify if the key parameter attributes explained variations in the data. Details are reported in Sangha (2003).

To examine the integrated effect of studied attributes (pasture yield, species diversity, litter production, SOC, NO_3^-, pH_w and soil microbial biomass (C and N)) in cleared and uncleared pasture systems, data were also analysed using a multivariate analysis technique i.e. canonical variates analysis (CVA). All the data were standardised for analysis.

The CVA was applied to determine the overall effect of clearing, as well as identifying the attribute(s) that differentiated between cleared and uncleared treatments in all tree communities. There were not enough replicates for cleared treatments within a tree community to apply CVA within in each tree community, pooled data was used for all the cleared and uncleared treatments. The CVA analysis finds linear combinations of the original variables that maximize the ratio of between group to within-group variation where groups are cleared and uncleared treatments. Two canonical variates (CV1 and CV2) were considered to explain variation between treatments. The output from CVA presents an integrated impact of clearing in pasture systems.

3. Experimental Results

Pasture yield

Pasture yield on the average was greater at cleared compared to uncleared sites, with maximum production at the medium age of clearing for *E. populnea* and *A. harpophylla,* and at recent age of clearing for *E. melanophloia* (Fig. 1). This confirms that vegetation clearing may generate pasture production gains. However, the gains in pasture biomass were not consistent over time-since-clearing and showed a declining trend at old compared to medium age of clearing (in *E. populnea* and *A. harpophylla*). In *E. melanophloia,* such a decline in pasture yield was evident even after recent age of clearing (Fig 1).

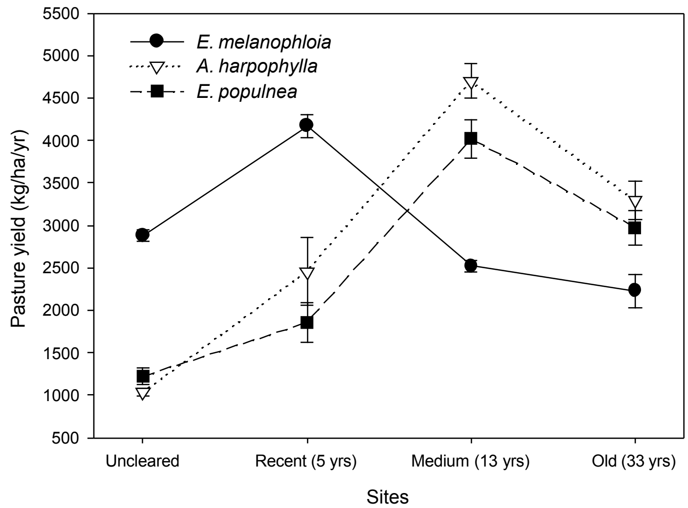

Fig 1. Average pasture yield (kg/ha/year) with standard error bars for various cleared and uncleared treatments *E. melanophloia, A. harpophylla* and *E. populnea* communities.

Financial value of pasture yield at the time of production (excluding tax and cost of clearing) was certainly improved with clearing (Fig. 2). However, the main question is whether these financial gains were sustainable over the time of clearing? In *E. populnea* and *A. harpophylla* communities, the financial gains declined from medium to old age of clearing, while in *E. melanophloia* such a decline started after recent age of clearing (Fig 2).

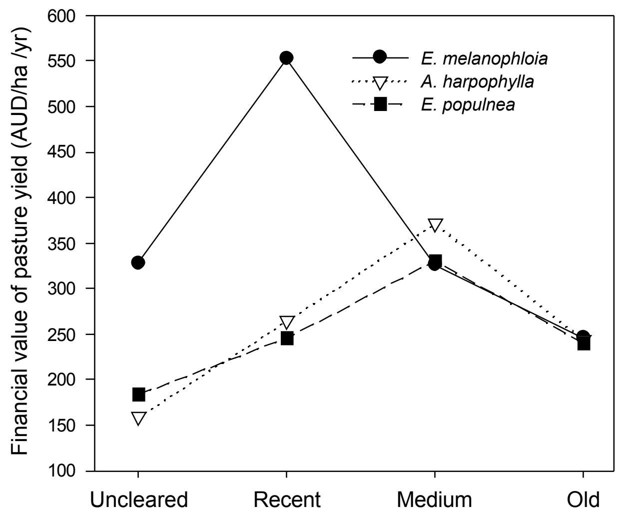

Fig 2. Financial value of pasture yield for various cleared and uncleared treatments for *E. melanophloia, A. harpophylla* and *E. populnea* communities.

Therefore, the main concern is if land is cleared to enhance pasture yield and hence the financial returns, then for how long such financial private benefits could be obtained and what could be the public cost?

4. Financial returns over 50 year period from clearing

To estimate the financial returns from clearing over 50 years, a model was run to simulate pasture yield and returns. A relationship between dry matter consumption and weight gain was assessed using the feed relationship reported by Minson and McDonald (1987). A 400 kilogram steer gaining 0.5 kilograms per day was assumed to consume an average of 7.52 kilograms of dry matter/day. Using the stocking rates on the property where the experiments were carried out, it has been estimated that 23.38 % of all dry matter produced above 500 kg/ha was consumed by cattle. The remainder of the feed may be consumed by kangaroos and other animals, burnt by fires or recycled into the soil. Using these estimates, the additional pasture biomass generated by clearing activities can be equated to changes in kilograms of livestock produced. This estimate was multiplied by an average market price of $1.50/kg for cattle to convert the estimate into gross value of additional production.

The following assumptions were applied:

- Livestock production changes in response to pasture yield.
- Pastures take time to establish when the land is cleared, so no benefits are considered for the first 2 years.
- Pasture yield decline continues until 50 yrs time at the same rate as from medium to old age of clearing (such trend was evident from field surveys and data).
- The cost of clearing is $150/ha, and similar costs are applied after every 20 years of clearing (at 20th and 40th years) to control regrowth and to maintain soil functions (to plough soil).
- Company tax 30% is deduced from the net benefits obtained from clearing.

The results from bio-economic model demonstrate that the increase in returns with clearing occurs in *E. populnea* and *A. harpophylla* until 30-35 years of clearing (Fig 3). After this, the returns from clearing are minimal in these tree communities. However, the scenario is different in *E. melanophloia* where annual returns are the maximum at 5 years of clearing, and then follows a downward trend with losses from 10th year of clearing onward.

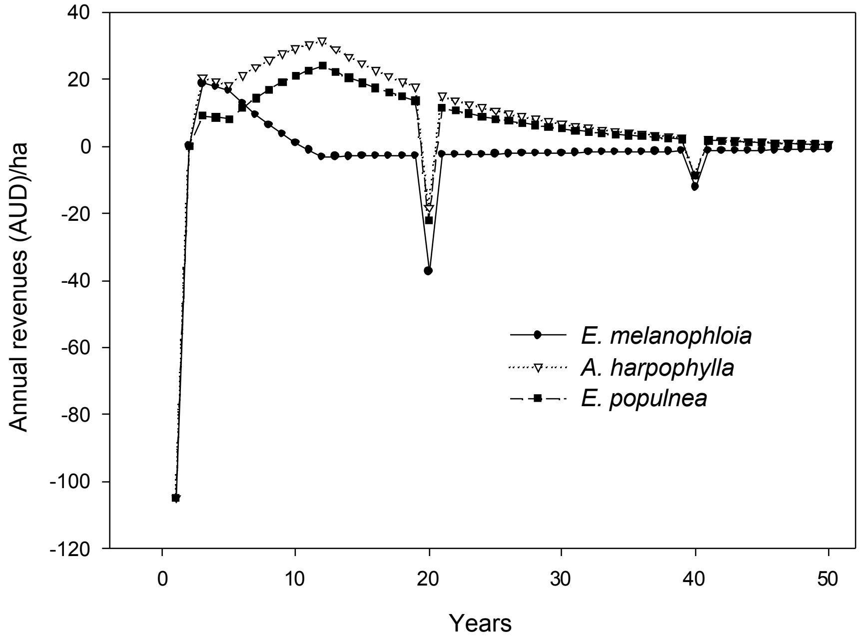

Fig 3. Annual revenues (net present value at 6% discount rate) from clearing over 50 years for *E. melanophloia, A. harpophylla* and *E. populnea* communities.

The net private benefits over 50 year time are significant for *A. harpophylla* and *E. populnea*, suggesting that clearing would return monetary benefits, thus leading to a notable increase in land prices. However, in *E. melanophloia* the net returns are negative, suggesting loss from clearing (Table 1). The figures in Table 1 suggest the increase in land prices with clearing in addition to the price of uncleared land. Over the similar time frame, uncleared pastures, in each of the tree community, also provide positive returns with the maximum returns in *E. melanophloia*.

Table 1. Net present value (AUD/ha) of benefits obtained from clearing for additional cattle production and their uncleared pastures in *E. melanophloia, A. harpophylla* and *E. populnea* communities after 50 years time.

	E. melanophloia	*A. harpophylla*	*E. populnea*
Cleared pastures			
6% discount rate	-140.07	435.75	265.86
8% discount rate	-64.06	268.56	177.98
Uncleared pastures			
6% discount rate	785.13	282.25	315.52
8% discount rate	620.87	223.2	245.49

The present study demonstrates that clearing benefits the landholders in terms of net private financial benefits over the long term, but such benefits can not be generalised for different tree types. For example, there are negative returns for clearing *E. melanophloia*. Moreover, there are ecological costs which could be onsite (private) and offsite that may contribute to further decline in pasture yield with age of clearing.

5. Public costs and hidden private costs

The costs associated with loss of ecological services are both public and private. For public these losses represent no/less species and poor/degraded soil with no trees for recycling of nutrients. There is also loss of scenic beauty and production potential of a landscape for the present and future generations. For private costs, once the returns are harvested, land is left in poor condition that may take much longer to repair than it would have taken to harvest the benefits. The landholder would also lose scenic beauty, production potential of land and will incur further costs to repair the degraded land. Moreover, there would be soil erosion that could impact the water streams offsite.

Each of these losses disturbs the natural equilibrium in processes which are responsible to carry out various ecosystem functions. For example loss of plant diversity disturbs nutrient utilization as each species has its own requirement (Tilman 1996) to use a particular amount of a nutrient. Diverse species complement each other for resource use and diverse systems are robust to tolerate pest invasion. In monoculture pastures, as established after clearing, such nutrient complementarity is lost and nutrient run-down occurs that leads to decline in pasture yield (Graham *et al.* 1981).

The major ecological losses associated with clearing are:

1. ***Loss of pasture plant diversity***
2. ***Loss of soil nutrients***
3. ***Loss of nutrients returned through litter recycling***

For each of the three communities, these losses are discussed as follow:

1. Pasture plant diversity

In the present study, species diversity was significantly greater at uncleared compared to all the cleared treatments in all tree communities (Table 2). The details on change in species diversity with clearing are discussed by Kaur *et al.* (2005). The diversity of native plant species is compromised with high production gains from exotic grass species in cleared pastures.

Table 2. Number of plant species at uncleared, and at recent, medium and old age cleared treatments of *E. populnea, E. melanophloia* and *A. harpophylla* communities.

	E. populnea	*E. melanophloia*	*A. harpophylla*
Uncleared	41^{a}	42^{a}	43^{a}
Recent	30^{b}	38^{b}	26^{b}
Medium	16^{c}	23^{c}	14^{c}
Old	17^{c}	22^{c}	14^{c}

*different superscripts in a column represent significant difference at $P<0.05$ for cleared and uncleared treatments within a tree community.

2. Soil nutrient loss and changes in other soil properties

Tree clearing had no major effect on available content of N (NO_3^-) and soil organic carbon, but there was an overall decline at old age of clearing (Sangha 2003). However, clearing strongly influenced soil pH_w across all tree communities. Soil pH_w increased significantly ($P<0.05$) with age of clearing across all tree types (Sangha *et al.* 2005a). Such an increase in pH_w adversely affects the availability of various nutrients as discussed by Sangha *et al.* (2005a).

Soil microbial biomass (SMB) is an important ecological indicator of soil health, for greater SMB is responsible for greater mineralisation of organic matter and hence the return of nutrients for pasture growth. Overall, the SMB-C and SMB-N was significantly ($P<0.05$) greater in uncleared pasture soils than cleared soils (SMB-C 386±37 (standard error of means) and SMB-N 40±3.29 mg kg^{-1} at uncleared compared to SMB-C 254±37 mg kg^{-1} and SMB-N 29±3.45 at cleared soils).

Available N, soil organic carbon, soil microbial biomass and soil pH_w are important soil properties, and any change in them could trigger change in other soil functions. For example, changes in soil microbial biomass would lead to a change in mineralisation and availability of nutrients for plant growth.

3. Litter production and nutrient return

The total amount of litter produced over a year (kg ha^{-1}), and the potential amount of N stored in litter produced (yearly) was greater at uncleared compared to the cleared sites in all the tree communities except the medium cleared treatments (in *E. populnea* and *E. melanophloia*) (Table 3). These results suggest that the amount of nutrient available for plant growth may become limited in cleared sites. Details of nutrient return through litter are discussed in detail by Sangha *et al.* (2006).

Table 3. Litter production (kg $ha^{-1}yr^{-1}$) and potential content of N and P (kg ha^{-1}) stored in annual amount of litter produced at uncleared and cleared (recent, medium and old) sites for *E. populnea*, *E. melanophloia* and *A. harpophylla* communities.

Site		Uncleared	Recent	Medium	Old
E. populnea	Litter production	1732^{a}	866^{b}	1299^{ab}	949^{b}
	N	15.30^{a}	8.04^{b}	6.63^{b}	4.49^{b}
	P	0.58^{b}	0.60^{b}	1.10^{a}	0.50^{b}
E. melanophloia	Litter production	1948^{a}	1107^{b}	1515^{ab}	1226^{b}
	N	11.40^{a}	4.38^{b}	6.56^{b}	10.39^{ab}
	P	0.84^{ab}	0.50^{b}	0.95^{a}	0.51^{b}
A. harpophylla	Litter production	2596^{a}	1346^{b}	1191^{b}	1084^{b}
	N	29.97^{a}	6.55^{b}	5.49^{b}	6.32^{b}
	P	0.87^{a}	0.55^{b}	0.63^{b}	0.67^{b}

*different superscripts in a row represent significant difference at $P<0.05$ between any two treatments in each of the tree community.

Integrated effect of studied ecological attributes on the stability of a pasture system

The combined effect of clearing on various ecological attributes on a pasture system was determined with CVA (Canonical Variates Analysis). Two canonical variates (CV1) and (CV2) were selected for recent, medium, old cleared and uncleared treatments across all tree communities. The first canonical variate (CV1) distinguished the oldest cleared treatment from medium and recent cleared, and uncleared treatments (CV1 explained 90 per cent of variation among these treatments) (Fig 4). The difference in the state of pastures at the old age of clearing compared to other treatments was mainly due to changes in soil NO_3^-, pasture biomass, litter production, species diversity and soil pH_w.

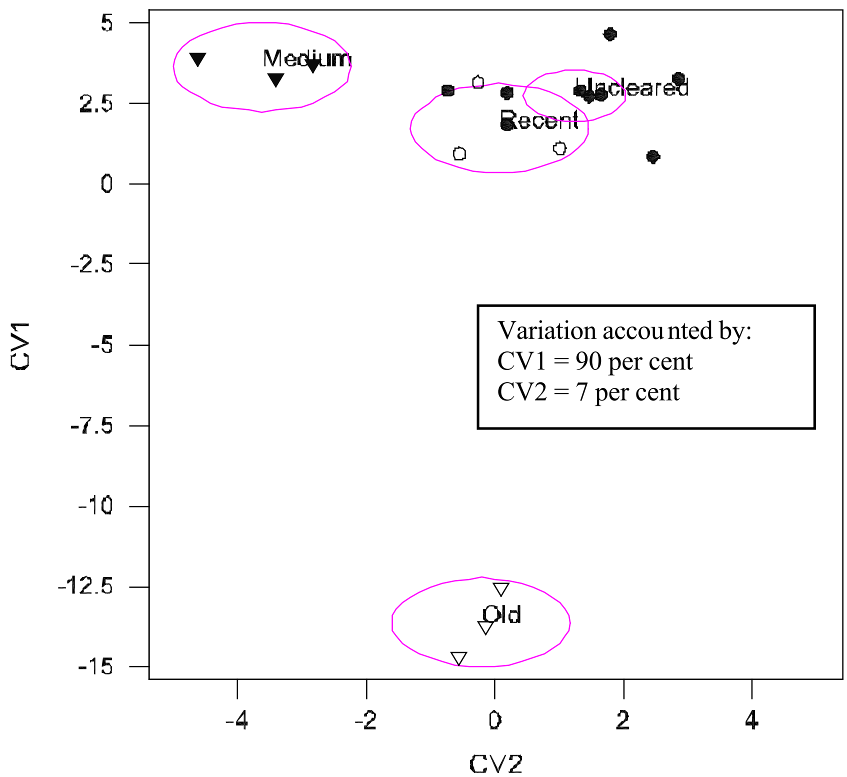

Fig 4. Relationship between first and second canonical variates for cleared (recent, medium and old) and uncleared treatments (with 95 per cent confidence regions around means).

A further 7 % of the variation between cleared and uncleared pasture systems was explained by CV2. CV2 showed that the medium cleared treatment was different to the recent and old cleared, and uncleared treatments (Fig 4).

Overall, the CVA suggested that clearing destabilises pastures over time, especially at old age, for change in soil pH_w, soil nutrients and loss of pasture plant diversity. The increase in pasture yields at medium clearing occurred at the cost of species diversity and some soil functions. The differentiation of results between different clearing ages indicates that post-clearing systems are not stable, and will deteriorate over time.

6. Discussion

Tree clearing generates financial private benefits, but the gains depend upon the type of tree community, age of clearing and soil condition. The earlier studies (Burrows 1993, Burrows *et al.* 1999, and Scanlan and Burrows 1990) suggested increase in pasture yield with clearing, for cleared pastures of <15 years old. This led the land holders with wrong assumption that the initial gains will continue over time of clearing, and ignored the ecological impacts of clearing. The present study suggests that the increase in financial gains from clearing is not sustainable, and that there may be longer term declines in pasture production and ecosystem functions associated with clearing. It was also notable that where this woodland had been cleared for more than 30 years, pasture production was lower than in the uncleared woodland areas.

The results from modelling economic returns demonstrate that clearing does generate high returns in *E. populnea* and *A. harpophylla* communities (but not in *E. melanophloia*), despite the potential impact of lost ecosystem services on pasture production. The discounting effect means that the future losses are small compared to productivity gains if considered over a short term, while the losses from ecosystem functions would be higher and gains in pasture yield will be small if considered over a longer term. The results also demonstrate that there are likely to be net on-farm economic losses from clearing (scenic beauty, loss of diversity).

Most importantly, the experiment results indicated that there were a range of losses in ecosystem functions associated with clearing activities, the implications of these are discussed in detail by Sangha *et al.* (2005b). The key ecological tradeoffs associated with clearing activities appear to be:

- Declines in pasture plant diversity which may affect ecosystem stability;
- Reduced return of nutrients, which can imbalance the nutrient cycle in cleared pastures; and
- Changes in soil properties that could, by implication, affect the growth of pasture species over a longer term.

A key issue is whether landholders take clearing decisions by considering the private gains and ignoring the public costs for loss of ecological services. A second issue is whether different decisions would be made by landholders if they were better informed about the longer term impacts on ecosystem functioning and productivity that might result from clearing activities.

Tree clearing leads to long term gains in private benefits (in *E. populnea* and *A. harpophylla*) and these benefits occur at the cost of ecological services which are responsible to maintain various ecosystem functions (such as soil mineralization to make nutrients available for plant growth). The total gains in private benefits may in fact represent the opportunity cost of lost ecosystem services. This cost is high for fertile soils as in *A. harpophylla,* followed by *E. populnea*. However, there would also be future costs to repair the degraded system, so the actual total cost of lost ecological functions would be equal to opportunity cost + cost of repair (of degraded ecosystem services). This suggests that clearing will result in negative returns over a long term. It is important to note that the cost of clearing is much higher in *E. melanophloia* where the net returns are negative after initial 5 years of clearing, in addition, there are costs associated with loss of ecosystem functions.

If clearing is preferred for private gains, then, in the long term the cleared land would become barren, of no use. Such evidences exist in parts of Southern parts of Australia (National action plan for salinity, 2003) where the landholders harvested the private benefits and ignored the cost of lost ecosystem services. A lesson should be learnt from such examples for the landholders in Queensland so as to consider the cost of ecological losses when clearing land for private benefits.

All the ecological costs are not easy to measure in monetary terms as we could do for the private benefits. This makes it difficult for the landholders to consider these costs while making clearing decisions. However, the ecological impacts could be analysed or modelled to show their impact on private returns. Canonical Variates Analysis in the present study suggests that clearing destabilises the ecosystem functions at the old age which indicates that the private benefits will be reduced/no longer available. Similarly, these impacts could be modelled for their impact on net private benefits, and the landholders could be informed about the long term negative ecological impacts of clearing in terms of their private gains.

There are some conflicts in terms of use of discount rate for pasture gains and for ecological services. The net private benefits from pasture yield decrease with time at >0% discount rate. The cost to ecosystem services, in fact, will increase with time, since the disturbance in one ecosystem function affects the other, and system becomes more complicated and degraded. Therefore, the value of lost ecological services from clearing will increase with time while the private benefits will reduce.

These results should also be viewed in a wider context for other parts of the world where tree clearing occurs to enhance pasture production. The case study reported in this research was in an area where dryland salinity is not expected to be a consequence of clearing, as common in southern parts of Australia where cleared land has turned saline. If dryland salinity were a consequence, the net on-farm benefits of clearing would be expected to be lower. The economic modelling results are focused on providing a more accurate economic assessment of the net on-farm impacts of clearing activities. A broader economic assessment of clearing options would also need to assess community values for biodiversity losses and social impacts.

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