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Benefits or Losses from Clearing Trees to Develop Pastures in Central Queensland, Australia?

[1]Kamaljit Kaur, [2]John Rolfe and [3]Owen Stanley
[1]Natural Resource Economist, Economics Program, School of Business, James Cook University, Townsville, Queensland 4811, Australia
[2]Faculty of Business and Law, Central Queensland University, Rockhampton, 4702
[3]Economics Program, School of Business, James Cook University, Townsville, Queensland 4811, Australia

Abstract: Clearing trees to develop land for exotic pastures that enhance pasture production and hence the financial gains, is an important issue in Queensland. Gains from clearing woodlands are questioned. Three tree communities i.e. *Acacia harpophylla, Eucalyptus melanophloia* and *Eucalyptus populnea* were selected at three different ages of clearing i.e. 5 yr, 11-13 yr and 33 yr to collect the data on pasture production, soil properties (biological and physicochemical), litter production and nutrient recycling and pasture plant diversity over 2-3 year period of the study. The net economic gains from clearing in terms of pasture production were compared to uncleared pastures and assessed against the tradeoffs of ecological services. The increase in pasture production post-clearing was not consistent with age of clearing. A bioeconomic model, applied to predict pasture production over the 50 years of time of clearing, though suggested economic benefits, however, it is difficult to predict how the loss in ecosystem functions in cleared pastures (> 30 years of clearing), by implication, affect pasture yield over time.

Key words: Cleared and uncleared pastures, pasture production, ecological services, economic gains and losses, tree clearing, tradeoffs, tropical pastures

INTRODUCTION

Tree felling/clearing or deforestation to develop productive agricultural systems is a significant issue of concern for the global community. Worldwide, each year 13 million ha of forests are lost[1]. In 2001, Australia ranked sixth with the average 564,800 ha of land cleared per year during 1990-2000 and about 75 per cent of the total clearing in Australia occurred in Queensland[2]. In Queensland, an average of 471,000 hectares were cleared each year over the last 15years (during 1988-2003), with 90-95 % of cleared land developed to improve pastures[3]. Pastoralism is the main industry for Queensland, contributing about $3.7 billion in 2002-2003 to the total state economy[4]. Development of land for pastures was highly favoured by various governmental policies from the beginning of the last century until 1985[5,6]. To increase pasture yield, hence the financial returns, was the main reason for landholders to clear land. In the process of developing ‘productive’ pasture systems, much of cleared area was sown to various exotic grasses especially buffel (*Cenchrus ciliaris* L.) and these exotic species performed well to capture the flux of nutrients available upon clearing that led to their fast growth[7]. Due to large scale cultivation of a few exotic grasses, a monoculture set of pastures has been created on most of the cleared land[8,9,10]. 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.

Recently, there has been increasing levels of control by the State Government over clearing activities (Vegetation Management Act 1999[11]), culminating in controls on freehold land from the 1st of September 2004. This placed a cap on the total area in the state 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 still unclear how economical it is to clear vegetation over a long term and that in particular for marginal soils, when long term ecological impacts are considered[12]. It is also unclear whether clearing activities trigger changes in ecosystem functioning that could increase the risk of losses in future production.

Corresponding Author: Kamaljit Kaur, Natural Resource Economist, Economics Program, School of business, James Cook University, Townsville, Queensland 4811, Australia

The present study quantifies the productive gains (including financial returns from pastures) and ecological impacts (in terms of soils, plant diversity and productivity) over a longer time of clearing in the central Queensland region. For this, three major woodland communities i.e. Brigalow scrubs (*Acacia harpophylla*), Box woodlands (*Eucalyptus populnea*) and Ironbark woodlands (*Eucalyptus melanophloia*) were selected on one property. The cleared pastures were taken at three different times of clearing: i. recent (<5 years), ii. medium (11-13years) and iii. old (>30 years) 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 and private costs of clearing activities associated with biodiversity loss, soil erosion, soil nutrient loss and nutrient loss through litter recycling are discussed. To assess the overall value of tree clearing activities for the community, the net private benefits of clearing activities are compared to the public costs resulting from the clearing activities.

MATERIALS AND METHODS

The case study-central queensland: 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 each site of the 18 sites, a representative area of 1 ha (of the total 5-10 ha area for different sites) was selected. At the centre of the selected 1 ha area, a fenced plot of 10 m x 10 m (an exclosure to exclude cattle) was established to determine pasture above-ground biomass and composition (pasture species diversity). 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 °C for 48 hours to determine their biomass. The average quantity of pasture above-ground biomass available 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 any change in soil directly impact on pasture production. In the experiment, 8 soil samples were taken randomly per site from 1 ha marked area in January 2002 using a hydraulic soil rig. The samples were taken at different depths (0-5, 5-10, 10-20, 20-30 and 30-60 cm). All the samples of one site were bulked and processed for analysis at the soil laboratories of Incitec Ltd (Brisbane) for soil organic carbon (SOC), pH_w (1:5 soil: Water) and for available N (NO_3^-) and P. 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 at the Natural Resource Sciences Laboratories (Department of Natural Resources, Mines and Energy, Indooroopilly, Brisbane, Queensland). Further details of these methods used are reported by Sangha[13].

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 (same sampling timings as for pasture measurements) at unfenced sites using the paired-plot technique[14]. 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, species data and litter production were analysed applying the Residual Maximum Likelihood (REML)[15] method, using Genstat version 6[16]. 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. 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 soils, the REML procedure was also used to identify if the key attributes explained variations in the soil data.

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

The CVA determines the overall effect of clearing, as well as identifies 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.

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). Thus, confirmed that vegetation clearing generates pasture production gains. However, the gains in pasture biomass were not consistent over time-since-clearing and followed a decline at old compared to medium age of clearing in *E. populnea* and *A. harpophylla* communities. In *E. melanophloia,* such a decline in pasture yield was evident even after recent age of clearing (Fig. 1).

Financial value of pasture yield, at the time when measurements were taken in 2003 (excluding tax, discount rate and cost of clearing), was certainly improved with clearing (Fig. 2). A relationship between dry matter consumption and weight gain was assessed using the feed relationship[17]. 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

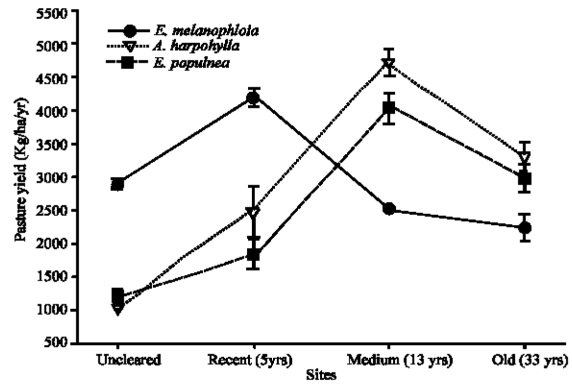

Fig. 1: Average pasture yield (kg/ha/year) with standard error bars for various cleared and uncleared treatments for *E. melanophloia, A. harpophylla* and *E. populnea* communities

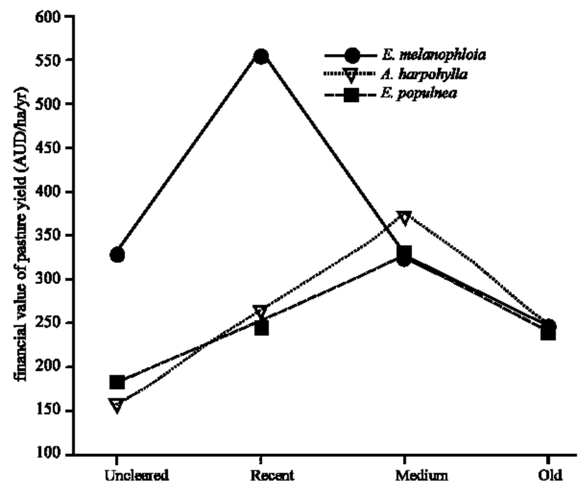

Fig. 2: Financial value of pasture yield for various cleared and uncleared treatments for *E. melanophloia, A. harpophylla* and *E. populnea* communities

above 500 kg ha^{-1} 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 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). The financial gains from increase in pasture yield with clearing, indeed, narrowed with age i.e.

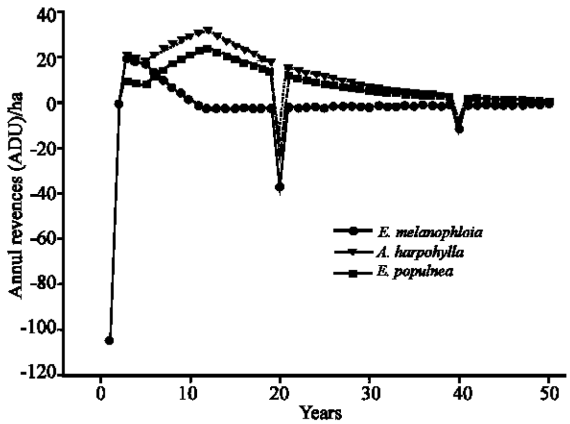

Fig. 3: Annual revenues (net present value at 6% discount rate) from clearing over 50 years for *E. melanophloia, A. harpophylla* and *E. populnea* communities

after 13 years of age in *E. populnea* and *A. harpophylla*, while this period was very short (5 years) in *E. melanophloia*.

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 will be the associated public costs?

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. 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.
- Decline in pasture yield continues until 50 yrs time at the same rate as from medium to old age of clearing (such trend was evident from the field surveys and data).
- The cost of clearing is $150/ha and similar costs are applied after every 20 years of clearing (at the 20th and the 40th years) to control regrowth and to maintain soil functions (ploughing 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 occurred in *E. populnea* and *A. harpophylla* until 30-35 years of clearing (Fig. 3). After this, the returns from clearing were minimal in these tree communities. However, the scenario

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

Table 2: Number of plant species at uncleared and at recent, medium and old age cleared treatments of *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

is different in *E. melanophloia* where annual returns were the maximum at 5 years of clearing and then followed a downward trend with losses from the 10th year of clearing onward.

Overall, the net private benefits for 50 years of clearing were 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 were negative, suggesting loss from clearing (Table 1) and thus a decline a land value. The Figs in Table 1 suggested 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 delivered positive returns, though lesser than cleared land, with the maximum returns in *E. melanophloia* (Table 1).

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

Public and private costs: There are both public and private costs associated with tree clearing for loss of ecological services. For public, these costs represent loss of species, landscape scenery and degraded soils with gullies. There is also loss of productive potential of a landscape for the present and future generations (such as decline in pasture yield[17]).

The private costs include loss of future production gains in addition to the public costs as mentioned above. 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 lose production potential of land and will incur further costs to repair the degraded land. Moreover, the cleared land under grazing will erode easily that could pollute the downstream waterways and may have serious impacts over a catchment scale (e.g. depletion of reef or fish in waterways) (as demonstrated in some studies in Queensland by the Department of Natural Resources and Mines and other institutions[18-20] and overseas[21,22].

Each of these losses further disturbs the equilibrium in natural processes which are responsible to carry out various ecosystem functions[23,24]. For example loss of plant diversity disturbs nutrient utilization as each species has its own requirement to use a particular amount of a nutrient. Diverse species complement each other for resource use and thus leads to efficient resource use compared to a monoculture[25]. Similarly, diverse systems are generally considered robust to tolerate pest invasion than monocultures[26]. In monoculture pastures, as established on pasture lands post clearing, such nutrient complementarity is lost and run-down of nutrients take place that leads to decline in pasture yield with age of clearing[27,17]. The soil processes that mineralise the organic matter to release nutrients are also affected with change in microbial composition that occur as a consequence of land clearing and changes in vegetation cover[28].

The major ecological losses associated with clearing are:

- Loss of pasture plant diversity
- Loss of soil nutrients
- Loss of litter and nutrients returned through litter decomposition

In the present study, these losses were quantified onsite (private losses) for each of the three communities and are discussed as follow:

Pasture plant diversity: Species diversity was significantly lesser at cleared compared to uncleared treatments in all the tree communities (Table 2), the details are discussed elsewhere[10]. With clearing, the diversity of native plant species was compromised for high production gains from exotic grass species in cleared pastures. Thus the opportunity to use native species in the future to explore and research their productive potential becomes limited and this will result in their increased option value.

Nutrient loss and changes in other soil properties with clearing: Tree clearing had no major effect on available content of N (NO_3^-), P and soil organic carbon, but there was an overall decline at old age of clearing[13]. However, clearing strongly influenced soil pH_w across all tree communities[28]. Soil pH_w increased significantly ($p<0.05$) with age of clearing across all tree types and such an increase in pH_w had adverse effects on the availability of various nutrients in cleared pastures.

Soil Microbial Biomass (SMB) is an important ecological indicator of soil health, as 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)[13].

Available N, available P, soil organic carbon, soil microbial biomass and soil pH_w are important soil properties and any change in them could trigger further changes in other soil processes. For example, changes in soil microbial biomass would lead to a change in mineralisation and availability of nutrients for plant growth, or change in pH will affect the availability of nutrients for plant growth. The experimental results suggested the changes in soil properties at cleared pastures could further complicate the natural processes that adversely impact upon future production gains.

Litter production and nutrient return: The total amount of litter produced over a year 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 suggested that the amount of nutrient available for plant growth will become limited in cleared sites. Details of nutrient return through litter are discussed elsewhere[29]. The recently cleared pastures support fast grass growth since the nutrients were released upon clearing, while with age of clearing not many nutrients would recycle for lesser litter production than that in uncleared pastures. This leads to changes in natural processes and nutrient run down with age of clearing in cleared pastures.

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

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

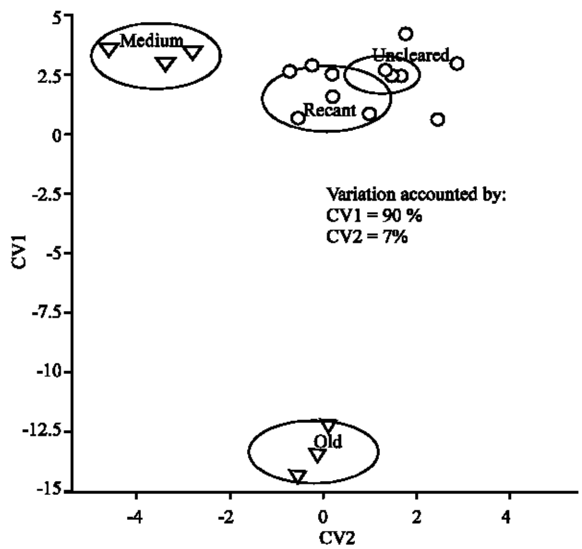

Fig. 4: Relationship between first and second canonical variates for cleared (recent, medium and old) and uncleared treatments (with 95% confidence regions around means)

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 the medium and recent clearedand uncleared treatments (CV1 explained 90 % 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.

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 clearedand uncleared treatments (Fig. 4).

Overall, the CVA suggested that clearing destabilises pastures over time, especially at old age of clearing. The differentiation of results between different ages of clearing indicates that post-clearing systems are not stable and will deteriorate over time.

DISCUSSION

Tree clearing generates financial private benefits, however these benefits depend upon the type of tree community, age of clearing and soil condition and such specifications were largely ignored when tree clearing was considered to promote pasture development in the 1950s till late 1980s. The earlier studies[20-32] suggested an increase in pasture yield with clearing, although the age for cleared pastures was <15 years and the ecological effects of clearing were invariably ignored. This led the land holders with the assumption that the initial gains will persist over time of clearing and without any long term ecological impacts. In contrast to the previous studies, the present study suggested that the increase in financial gains from clearing was not sustainable and that there were declines in pasture production and ecosystem functions over a longer term (> 30 years) of clearing. In natural systems, it is difficult to identify changes in a short time of 10-15 years since the natural systems have a resilient capacity and the changes takes time to appear but once the system is altered then the costs to repair the system could be too high and involves a lot of time. In the present study, where woodland had been cleared for more than 30 years, pasture production was lower than in the uncleared woodland areas, in particular for *E. melanophloia*.

The results from modelling the economic returns indicate that clearing does generate high returns in *E. populnea* and *A. harpophylla* communities, but not in *E. melanophloia*. 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 (loss of floral diversity, nutrient recycling and loss of soil). Thus, to account for total net benefits from clearing for pasture development, it is also important to consider the negative ecological effects that could impact on future production gains.

There are a range of losses in ecosystem functions associated with clearing activities. 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.

No doubt tree clearing led to gains in private benefits (in *E. populnea* and *A. harpophylla*) but these benefits occurred 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, or soil hydrological balance to keep the salt levels low). 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.

A key issue is whether landholders take clearing decisions by considering the private gains and ignoring the public costs for loss of ecological services or even their private costs which have future implications. This will have many negative repercussions in the future for resulting in degraded/barren land, soil salinity or acidity and a permanent loss of native species that could prove useful in pasture improvement. If clearing is preferred for private gains over 50 years, then, the cleared land would become barren, of no use after that time (as demonstrated from the change in ecological condition of pastures, Fig. 4); the time to repair degraded land could be actually much longer time than the time taken to harvest benefits. Such evidences exist in Southern parts of Australia[33] 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 and their future repercussions when clearing land for private benefits.

Another 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. It is important to note that to estimate the cost of lost ecosystem services is rather difficult since the natural processes that provide ecosystem services are interconnected, vary with climate, soil or vegetationand a minute change in one process can trigger a big change in others. Moreover, the ecological costs are not easy to measure in monetary terms as could be done for the private benefits due to imperfect markets. 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 or no longer available with age of clearing. Similarly, these impacts could be modelled for their impact on net private benefitsand the landholders could be informed about the long term negative ecological impacts of clearing in terms of losses in their private benefits.

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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