Asia Pacific School
of Economics and Government

WORKING PAPERS

AUSTRALIAN NATIONAL UNIVERSITY

International and Development Economics

An economic assessment of the role of commercial tree crops to achieve greenhouse gas neutrality in predominantly grazing systems of south-western Australia

Elizabeth H. Petersen,
Steven Schilizzi,
David Bennett

02–8

Asia Pacific School of Economics and Government
THE AUSTRALIAN NATIONAL UNIVERSITY

http://apseg.anu.edu.au

© Elizabeth H. Petersen, Steven Schilizzi, David Bennett 2002

Abstract
The results of this analysis show that a long-term tree crop plantation is effective at reducing carbon emissions from a predominantly grazing farming system. However, if the plantations are destumped, much of the carbon will be returned to the atmosphere in time, in which case benefits are confined to their ability to 'buy time' for the development of less-polluting technologies. The accreditation of commercial tree crops may provide a socially and politically feasible solution for medium-term environmental policy. The benefits of the policy would be strengthened if implemented in conjunction with salinity abatement policy.

Asia Pacific School of Economics and Government
THE AUSTRALIAN NATIONAL UNIVERSITY

http://apseg.anu.edu.au

An economic assessment of the role of commercial tree crops to achieve greenhouse gas neutrality in predominantly grazing systems of south-western Australia[†]

Abstract

The results of this analysis show that a long-term tree crop plantation is effective at reducing carbon emissions from a predominantly grazing farming system. However, if the plantations are destumped, much of the carbon will be returned to the atmosphere in time, in which case benefits are confined to their ability to 'buy time' for the development of less-polluting technologies. The accreditation of commercial tree crops may provide a socially and politically feasible solution for medium-term environmental policy. The benefits of the policy would be strengthened if implemented in conjunction with salinity abatement policy.

Elizabeth H. Petersen, National Centre for Development Studies, The Australian National University, Canberra ACT 0200, Australia

Steven Schilizzi, Agricultural and Resource Economics, Faculty of Agriculture, University of Western Australia, Nedlands WA 6907, Australia

David Bennett, NRMC Pty Ltd (Natural Resource Management Consultants), PO Box 217, North Fremantle WA 6159, Australia

Keywords: Greenhouse gas abatement; whole-farm modelling; commercial trees

Contributed paper presented at the 46th Annual Conference of the Australian Agricultural and Resource Economics Scoiety, Canberra, 13th – 15th February 2002

[†] The authors gratefully acknowledge the helpful comments of anonymous reviewers and the financial support of Agriculture Western Australia. This paper was.

1. Introduction

Many scientists claim that atmospheric concentrations of greenhouse gases have increased markedly due to human activity, such as the burning of fossil fuels, land clearing and agricultural production. These scientists argue that increases in atmospheric greenhouse gases are having a discernible impact on climatic conditions, especially global warming (Intergovernmental Panel for Climate Change 2001). Concern for the risks of human induced climate change, and the realisation that addressing the issue requires an international co-operative effort, led to the establishment of the United Nations Framework Convention for Climate Change. One of the most significant initiatives of the parties to the Convention is the Kyoto Protocol, an agreement that requires ratifying countries to restrict emissions to a specified percentage of 1990 emissions (United Nations Framework Convention on Climate Change 1997). Australia is a signatory to, but has not ratified, the Protocol. If ratified, Australia will have to restrict emissions to 108 percent of 1990 levels in the first commitment period of 2008 to 2012. Most Australian emissions have their source in the burning of fossil fuels (53 percent in 1990, 55 percent in 1996); however, agriculture is the second biggest contributor (16 percent in 1990, 20 percent in 1996). Ruminant livestock are the greatest source of emissions in the agricultural sector, contributing 70 percent of agricultural emissions (although emissions from livestock decreased by 5.1 percent from 1990 to 1998 (NGGI 1998a), mostly due to the drop in sheep numbers associated with the drop in wool price).

This analysis specifically focuses on the Great Southern region of Western Australia, a region with relatively high-rainfall compared with other agricultural regions in the state. Petersen et al. (2001) found that, in the absence of carbon sinks, there are few economically feasible management options for greenhouse gas abatement in the region due to the dependence of the system on ruminant livestock (typically 85 percent of the system is grazed). Any abatement policy would rapidly cause the present system to become unprofitable unless swift technological change provided alternative enterprises or reduced emission levels in current practices. Given current conditions, any abatement policy to decrease agricultural emissions in predominantly grazing systems is likely to be politically impossible.

The aim of this paper is to contribute to the environmental policy debate by assessing the viability of a commercial tree crop, specifically oil mallee, for greenhouse gas abatement on mixed cropping enterprises in Western Australia. The introduction of a commercial tree crop is considered to be an example of a technological change; however, the use of forests and other plantations as carbon sinks under the Kyoto Protocol is a contentious issue (as the Sixth Conference of the Parties to the United Nations Framework Convention on Climate Change at The Hague (COP6) demonstrated). The properties of trees as a carbon sink are not yet well understood and are difficult to define and measure. In addition, certain signatories to the Protocol are resisting the inclusion of trees as sinks on the grounds that it allows parties to continue the burning of fossil fuels at a higher rate.

Another criticism of using trees as a carbon sink is that the effect is only temporary. Carbon will be released into the atmosphere at harvest and with the treatment of the harvested timber. However, defenders of this criticism argue that tree crops could permanently contribute to reductions in atmospheric carbon levels if they are used to replace products that take a lot of energy to produce, i.e. replacing steel, aluminium and cement with wood products. Irrespective of the time period for which the carbon is sequestered, it is generally argued that accrediting tree crops as carbon sinks will 'buy time' so that new less polluting technologies (such as alternative energy sources) can be developed (Shea 1999). The displacement of fossil fuels for energy generation cannot be counted as a benefit given that one source of carbon emitting fuel will be replaced by an approximately equivalent one.

In recognition of the argument that carbon sequestration from trees is temporary, only carbon sequestered by the trees in the long-term is considered in this analysis. It is assumed that each time carbon is removed from the farm through tree harvests, the on-farm pool of carbon is reduced by the same amount. Hence, it is assumed that all sequestered carbon is released again through time in the various uses of the biomass. This means that only the carbon sequestered by the trees during the six years before the first harvest (as subsequent harvests will be offset by the growth of trees prior to the next harvest), and the carbon accumulated in the rootstock, is used to offset other emissions on the farm. It is assumed that the planting of trees is permanent, although

benefits and costs are only calculated for a 30 year time period. In time, if the trees are destumped, the only abatement benefits from tree planting are from buying of time for the development of less polluting technologies (for example, solar and wind technologies).

Another benefit of reforestation is the possible reduction in the extent of dryland salinity. Along with biodiversity degradation, dryland salinity is the most important environmental problem facing Western Australia and has received much public attention (Western Australian Government 1998). Campbell et al. (2000) argue that the Great Southern region has the potential for being the region with the highest proportion of land affected by salinity in the state. Secondary dryland salinity is directly linked to Australia's history of land clearing that started with European settlement. It is caused by the increase of recharge into the soil profile causing the water table to rise and eventually to intercept the soil surface, bringing salt with it (Wood 1925). The impact of reforestation on recharge abatement in the Great Southern is also investigated in this paper as an extra benefit derived from reforestation.

The paper proceeds as follows. In Section 2 the methodology of the study is presented, giving a brief discussion of the tree crop species analysed (oil mallee) and the modelling techniques used. Results are presented with discussion in Section 3. Some conclusions are drawn in the final section.

2. Methods

The instrument of analysis is a linear programming model of a steady-state single-period representation of a farming system. Named MIDAS (Model of an Integrated Dryland Agricultural System), the model was originally developed for the Merredin region of Western Australia, but has since been calibrated for several other regions. MIDAS includes the relevant biological complexities and interactions between enterprises in a typical wool or wheat belt farming system by employing a whole-farm modelling framework (Pannell 1996). MIDAS has been used to analyse issues concerning greenhouse gas abatement (Petersen et al. 2001), farm management (Schmidt and Pannell 1996), agricultural policy (Morrison and Young 1991) and research (Pannell 1999).

The Great Southern region was chosen as, due to its soil-climate constraints, it supports a predominantly grazing farming system. Ruminant livestock contribute far more greenhouse gases than crops, especially non-irrigated crops. This region is approximately one million hectares in size with approximately 1000 farms of an average of 1100 hectares (Australian Bureau of Statistics 1997). Readers are referred to Morrison and Young (1991) and Young (1995) for detailed expositions of the nature and structure of the Great Southern MIDAS model (GSM) (which excludes accounting for greenhouse gas emissions). Petersen et al. (2001) present a detailed description of the developments made to the standard version of GSM to include greenhouse gas emissions. A brief description of GSM and the modelling of greenhouse gas emissions is presented in Section 2.1, and a detailed discussion of the inclusion of the tree crop in GSM is documented in Section 2.2.

2.1 Brief description of the Great Southern MIDAS

The Great Southern region of Western Australia typically has a Mediterranean climate with the majority of the annual rainfall (approximately 500 – 600mm) falling between April and the beginning of November. The production enterprises included in GSM are livestock (sheep) and crops (cereals, lupins and canola) with an average of 15 percent of land cropped in both the standard solution and observed field data. The model farm is highly mechanised which represents the nature of the Great Southern farming systems.

Soil types

The soil types are modelled in five land management units (LMUs, see Table 1). The LMUs display a range of fertility with the saline (LMU1) and waterlogged (LMU2) soils (25 percent of farm area) being the least fertile, and the sandy gravels (LMU4) being the most fertile (50 percent of farm area). Rotational options for the LMUs are presented in Table 2. LMUs 1 and 2 (25 percent of land) are *generally* not suitable for cropping and, although there are allowances in GSM, cropping on these soils is only rarely selected. Canola production is only suitable on the heavier soils LMUs 4 and 5 (70 percent of farm area). To increase the model's accuracy as a representation of reality, a number of interdependencies are represented in GSM. The three main interdependencies are the rotational benefits between phases in a rotation; the grazing

of stubble by sheep; and the subsequent grazing of remnant grain in the paddock after harvest.

[Table 1]

[Table 2]

Greenhouse gas emissions

Greenhouse gases are assumed to have four main sources: sheep in the form of methane (CH_4), nitrogenous fertiliser application in the form of nitrous oxide (N_2O), fuel use in the form of carbon dioxide (CO_2) and stubble burning (which creates a range of greenhouse compounds). All of these emission are modelled according to the National Greenhouse Gas Inventory (NGGI) published by the Australian Greenhouse Office (National Greenhouse Gas Inventory 1998a; National Greenhouse Gas Inventory 1998b; National Greenhouse Gas Inventory 1998c; National Greenhouse Gas Inventory 1998d). Emissions are converted to carbon dioxide equivalents (CO_2-e) through multiplication by their average global warming potentials. These relative potentials are presented in Table 3. For a detailed exposition on the modelling of greenhouse gas emissions in the GSM, the reader is referred to Petersen et al. (2001).

[Table 3]

Model characteristics

The objective of the model is to maximise farm profit where profit is defined to be net return to capital and management. It equates to residual income from production receipts after depreciation, operating overheads and opportunity costs have been deducted (the latter associated with farm assets exclusive of land). GSM is based solely on expected values (the first moment of the probability distribution) and therefore assumes risk-neutral decision-making. Model output indicates optimal (that is, profit-maximising) enterprise or rotational activity levels given CO_2-e emissions from each source.

2.2 Modelling of the commercial tree crop

Two species of commercial trees are considered to be suitable for the Great Southern region of Western Australia. Oil mallees are a group of *Eucalyptus* species with high oil content in their leaves that grow in the mallee form (many trunks forming a spreading habit). Oil mallees are native to Australia, being present in the original native bushland. They have potential as a short rotation tree crop producing

eucalyptus oil for the pharmaceutical industry as inhalants, soaps, gargles, lozenges, perfumery and disinfectants; and for the industrial industry as solvents and hand cleaners (Boland 1991; Barton and Knight 1997). The above ground biomass also has potential as a fuel for electricity production and for the manufacture of charcoal and activated carbon (Shea et al. 1998, Rural Industries Research and Development Corporation 1999). The mallees are harvested by cutting them off a few centimetres above the ground (Abbott 1989). The trees re-sprout from underground lignotubers using energy stored in these tubers (Canadell and Lopez-Soria 1998).

The second species of tree crop suitable for the Great Southern region is *Pinus Pinaster*, or maritime pine. Unlike oil mallees, maritime pines are not native to Australia (they are native to Portugal) but has been grown in Australia for more than 80 years. They require sandy, free draining soil (Shea et al. 1998). Hence, their use is limited to LMU3 (deep sands) that constitutes just five percent of GSM. Because of this limited area on which they can be planted, they are not included in this analysis.

Commercial plantings of oil mallee started in 1994 and more than 2.64 million trees have been planted to 1999 in the Great Southern. 1.5 million were to be planted in 2000 and 2.5 million are targeted for planting in 2001 (Grzyb et al. 2000). As yet the oil mallee industry is in its infancy with a 20,000 tonne demonstration-scale plant in Narrogin expected to consume most of the established mallees within 400 kilometres of the plant over the next few years. Upon successful completion of this demonstration, the plant is expected to expand to 100,000 tonne capacity in the subsequent five years, and up to nine full-scale plants (100,000 tonne capacity) are likely to be built in the low to medium rainfall agricultural region of south-western Australia (Rural Industries Research and Development Corporation 1999).

Oil mallees were included in GSM for this analysis as a source of income from their timber and eucalyptus oil products, and as a sink for greenhouse gases. They perform poorly on saline or waterlogged soils; hence they are modelled only on LMUs 3, 4 and 5 in GSM. The productivity of the mallees is assumed to be equivalent on each LMU with the assumption that different species will be grown on each soil type for maximum productivity. This assumption is realistic given that oil mallees are native and hence, well adapted to the soils and climate of the Great Southern region (Cooper

1999). Further, Wildy (2000) found that soil nutrient level had no effect on oil mallee growth rates in the Western Australian wheat belt, giving weight to this argument.

Economics and carbon sequestration rates

Establishment costs of the oil mallees are listed in Table 4. It is assumed that the farmer uses available farm labour to establish the trees, hence, no contracting labour requirement is included.[1] The benefits and costs of a 30-year rotation is assumed although, in reality, oil mallees can keep producing timber and oil indefinitely. However, for modelling purposes, the time frame needs to be specified. When modelling an enterprise where most benefits and costs are accrued in the future in a single-period model such as MIDAS, certain assumptions need to be applied. Firstly, it is assumed that the annuity is received at the end of the year, so that no interest on these benefits is received throughout the year. Secondly, future benefits need to be discounted by the real interest rate a farmer would face. The discount rate is equated to the real interest rate. The maintenance costs of the oil mallees presented in Table 5 are in nominal terms.

[Table 4]

[Table 5]

The typical proposed rotation for the oil mallees is to harvest first in year six and then every three years subsequently. Hence, in the 30-year life of the plantation, the crop will be harvested nine times. The average above ground biomass is 25kg/tree (Herbert 2000). Each subsequent triennial coppice is the same as the first harvest. Assuming a seeding rate of 2667 trees/ha, 9 harvests in the 30-year rotation and 25kg/tree, total biomass harvested is 600 tonnes/ha. The gross price received for the oil mallees is $30/t over the 30 years. However, transport, harvest and harvest coordination costs are approximately $15/t, hence the net price received is $15/t (Herbert 2000). This $15/t is received for all above ground biomass.

Financial returns of the oil mallees are presented in Table 6. The annuity is the present value of the benefits divided by the length of the rotation, and represents the average benefit received in each year. This is regarded as the annual gross margin of the tree enterprise. The gross margin of the sheep enterprise is typically between $70/ha and $200/ha depending on the class of sheep, wool and meat prices, grazing rotation and stocking rate. The main class of sheep is ewes sold at five years of age,

which have a gross margin of approximately $110/ha. Hence, the annuity of the oil mallees ($127/ha) is larger than the gross margin of the majority of the sheep enterprises, the main production activity of the GSM, and will be selected in preference to the sheep activities in the optimal (profit maximising) solution. The last of the financial return statistics, the internal rate of return (IRR), is the interest rate received for an investment. Hence, the interest rate received for money invested in oil mallees is 7.6 percent. This is higher than the interest received if the money was left in a bank (interest rates for a bank account is assumed to be six percent).

[Table 6]

Because research into carbon sequestration by plantations is still in its infancy, no data are available at present for oil mallees. Hence, sequestration rates were estimated through use of the following assumptions:

(1) Aboveground biomass production is a sigmoid function resulting in 25kg/tree at first harvest (year 6);

(2) Aboveground biomass in the first year after is 6kg/tree, the second year after coppice is 15 kg/tree, and the third year after coppice is 25kg/tree prior to the next coppice (McCarthy pers. comm. [2]);

(3) Dry weight of the aboveground biomass is 50 percent of the wet weight (Shea 1999);

(4) Carbon weight of the biomass is 50 percent of the dry weight (Hassall and Assoc 1996); and

(5) Belowground biomass is 20 percent of aboveground biomass (Hassall and Assoc 1996).

Given these assumptions, and converting carbon weight to carbon dioxide weight (by multiplying by approximately 3.5)[3], the carbon dioxide sequestration rates for oil mallees (including above ground biomass to the first harvest and all below ground biomass) are presented in Table 7. These rates (277t CO_2/ha over 30 years and 9t CO_2/ha annually) are low compared with those quoted in the literature[4]. However, it is considered safer to err on the side of caution given the uncertainty still surrounding the properties of tree crops as carbon sinks.

[Table 7]

2.3 Recharge flows from the system

Recharge values for each rotation are presented in Table 8. Values were obtained using the AgET Water Balance Calculator[5], using rainfall data for Kojonup for the years 1954 to 1993. The first author, in consultation with Paul Raper[6], specifically created data files that matched the biological and physical characteristics of the GSM LMUs. The recharge values depend on the type, number and order of crop and pasture phases in each rotation. Recharge is assumed to be negligible under oil mallees given that studies have demonstrated that recharge under native vegetation is less than one mm per year (Allison et al. 1990; Kennett-Smith et al. 1992; Salama et al. 1993). Although tree plantations may not mimic native vegetation which includes a combination of pasture and trees, a large number of hydrologists and agronomists estimate that trees will lower water tables and therefore recover saline and waterlogged land. Hence, the assumption of zero recharge under tree plantations is reasonable.

[Table 8]

3. Results and Discussion

This section comprises three parts. Firstly the economic performance of oil mallees in the Great Southern region is presented (Section 3.1). Secondly, the economics of oil mallees for greenhouse gas abatement is discussed (Section 3.2). Thirdly, the recharge abatement value of greenhouse gas abatement policies is demonstrated (Section 3.3).

3.1 Economic performance of the tree crops in the Great Southern

Figure 1 presents farm profit for increasing areas of oil mallees under different wool prices. Firstly, farm profit, especially in the absence of oil mallees, is highly dependent on wool price. This is not surprising given the dependence of the system on sheep production (85 percent of the farm is typically allocated to sheep production). Secondly, the optimal area of land planted to oil mallees increases with decreasing wool price. This occurs as the farm substitutes oil mallees for sheep production as the profitability of the sheep enterprise decreases. Optimal mallee area for each wool price is 50ha (450c/kg greasy), 93ha (400 c/kg greasy), 250ha (350 c/kg greasy) and 594ha (300 c/kg greasy). Note that the optimal area of oil mallees depends on the farmer's attitude towards risk. A formal risk analysis is not included here, but it follows that a risk-averse farmer would assume a high wool price when

deciding on the optimal area of land to plant to oil mallees due to the irreversibility of the planting decision. This should also be equated with the riskiness of the tree crop enterprise including price, production, flood and fire risks. Further discussion of decision-making under risk and uncertainty could be the topic of another paper.

[Figure 1]

It is clear that it is profitable to plant part of the farm to oil mallees even at a high wool price. At the highest wool price (450c/kg greasy) it is optimal to plant all of LMU3 (deep sands) to the mallees. LMU3 is less suited to crop and pasture production than LMUs 4 and 5, hence the opportunity cost of growing mallees on LMU3 is the smallest. With decreasing wool price, it is optimal to plant more mallees on LMU 5 and then LMU 4, as the opportunity cost of planting the mallees on LMU5 is less than that of LMU 4. Note, also, that for all soil types and wool prices, mallees generally replace both crop and pasture land simultaneously, although the rate of replacement is faster on cropped land than pasture as cropping is the less profitable of the two enterprises. The medium term forecast of wool price is currently 400c/kg greasy[7]. All subsequent results will be presented assuming this forecast price.

Sensitivity analysis

Results presented so far have assumed the financial details presented in Table 6. Now consider a sensitivity analysis on these financial assumptions. Figure 2 is a presentation of the impact of varying the annuity on farm profit with different oil mallee areas. Farm profitability is highly sensitive to this annuity, especially with relatively large areas of land allocated to the mallees. It is important to note that while farm profit is increased substantially with increased mallee annuity, the mallee enterprise becomes unprofitable on all soil types if the annuity is decreased. It must be remembered for all subsequent results that mallee production is profitable under present or more optimistic financial assumptions but is unprofitable under less optimistic financial assumptions.

[Figure 2]

Results presented so far are dependent on the relative areas of each LMU. A sensitivity analysis on these relative proportions is not included here; however, it is clear that a farm with greater proportions of the productive LMUs (i.e. 4 and 5) would be more profitable than farms with greater proportions of the more marginal LMUs (i.e. 1, 2 and 3). Additionally, the commercial potential of oil mallees would be larger

for a more marginal farm (at least one with a higher proportion of LMU3) due to the smaller opportunity cost of crop or livestock production associated with marginal land compared with productive land.

3.2 Greenhouse abatement options in the presence of commercial tree plantations

Petersen et al. (2001) found that in the absence of on-farm greenhouse gas sinks, any farm-level policy for greenhouse gas abatement would have dramatic negative consequences on the farm enterprise, and without technological change, would cause the current farming systems to fail and be replaced by alternative land-uses. However, Petersen et al. (2001) found an emissions restriction policy (one where the farmer is legally required to restrict emissions) to be more effective and efficient than a policy of taxing emissions. With the emissions restriction policy it was found that farmers were able to remain profitable while abating up to 48 percent (850 t CO_2-e) of their emissions levels by substituting pasture for crop on the most productive soil types (LMU 3, 4 and 5). Note that the farmers are not financially compensated for meeting these restrictions. A policy of restricting greenhouse gas emissions is the tool considered in this section.

The impact of varying levels of emissions restrictions on profit with and without the inclusion of a tree crop is presented in Figure 3. As was found by Petersen et al. (2001), in the absence of tree crops, the farm falls to zero profits at a level of 48 percent abatement. In the presence of oil mallees as a carbon sink, farm profitability changes little with higher levels of abatement. The profit-maximising area of mallees is 93 hectares, where the trees sequester 70 percent of total emissions from other farm enterprises (sheep, nitrogenous fertilisers and fuel use). This is about 11 percent of the farm area with the given LMU distribution. The area of oil mallees needed for the farm to be emissions-neutral is 166 hectares, 17 percent of farm area (sequestering 1745 t CO_2-e). Farm profit decreased by less than $800 to reach greenhouse neutrality in the presence of tree crops (which is still higher than optimal farm profit without trees or greenhouse gas emission restrictions). A sensitivity analysis on sequestration efficiencies was conducted, and although results are not presented here, they showed that these findings are robust. Areas of oil mallees required for emission neutrality vary little with moderate changes in sequestration efficiencies.

[Figure 3]

Consider now the impact of emissions restrictions on land use (Figure 4). In the absence of mallees, pasture area decreases with increasing abatement as the farm substitutes out of pasture production into crop production, a relatively more efficient enterprise in terms of greenhouse gas abatement than pasture production. At an approximately 90 percent abatement level the system substitutes back into pasture production but removes livestock from the system (crop production emits more gases than pasture production in the absence of livestock), hence the upswing at the end of the curve in Figure 4. However, the farm is made unprofitable at an abatement level of 48 percent at which the system fails and, in the absence of technological advancement, would be replaced by alternative land-uses. In the presence of the accreditation of tree crops as carbon sinks, land-use changes only marginally, even at 100 percent abatement levels.

[Figure 4]

So far it has been assumed that farmers are not compensated for restricting emissions. Petersen et al. (2001) found that it would cost the regulator approximately A$3.5 million a year in subsidies to achieve approximately 50 percent abatement in the Great Southern alone. If commercial plantations were credited as a source of sequestration, implementing such a policy would virtually be costless to the regulator as optimal areas of these plantations exceed areas required for 50 percent (or even 70 percent abatement) with current or more optimistic financial assumptions. Also, the value of the tree crops is increased in the presence of this policy and would be especially so if tradeable emission permits were permitted. Such a mechanism is likely to encourage faster growth of the tree crop industry in the Great Southern of Western Australia. Expansion in tree crop areas has external benefits other than greenhouse gas abatement, one of which is salinity abatement.[9]

Abatement of recharge[10]

It is not suggested here that a policy should be introduced with the aim of decreasing greenhouse gas emissions and soil water recharge simultaneously. This would be breaking the policy rule of only using one policy instrument to achieve the one policy objective. Tinbergen (1952) notes that there is no guarantee of achieving more than one policy objectives with one policy instrument, it is likely that none of the

objectives will be achieved efficiently. What is being investigated here is the impact of a greenhouse gas abatement policy on recharge abatement.

First consider the impact of recharge abatement on farm profit (Figure 5). In the absence of tree crop production, it is only possible to abate 35 percent of recharge as no enterprise uses all the rainfall. Farm profit is relatively insensitive to low levels of recharge abatement. At approximately 20 percent abatement, profit decreases relatively quickly as the system substitutes into more crop intensive enterprises due to their relative recharge abatement efficiency (see Table 8). When mallee production is introduced, farm profit is maximised at a level of approximately 17 percent recharge abatement where 93 hectares of oil mallees are planted. Greater levels of abatement come at a cost. Note that it is still not possible to abate 100 percent of recharge as only 75 percent of land is suitable for commercial oil mallee production. A maximum of 88 percent of recharge can be utilised at a cost to the farmer of approximately A$15,000 per year (25 percent of optimal farm profit). Note that 88 percent recharge abatement in the presence of a commercial plantation comes at a comparable cost to 35 percent recharge abatement in the absence of a commercial plantation.

[Figure 5]

The effect of recharge abatement on land use is illustrated in Figure 6. First consider the impact of recharge abatement on pasture area in the absence of oil mallees. To achieve 35 percent abatement, pasture area decreases by approximately 200 hectares (or 20 percent), and is replaced by crop production. In the presence of oil mallees, a similar decrease in pasture production is required to achieve 35 percent recharge abatement, however, this abatement comes at a profit rather than a cost as pasture is replaced by the more profitable oil mallee enterprise. As stated earlier, a high proportion of recharge is possible in the presence of oil mallees, although this requires the majority of the farm to be set aside for tree production.

[Figure 6]

4. Conclusions

This study focuses on the predominantly grazing systems of the Great Southern region of Western Australia. The one tree crop suitable for widespread production in the region was analysed. Oil mallees, a native to the region, were found to be a profitable enterprise. The lower the wool price, the larger the profit-maximising area planted to oil mallees. This is understandable given the reliance of the system on

sheep production. Farm profit was found to be sensitive to the oil mallee annuity. At standard and increased annuity, farm profit increased. However, decreases in the mallee annuity caused decreases in farm profit highlighting the importance of the financial assumptions for all subsequent results.

With the inclusion of an emissions restriction policy, the system was found to fall to zero profits at 48 percent abatement in the absence of the tree crop. In the presence of the tree crop, farm profitability varies little with increasing levels of abatement. The optimal area of oil mallees was 93 hectares (less than 10 percent of the farm area) leading to annual carbon dioxide sequestration volume of 1125 tonnes, 70 percent of total emissions. The area of oil mallees needed for the farm to be emissions-neutral is 166 hectares, 17% of farm area (causing farm profit to decrease by less than $800). The accreditation of tree crops as carbon sinks (especially in the presence of emission trading) is likely to increase their profitability and hence, lead to expansion of area allocated to commercial plantations in Western Australia, in turn further increasing greenhouse gas sequestration. Additionally, this study shows that the recharge abatement value of tree crops is substantial.

The accreditation of tree crops as carbon sinks is a contentious issue. The results of this analysis show that a long-term tree crop plantation is effective at reducing emissions from a predominantly grazing farming system. However, if the plantations are destumped in time, then it is likely that most of the carbon will be returned to the atmosphere, and benefits are confined to the ability to 'buy time' for the development of less polluting technologies. Hence, the accreditation of tree crops has limited carbon abatement benefits. However, if the Australian government introduces a greenhouse gas abatement policy that includes the agricultural sector, in the absence of accreditation of trees as carbon sinks, predominantly livestock farming systems are likely to fail, making the policy all but politically impossible. In this case, the accreditation of commercial tree crops as part of medium-term government environmental policy may provide a socially and politically feasible solution. This environmental policy would have greater benefit if used in conjunction with the government's salinity abatement policy, where the positioning of the tree crops in the landscape will be a defining factor in the policy's success.

This paper has focused on the role of commercial tree crops for greenhouse gas abatement in south-western Australia. An interesting extension to this work would be to analyse the economics of non-commercial tree plantations in these farming systems. O'Connell (1999) found that the cost associated with establishing enough non-commercial trees to significantly impact on recharge in the eastern wheatbelt of Western Australia is likely to lead to negative profits. Although Hassall and Assoc (1999) found that carbon farming is only profitable when associated with commercial trees, the Protocol may increase their value enough for more widespread plantings of trees than is happening now for environmental purposes.

Petersen et al. (2001) and this analysis have focused on greenhouse gas abatement in the predominantly *grazing* systems of south-western Australia. Further analysis should focus on similar studies of the predominantly *cropping* systems of south-western Australia. Predominantly cropping systems are not so dependent on ruminant livestock and may have other options for cost-effective greenhouse gas abatement, such as stubble retention, lowering or changing fertiliser inputs, lowering fuel use and minimum tillage. Howden et al. (1994) found these options just mentioned to be cost-effective and efficient at reducing emissions for the Wimmera region of Victoria. Furthermore, commercial or non-commercial plantations are not so prevalent in the predominantly crop-based farming systems of Western Australia east of the Great Southern Region studied here, due to rainfall constraints. Accreditation of trees as carbon sinks may add sufficient value to the trees to encourage expansion of tree plantings in these areas.

References

Abbott, P.S. 1989, 'Commercial Eucalyptus oil production', in *Eucalyptus oil production*. Gnowangerup, Western Australia, pp. 29-48.

Australian Bureau of Statistics 1997, *Agstats: Small Area Agricultural Commodity Data*, Perth.

Australian Greenhouse Office 1999, *National Emissions Trading: Issuing the Permits*, Canberra.

Allison, G.B., Cook, P.G., Barnett, S.R., Walker, G.R. and Jolly, I.D. 1990, 'Land clearance and river salinisation in the Western Murray basin, Australia', *Journal of Hydrology*, vol. 119, pp. 1-20.

Barton, A.F.M. and Knight A.R. 1997, 'High cineole eucalypts in degreasing applications', *Chemistry in Australia*, vol. 64, pp. 4-6.

Boland, D.J. 1991, 'Brief history of the eucalyptus oil industry and essential oil research in Australia', in Boland, D. J., Brophy, J. J. and House A. P. N. (eds.), *Eucalyptus leaf oils: use chemistry, distillation and manufacturing*, Inkata Press, Canberra, pp. 3-10.

Canadell, J. and Lopez-Soria, L. 1998. 'Lignotuber reserves support regrowth following clipping of two mediterranean shrubs', *Functional Ecology*, vol. 12, pp. 31-38.

Campbell, N., George, R., Hatton, T., McFarlane, D., Pannell, D., van Bueren, M., Beetson, B., Caccetta, P., Clarke, C., Evans, F., Ferdowsian, R. and Hodgson, H. 2000, *Using Natural Resource Inventory Data to Improve the Management of Dryland Salinity in the Great Southern, Western Australia*, National Land and Water Resources Audit, Implementation Project 2, Theme 2 - Dryland Salinity.

Cooper, D. 1999, *An economic analysis of oil mallee industries in the wheatbelt of Western Australia*, unpublished Masters thesis, Agricultural and Resource Economics, University of Western Australia, Perth.

Grzyb, H., Mcleod, P., Sutherland, B. and Safstrom, R. 2000, *Great Southern Regional Wood Processing Industry Capability Study*, Report prepared for Timber 2002.

Hassall and Assoc 1996, *Sequestration of Atmospheric Carbon Dioxide in Trees*, Report prepared for the Australian Nature Conservation Agency.

Hassall and Assoc 1999, *Greenhouse, Carbon trading and Land Management*, Land and Water Resources Research and Development Corporation, Canberra.

Herbert, A. 2000, *Economics of oil mallees*, Agriculture Western Australia South, Perth.

Howden, S.M., White, D.H., McKeon, G.M., Scanlan, J.C. and Carter, J.O. 1994, 'Methods for exploring management options to reduce greenhouse gas emissions from tropical grazing systems', *Climatic Change*, vol. 30, pp. 1-19.

Intergovernmental Panel for Climate Change 2001, *Climate Change 2001: The Scientific Basis - Summary for policy makers*, Report prepared by Working Group 1 of the Intergovernmental Panel on Climate Change, Shanghai.

Kennett-Smith, A.K., O'Leary, G.J. and Thorne R. 1992, *Estimation of recharge from soil water profiles under dryland agriculture, Eucalyptus plantation, an natural woodland in the Wimmera district of Victoria*, Rep. No. 92/2, CSIRO Division of Water Resources, Canberra.

Morrison, D. A. and Young, J. 1991, 'Profitability of increasing lambing percentage in the Western Australian wheatbelt', *Australian Journal of Agricultural Research*, vol. 42, pp. 227-241.

National Greenhouse Gas Inventory 1998a, *National Greenhouse Gas Inventory Fact Sheet 4: Agriculture*, Australian Greenhouse Office, Canberra.

National Greenhouse Gas Inventory 1998b, *Workbook for Livestock*, Australian Greenhouse Office, National Greenhouse Inventory Committee, Canberra.

National Greenhouse Gas Inventory 1998c, *Workbook for Non-Carbon Dioxide Gases from the Biosphere*, Australian Greenhouse Office, National Greenhouse Inventory Committee, Canberra.

National Greenhouse Gas Inventory 1998d, *Workbook for Transport Mobile Sources*, Australian Greenhouse Office, National Greenhouse Inventory Committee, Canberra.

O'Connell, M. 1999, *The Impact of Non-Commercial Trees on Groundwater Recharge and Farm Profits in the Eastern Wheatbelt*, Agriculture Western Australia, South Perth.

Pannell, D. J. 1996, 'Lessons from a decade of whole-farm modelling in Western Australia', *Review of Agricultural Economics*, vol. 18, pp. 373-383.

Pannell, D. J. 1999, 'On the estimation of on-farm benefits of agricultural research', *Agricultural Systems*, vol. 62, pp. 123-134.

Petersen, E.H., Schilizzi, S. and Bennett, D. 2001, 'An assessment of policy options for greenhouse gas abatement on mixed cropping enterprises in the Great

Southern of Western Australia', paper presented at the *45th Annual Conference of the Australian Agricultural and Resource Economics Society*, Adelaide, 22-25 January (Submitted for publication in *Agricultural Systems)*.

Rural Industries Research and Development Corporation 1999, *Integrated tree processing of mallee eucalypts.*

Ritson, P. 2000. Data from unpublished PhD thesis, Department of Conservation and Land Management, South Perth.

Salama, R.B., Farrington, P., Bartle, G.A. and Watson, G.D. 1993, 'Salinity trends in the wheatbelt of Western Australia: results of water and salt balance studies from Cuballing catchment', *Journal of Hydrology*, vol. 145, pp. 41-63.

Schmidt, C. and Pannell, D. J. 1996, 'Economic issues in management of herbicide resistant weeds', *Review of Marketing and Agricultural Economics*, vol. 64, pp. 307-308.

Shea, S. 1999, 'Farming Carbon', in *Landscope Tree Crops for Farms*, Department of Conservation and Land Management, South Perth, pp. 36.

Shea, S., Butcher, G., Ritson, P., Bartle, J. and Biggs, P. 1998, 'The potential for tree crops and vegetation rehabilitation to sequester carbon in Western Australia', paper presented at the *Carbon Sequestration Conference*, Melbourne, 19-21 October.

Tinbergen, J. 1952, *On the Theory of Economic Policy*, Elsevier, North Holland.

United Nations Framework Convention on Climate Change 1997, 'Kyoto Protocol to the United Nations Framework Convention on Climate Change', available from the UNFCCC website: http://www.unfccc.de/.

Western Australian Government 1998, 'Environment Western Australia 1998 State of the environment report', Department of Environmental Protection, Perth.

Wildy, D.T. 2000, 'Sapling and coppice biomass production by alley-farmed 'oil mallee' *Eucalyptus* species in the Western Australian wheatbelt', *Australian Forestry*, vol. 63, pp. 147-157.

Wood, W. E. 1925, 'Increase of salt in soil and streams following the destruction of native vegetation', *Journal of the Royal Society of Western Australia*, vol. **X**, pp. 35-47.

Young, J. 1995, 'MIDAS: Model of an Integrated Dryland Agricultural System: Manual and Documentation for the Great Southern Model Version GS92-3', Centre for Legumes in Mediterranean Agriculture, Nedlands.

Footnotes

[1] It is assumed that the opportunity cost (and marginal cost) of labour for tree esablishment is zero as the farmer does the planting when no other work is required on the farm. The farmer's labour is costed as a yearly salary not dependent on the individual tasks he or she carries out.

[2] Andrew McCarthy, Department of Conservation and Land Management (CALM), South Perth.

[3] This is done by multiplying the carbon weight by the atomic weight of carbon dioxide (44) and dividing by the atomic weight of carbon (12).

[4] Shea et al. (1998) quote average annual sequestration rate of oil mallees (including above and below ground biomass) to be 114t/ha, but do not offer an explanation for how they obtained this number. This is more than double the calculations made in this analysis (45t/ha) when above and below ground biomass is considered.

[5] AgET was developed by Agriculture Western Australia and The University of Melbourne. It can be obtained from the Agriculture Western Australia website: http://www.agric.wa.gov.au/

[6] Paul Raper, Research Hydrologist, Agriculture Western Australia, Bunbury

[7] This was the forecast at the time the paper was written.

[8] Note that the assumed sequestration rates are low compared with those estimated in the literature. Hence, optimal areas of oil mallees here are over-estimated if anything.

[9] Analysis of maritime pines for carbon sequestration in the region was also analysed although results are not presented here. It was found that maritime pines are not profitable under current financial assumptions, although their carbon sequestration efficiency is superior to that of oil mallees.

[10] In this section we have not included the changes in area of LMU2 (waterlogged), as this would require MIDAS to contain a spatial analysis of recharge effects. This is beyond the ability of the model in its current configuration.

Table 1 GSM soil types

Soil class	Description	Area (ha)
LMU1 (Saline soils)	Shallow saline sands over heavy gleyed or mottled clay.	100
LMU2 (Waterlogged soils)	Deep sands often waterlogged over grey gleyed clay.	150
LMU3 (Deep sands)	Deep sands but not waterlogged over mottled clay.	50
LMU4 (Sandy gravels)	Gravels and sandy gravels to 50cm over clay or gravelly clay.	500
LMU5 (Sandy loams)	Sandy loam, loamy sand over clay; rock outcropping in landscape.	200
		Total = 1000

Table 2 Rotational options in GSM

Rotations on all land management units[a]	Rotation on land management units 4 and 5 only (70 percent of area)
PC, PPC, 4PC, 8PC, 5PCC, 5PLC, 5PCCC, 5PCLC, PPPP, 5PS	5PNC

[a] P=Pasture, C=Cereal, L=Lupin, S=Fodder Crop, N=Canola

Table 3 Global-warming potential of greenhouse gasses relative to carbon dioxide

	Greenhouse Gas				
	CO_2	CH_4	N_2O	CO	NMVOC[a]
Global-warming potential relative to CO_2	1	21	310	1	1

Source: Australian Greenhouse Office (1999)

[a] Non-Methane Volatile Organic Compounds

Table 4 Establishment costs ($/ha)

Site preparation	30
Delivery of plants	35
Ripping, mounding and scalping	150
Pest management	5
Weed control	70
Seedlings	720[a]
Planting	0
Total	1020

[a] Assuming 2667 seedlings/ha at 27c per seedling

Table 5 Nominal maintenance costs ($/ha)

Year of cost	Cost description	Nominal maintenance cost
1	Cost of replanting if failure [a]	51
1	Pest control	10
1	Weed control	35
Harvest years	Weed control	35
Each year	Maintenance of firebreaks	5
Each year	Insurance	5
Total		**791**

[a] Five percent of establishment cost

Table 6 Financial returns

Discounted total costs ($/ha)	1385
Discounted total returns ($/ha)	3136
Net present value @ 6% ($/ha)	1751
Annuity ($/ha) [a]	127
IRR (%)	7.6

[a] The annuity can be equated with the gross margin of the enterprise.

Table 7 Carbon dioxide sequestration rates oil mallees

Total CO_2 sequestration over 30 years (t CO_2/ha)	277
Average annual CO_2 sequestration (t CO_2/ha)	9

Table 8 Recharge levels for each rotation in GSM (mm/year) [a]

	LMU1	LMU2	LMU3	LMU4	LMU5
PC	5	5	57	49	28
PPC	11	6	61	55	31
4PC	13	7	62	55	31
8PC	17	9	64	58	32
5PCC	12	8	57	56	28
5PLC	12	8	57	56	28
5PCCC	12	8	57	49	28
5PCLC	12	8	57	49	28
PPPP	17	15	65	60	33
5PS	14	8	62	57	32
5PNC				56	28
Oil mallees	0	0	0	0	0

[a] Note that the Great Southern aquifers have a storage coefficient of between 0.1 and 0.2, so that 10mm of recharge equates to 50 to 100mm groundwater rise.

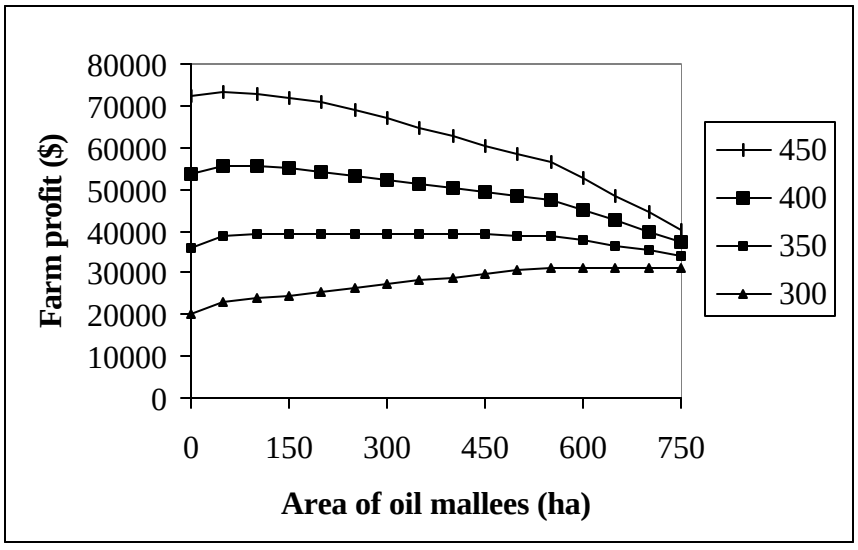


Figure 1 The impact of the introduction of oil mallees on farm profit for varying wool prices (wool price is in c/kg greasy) in the absence of any greenhouse penalties

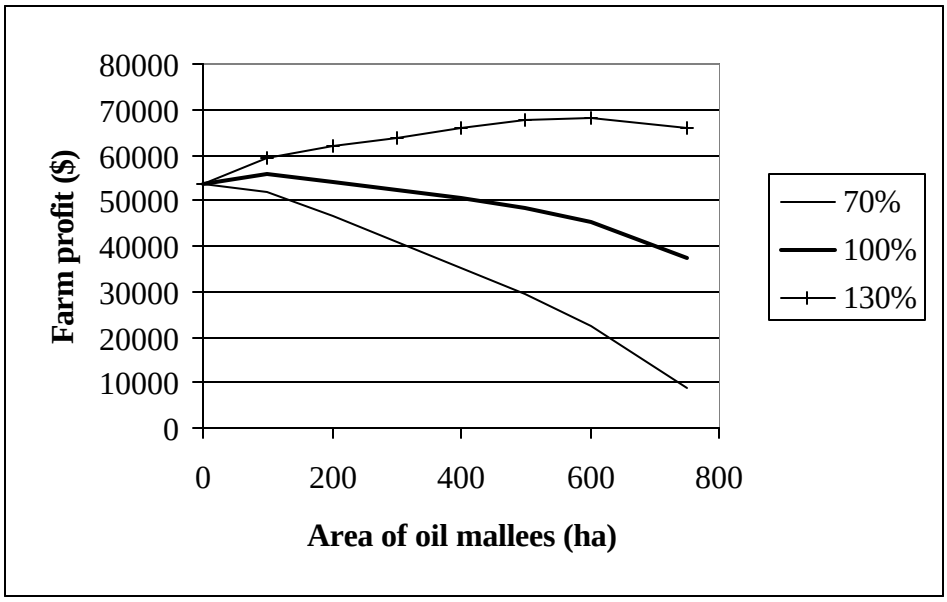


Figure 2 Sensitivity on oil mallee annuity

Note: Sensitivity includes 70, 100 and 130 percent of the oil mallee annuity of $127/ha.

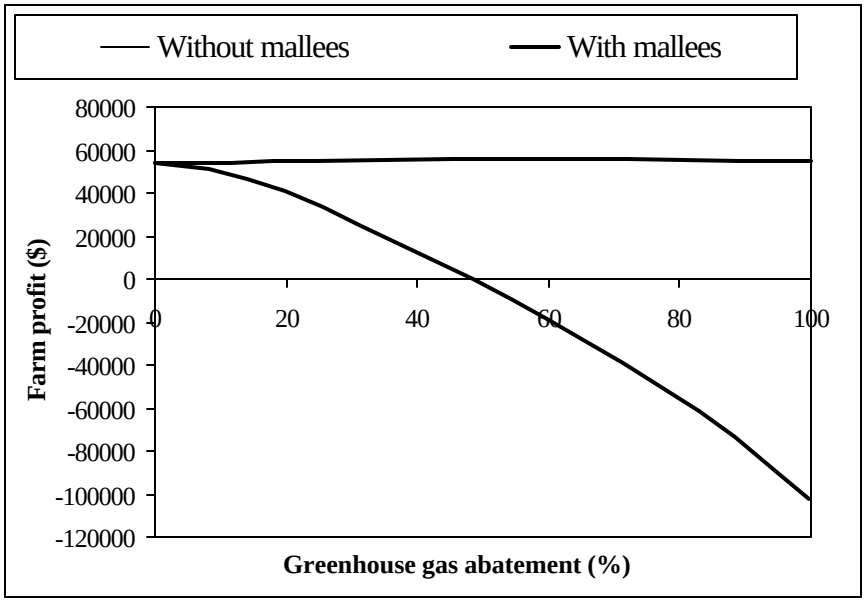


Figure 3 The impact of greenhouse gas abatement on farm profit

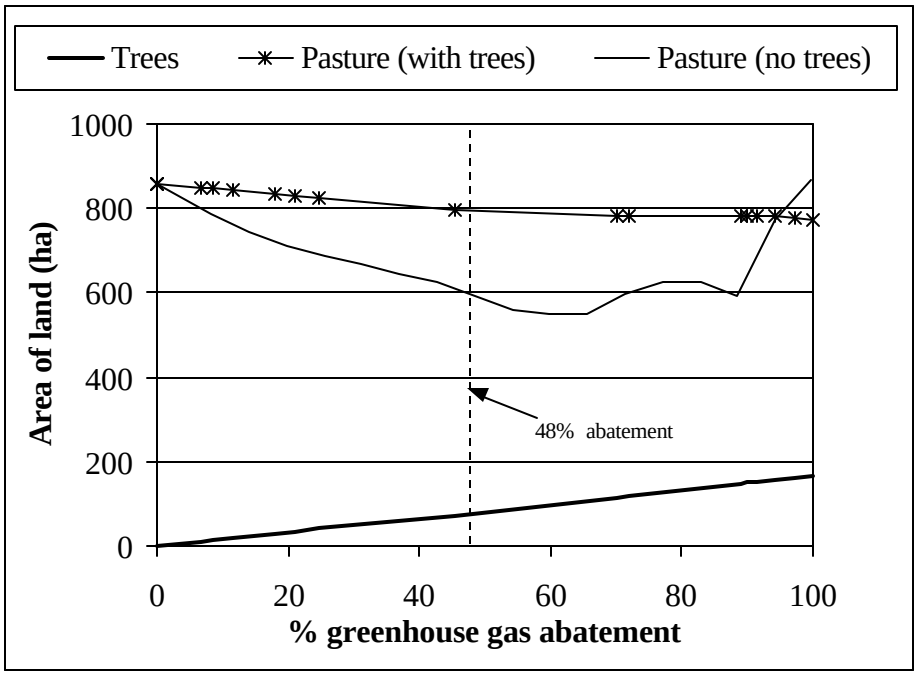


Figure 4 Land use with different levels of greenhouse gas abatement

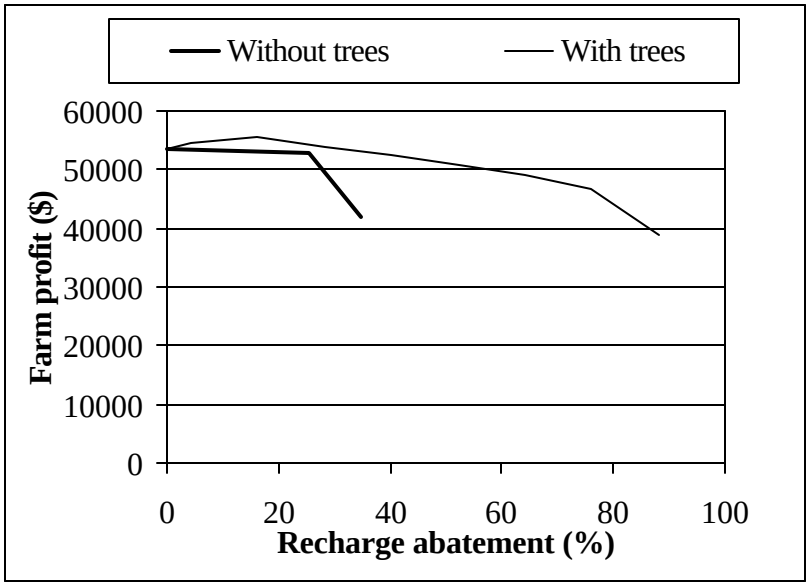


Figure 5 The effect of recharge abatement on farm profit

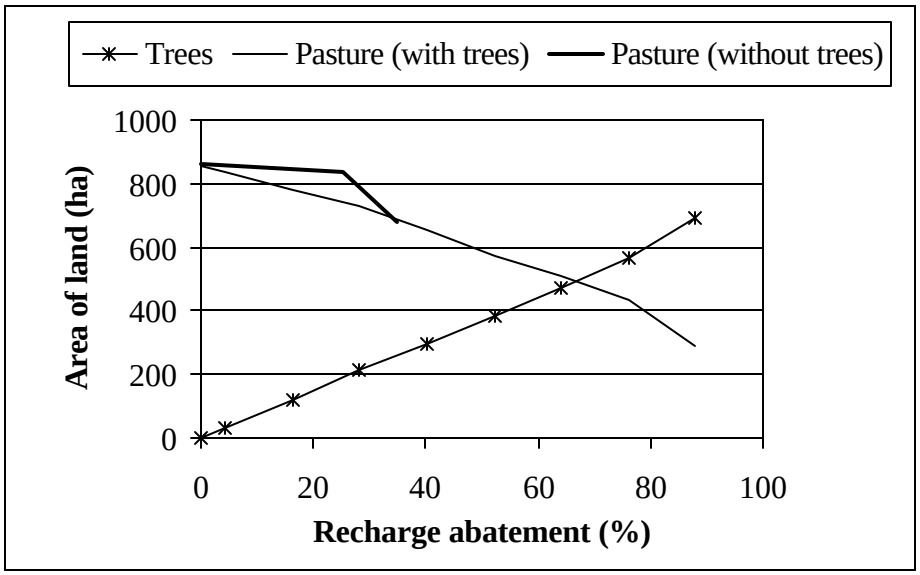


Figure 6 The effect of recharge abatement on land use