THE REGIONAL ECONOMIC IMPACTS OF INTRODUCING DUAL FUNCTION FORESTRY INTO AN AGRICULTURAL LANDSCAPE

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ABSTRACT: A greenhouse gas emissions abatement scheme that includes payments for sequestration could encourage the establishment of plantations in agricultural areas, which could in turn, change regional economic output. This study is an examination of the regional economic impacts of establishing woodlots for both timber production and carbon sequestration in an Australian agricultural region. Financial and spatial analyses are used to identify where this dual function forestry might be more profitable than current land use while input-output tables and direct expenditure projections are used to estimate regional impacts. Results suggest there will eventually be an increase in gross regional output if a sustainable timber production system was to be established. However there would be a decrease in output during the first plantation cycle despite the injection of emissions credit payments.

In 1996 the Australian Ministerial Council on Forestry, Fisheries and Aquaculture set a timber plantation target of 3.3 million hectares (ha) to be established by 2020 with 'farm forestry' expected to comprise up to 390,000 ha (12 percent) (Centre for International Economics, 1997). To achieve the 2020 farm forestry target, it was expected that plantations would need to be established beyond the high-rainfall areas of eastern, south-eastern and south-western Australia (Centre for International Economics, 1997; National Forest Inventory, 1997) where most large-scale plantations are located. Further to that, the 2000 Low Rainfall Forestry Strategy (National Farm Forestry Roundtable, 2000) included a proposal for an incremental extension of plantations from coastal/hinterland areas into nearby agricultural regions. It had previously been argued that an expansion of forestry into such regions would contribute to economic diversification and an increase in regional output (National Plantations Advisory Committee, 1991).

The plantations in these inland agricultural areas, were not expected to be as profitable as the large-scale plantations in the higher rainfall zones but they could provide a range of environmental benefits (AACM International, 1996; Binning *et al.*, 2002; Buffier and The Allen Consulting Group, 2002). A number of reviews proposed that the development of an inland farm forestry sub-sector could best be facilitated by a system of supplementary payments for environmental services (PES) (Hassall and Associates, 1999; State Forests of NSW and Commonwealth Bank, 1999; Pritchard and Donaldson, 2000; van Bueren, 2001; Binning *et al.*, 2002; Buffier and The Allen Consulting Group, 2002), along the lines of schemes such as those operating in Costa Rica (Pagiola, 2002; Pagiola *et al.*, 2004). In Costa Rica payments from utility corporations, the national government and international development organizations are 'bundled' together into a single-stream of income to landholders (Pagiola, 2002; Pagiola *et al.*, 2002). In this scheme the Government is both a buyer of services and a regulator, creating the requirements for resource users to purchase various forms of offsets.

In Australia, the early enthusiasm for multi-function PES schemes was not realised, as Federal governments did not really move beyond funding research and development, demonstration plantations and regional planning activities for small-scale plantations (Donaldson and Gorrie, 1996; Donaldson, 2001), while some state forestry agencies engaged in joint ventures with private landholders. In the meantime, large-scale managed investment schemes became the main driver of timber investment, accounting for 34 percent of the national plantation estate, largely located in higher rainfall areas (Bureau of Rural Sciences, 2009). The potential for an environmental payments scheme re-emerged in 2008 with the proposal for a national Carbon Pollution Reduction Scheme (CPRS). This scheme was to allow reforestation activities to be eligible for sequestration credits which could then be sold to offset greenhouse gas emissions. Hence, dual function forests could provide income from carbon sequestration during the growing period and income from timber, less the estimated value of greenhouse gas releases, at harvest time.

Researchers from the Australian Bureau of Agricultural and Resource Economics (ABARE), using Australian Treasury price modelling, developed some scenarios to speculate about the potential for Australian farmland to be converted to forestry if the CPRS were to be introduced (Lawson *et al.*, 2008; Burns *et al.*, 2009). Even under the most ambitious scenario with the higher target for emission reduction and the higher starting price for emissions permits (\$28/tCO_2-equivalent), the researchers expected that most plantations for timber would remain in the higher rainfall areas because of the higher growth rates and established processing infrastructure (Burns *et al.*, 2009). Nonetheless, as with the low-rainfall strategy, they suggest there might be some limited expansion into areas adjacent to current production zones (Lawson *et al.*, 2008). The study region for this analysis is one such area with the advantage of existing timber processing businesses that were developed for native forest timber.

For this study, the prospect of the CPRS led to some revision of earlier work that started to examine the potential for a multi-benefit PES. The first part of the study ran from 2000 to 2005 in the wake of the early enthusiasm for such schemes. However with no programs or regulations to reveal services prices and no concrete policy proposals, work was suspended. With the prospect of a carbon market, the work was revised in 2010.

For the first stage of the modelling, there is a financial analysis of a set of example farms to estimate the impact of switching from current land uses to timber-only (single function) plantations. Then the potential sequestration volumes in carbon dioxide equivalent (CO_2-e) for the plantations are estimated using the FullCAM modelling software (Richards and Evans, 2005). Third, the ‘carbon’ price is derived from two things: the initial CPRS starting price proposed by the Australian Government in 2010 (\$10/tCO_2-e hereafter \$10/t) and Australian Treasury/ABARE modelling which postulated a price increase of 4 percent per year (Burns *et al.*, 2009). This price trend and the sequestration over the plantation life cycle are combined to estimate the total additional income from sequestration. This identifies situations where dual function forestry might displace current land uses. From that, *ArcView* 3.2 GIS software is used to identify potential plantation areas, based on soil fertility and current land use. The resources data and timber growth rates are then used to estimate changes in gross output if dual function plantations were included in the agricultural landscapes. The resulting production data are then entered into input-output (I-O) tables which are used to estimate impacts on regional incomes, output and employment.

1. STUDY SITES AND PRODUCTION DATA

The spatial analysis was conducted in the Hodgson Creek Catchment (watershed), hereafter the study site and the resulting land use change estimates were included in an I-O model for the whole study region, which is the Eastern Downs in south-east Queensland (see Figures 1 and 2). The availability and cost of comprehensive spatial data and the time required to process images mandated a restricted spatial analysis, and hence the use of a subset of the greater region as a study site for more detailed investigation. This site covers 81,842 ha and is 9.7 percent of the study region (842,705 ha). The location and main features of the site are shown in Figure 1. The study region comprised seven local authorities, since formally amalgamated into one regional council, with economic data from those shires aggregated and included in a regional I-O table. Figure 2 shows the Eastern Downs region and the location within that of the Hodgson Creek Catchment. The regional rainfall range is 640-840 mm per year and landscapes are heavily modified for crop and livestock production. There is both summer and winter rainfall and a mix of dryland and irrigated cropping, intensive animal industries and extensive beef production.

Most timber plantations in the southern part of Queensland are east of the study region in the 820+ mm/yr areas, given rainfall requirements and proximity to timber processing infrastructure (Davey *et al.*, 2006). The eastern-most part of the study region is however just in the zone that was targeted for the state forestry agency's (Forestry Queensland) hardwood joint ventures (Forestry Plantations Queensland, 2007). The region in question also contains salinity hazard areas (Figure 1) and is therefore a target for what has become known as 'commercial environmental forestry', whereby timber species are to be encouraged to be planted so as to lower the relevant water tables (Davey *et al.*, 2006).

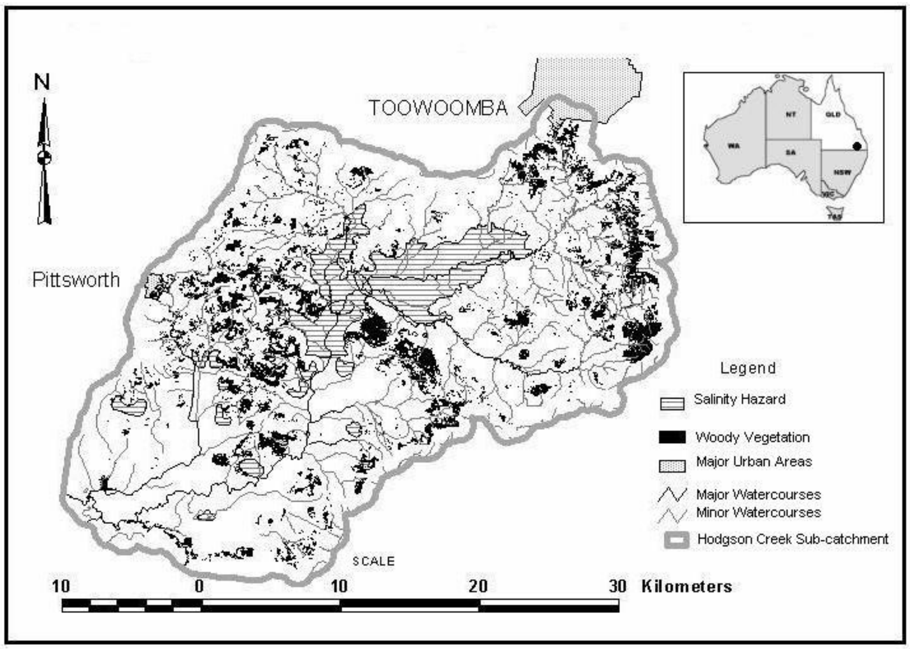

Figure 1. Hodgson Creek Catchment Location and Features. Source: the Authors

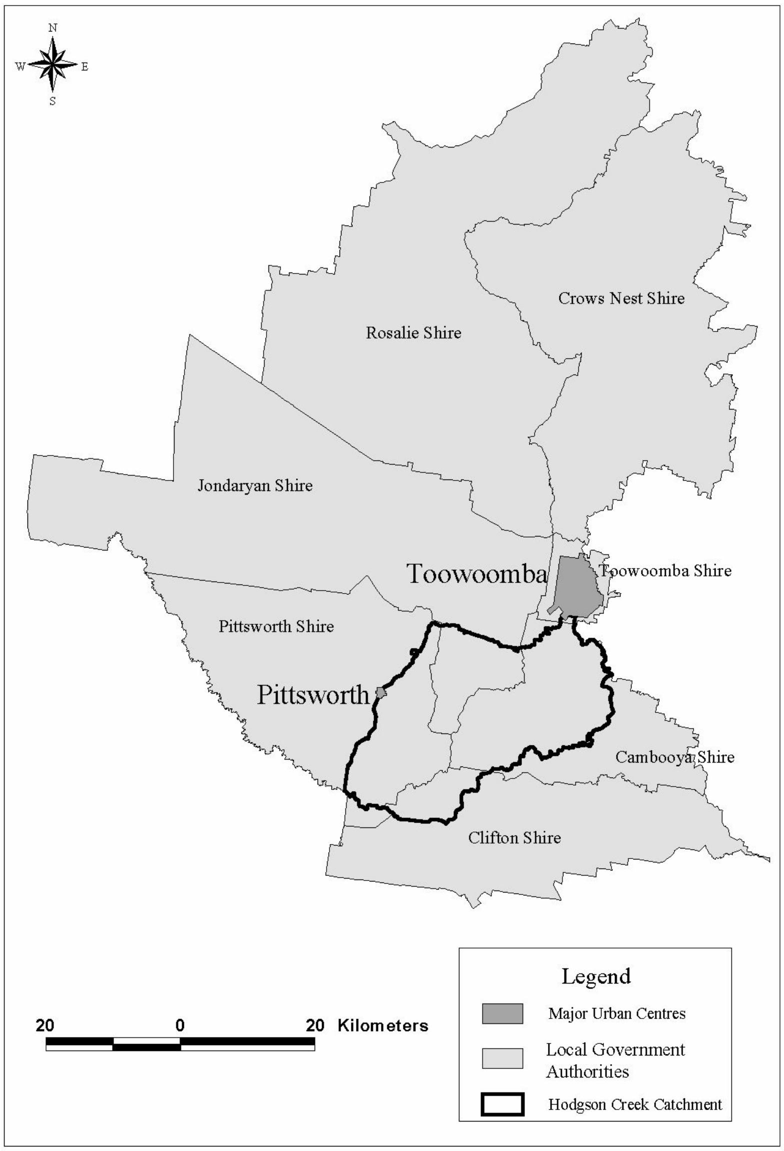

Figure 2. Study region and study site. Source: the Authors

The native hardwood plantation species used to develop the production part of the model are the frost tolerant western white gum *(Eucalyptus argophloia)* for lower lying areas and spotted gum *(Corymbia citriodora* subs. *variegata)* for the upper slopes (Bailey, 2001). Production data for these species are very limited (Venn, 2005) but a growth curve and final yield for spotted gum has been extrapolated from plantation and native forest measurements (Maraseni, 2007), though for slightly more favourable conditions just to the north of the study region. From this work, the optimum economic harvest point (timber only), on fertile soil, was approximately 31 years (Maraseni, 2007 p. 170), in line with Venn's (2005) estimate of 30 years derived from expert opinion. Maraseni however, calculated the optimum harvesting point with carbon values, at a price of \$10/t CO_2-e (2007 terms), as being 34 years. For this analysis, a 30 year cycle is used for timber-only plantations and where carbon payments are included, 35 years is used.

The production variables and values are summarized in Table 1. The base final stem count for plantations is derived from field trials in which 200-250 trees per hectare produced the best economic outcomes (Maraseni *et al.*, 2007), though this site was 80 km to the east of the study region. Given the slightly lower rainfall in the study region, a rate of 200 stems/ha was assumed for the more fertile soils and 150 stems/ha for the less fertile soils. From the spotted gum growth curve (Maraseni 2007), the average yield at 35 years was 1.4 cu. m. per stem but this was adjusted to a range of 0.9-1 cu. m/stem to allow for site variations and lower fertility soils. The average timber price is assumed to be \$50 per cu. m at stumpage (on-farm), in line with Venn's (2005) averaging of prices for different timber grades. All estimations exclude inflationary effects, holding returns and costs at 2002 values and all are expressed in Australian dollars. Agricultural commodity prices were taken from the Australian Bureau of Agricultural and Resource Economics statistics (2001-2005) (Australian Bureau of Agricultural and Resource Economics, 2005) and production costs are based on market research and estimates from the Queensland Department of Primary Industries (Strahan, 2002) and a farm adviser (Clarke, 1997). Plantation establishment costs are based on advice provided by local forestry advisers (Voller, 1997; Allworth, 2002; Bailey, 2002) and market prices for plant hire.

To estimate the carbon sequestration 'price', the final proposed starting price for the CPRS, of \$10/t (2009 terms) was selected as a conservative position, hereafter $8.40 in 2002 terms. Actual trades through the Australian Climate Exchange (2008) from 2006 to 2008 were between $8.50 and $8.75 but it was presumed that a cap and trade scheme would force prices to rise, especially since the proposed CPRS was to have a greater coverage than even the European scheme (Maraseni *et al.*, 2009), which was the most developed market to that point. During 2009 European Union prices ranged from A$13-26/tonne (European Climate Exchange, 2009) but moral suasion in regard to carbon footprints is more heavily deployed in Europe than in Australia. The annual price increase for this study of four percent is drawn directly from the ABARE/Treasury modelling (Burns *et al.*, 2009).

Table 1. Major production variables. Source: the Authors

Variable	Source	Value/s
Beef prices	Market information; ABARE (2001-2004)	$1.40-1.80/kg*
Carrying capacities	Clarke (1997); Thompson and Bailey (1997)	0.25-1 head/ha
Grain prices	Market information; ABARE (2001-2004)	$160-400/tonne**
Plantation establishment costs	Retail information; Voller (1997); Allworth (2002); Bailey (2002)	$1790/ha
Timber price	Market information; Venn (2005)	$50/cu. m
Timber yields	Extrapolated from Maraseni et al (2007) and Venn (2005)	0.8-1.2 cu. m/stem
Final tree density	Extrapolated from Maraseni et al (2007)	150-200 stems/ha
Plantation rotation age	Extrapolated from Maraseni (2007)	35 years

* Calculations based on fattening livestock so purchase price is different to sale price. **Based on up to four crops in rotation (wheat, sorghum, chickpeas, mung beans).

2. METHODS OF ANALYSIS

In order to identify what current land uses could be displaced by dual function (carbon sequestration and timber) forestry several farm types were developed. The types represent a selection of farm businesses across the study region, with intensive crop farms predominating in the eastern and central areas, and some of the smaller ones being operated with one or both partners taking some off-farm income. The larger mixed (crops and extensive livestock) farms are in western areas, while the smaller, low intensity farms tend to be near the more populated eastern areas. The tax effects of off-farm income were included in the estimation since tax deductibility may influence decision making, though direct off-farm income was excluded from the comparisons of land use. The estimates of opportunity cost included all direct and fixed costs but excluded a return on the land value, this being common to all forms of land use. To compare expected financial returns, the potentially competing land uses are all treated as projects over 30 years with a discount rate of 6 percent. In addition, there is a comparison of annual returns from crops and a sustainable forest enterprise over a whole farm, to see if timber-only plantations could be relatively profitable after the start-up phase. We define a late stage, or steady state, forestry system as one in which $1/30^{th}$ of the area or $1/35^{th}$ with sequestration income, is harvested annually and subsequently replanted.

For the spatial analysis, we adapted Apan and Peterson's (1997) approach to assessing reforestation site suitability. The soil, elevation, topographic and other thematic map layers were obtained from the Queensland Department of Natural Resources and Water and the Landsat 5 satellite imagery was obtained from the Australian Centre for Remote Sensing (ACRES). The land use map layer is derived from a combination of a detailed on-ground survey in the eastern part of the catchment, aerial imagery and some ground-truthing. Land uses are classified into crops and managed (planted and fertilized) pastures, untended (no cultivation or fertiliser) pastures and ley areas (not used for any substantial activity). A masking layer including all areas unavailable for plantations was created. Crops and managed pastures, urban areas, road verges and waterways were all combined for the first draft of the mask.

A soil suitability layer was derived from a map of Agricultural Management Units (AMUs) with all units having low fertility and/or poor structure aggregated and added to the mask layer. Any areas with a slope greater than 30 percent are also added to the mask and thereby effectively excluded from consideration. Forestry is undertaken in some countries on steeper land but it is assumed that harvesting will be highly mechanised and so a conservative position is taken. In addition, in the study site, steeper land is generally associated with poor fertility and so was likely to be excluded anyway. For major and minor waterways, it was assumed that plantations would not be established immediately adjacent to the core waterway, as recommended practice is to minimise disturbance in the immediate riparian area.

For the major waterways, the main channels were estimated to be 20m wide on average and then a 20 m buffer zone was added to each side, to create a total width of 60 m. Minor waterways, such as gullies, were buffered to produce a total width of 50 m. Then areas of existing native vegetation were excluded, following the Kyoto protocol requirement that eligible plantations should be established on cleared land to gain environmental benefits (Burns *et al.*, 2009). Finally, those patches of less than one ha, isolated from other potential forestry sites were identified and excluded, being considered as too small to warrant the high start-up costs of planting and harvesting. All other sites were then considered as available for farm forestry. Sites were then further categorised according to relative levels of fertility and potential forestry yields, as summarised in Table 2. For simplification 18 soil types were grouped into 4 broad categories and beef production was based on fattening, rather than breeding, to get a consistent annual yield.

The land suitability analysis identified 9,482 ha, currently used for extensive grazing and a further 6,311 ha with little or no agricultural activity taking place. The total available area (15,793 ha) is 19 percent of the study site or 1.9 percent of the study region (Eastern Downs). Having used the study site (catchment) to locate areas for potential plantations, the production data (Table 2) and expenditure (on inputs) (Table 1) and income data, including the sequestration payments to forest holders, were included in the flows.

The quantity (of CO_2-e) sequestered was estimated using the FullCAM model (Richards and Evans, 2005) from the Federal Government's National Carbon Accounting Toolbox. There is some questioning of the accuracy and methodology of FullCAM (Maraseni, 2007) but this was expected to be the means of estimating sequestration payments under CPRS (Burns *et al.*, 2009). That is, despite concerns about the technical accuracy of the model, it would have been used to estimate payments and so the model is used here. Pre-loaded forest species scenarios for the study site were run; one being for a medium growth spotted gum plantation; and the other being a low growth white gum plantation. Both were assumed to be established on low productivity pasture land. Soil carbon was excluded, as there was uncertainty about the eligibility of this potential sequestration 'sink' at the time of writing. The sequestration of carbon was assumed to be zero in the harvest year, with no attribution based on locking up carbon in the end use, in this case construction timber. Finally, the quantity of carbon sequestered was averaged over the life of the plantation (Table 4), as this was the approach recommended for a stream of payments in the Government's emissions trading White Paper (Australian Government, 2008).

Table 2. Land use and production. Source: the Authors

Current land use	Soil Type	Beef production (kg/ha/yr)	Final timber yield (cu. m/ha)
No notable agricultural use	Deep, heavy clays	0	200
	Medium-shallow clays	0	200
	Clay-loams	0	150
	Light clay-loams	0	135
Predominantly introduced pasture	Deep, heavy clays	108	200
	Medium-shallow clays	90	200
	Clay-loams	81	150
	Light clay-loams	72	135
Predominantly native pasture	Deep, heavy clays	60	200
	Medium-shallow clays	52.5	200
	Clay-loams	45	150
	Light clay-loams	37.5	135

I-O analyses have been used to: compare the impacts from adopting different types of forestry systems (Thomson and Psaltopoulos, 2005); assess the impacts of eliminating or downsizing the forestry sector (Munday and Roberts, 2001); anticipate the impacts of changes in trade and environment policies, in relation to the substitution of agriculture by forestry (Thomson and Psaltopoulos, 2005); compare the economic impact of different forms of forestry (Eiser and Roberts, 2002); and, as in this study, estimate the impacts of changing land use to forestry (Eiser and Roberts, 2002). To our knowledge, there has been little in the way of regional analysis that includes the effects of a carbon mitigation scheme. To do this, a sub-sector (small-scale forestry) is created out of the larger forestry sector (Psaltopoulos and Thomson, 1993; Thomson and Psaltopoulos, 2005; Todd *et al.*, 1997). That is, the flows between sectors from processing on through the value chain are much the same for the small-scale forestry sub-sector as for the overall forestry, with the inputs to production (chemicals, contracting etc) and yields developed specifically for the sub-sector (Table 2).

The I-O tables were constructed using a combination of state-level (Queensland) tables (1996-97 data) and (2001) economic data for the shires that comprise the study region. The tables estimate the flow-on effects of transactions associated with an increase in forestry, including establishment and harvesting expenditure and income, as well as the decrease in direct and indirect incomes as a result of reduced beef production. The I-O model was developed using the Generation of Regional Input-output Tables (GRIT) approach developed by Jensen, Mandeville and Kurunaratne (1979), as used for forestry establishment at the sub-regional level in Ireland (Crowley *et al.*, 2001) and in the Goulburn region of Australia (Todd *et al.*, 1997). The specific application to the displacement of beef by eucalypt plantations follows most directly from the work of Thompson and Bailey (1997). There are three broad stages in the farm forestry sub-sector. The plantation component includes the establishment, maintenance and initial sale of the inputs. Thinning is included as maintenance because there is no market for smaller stems. The second stage, logging (harvesting) is assumed to be undertaken by contractors and finally the milling includes only primary processing (e.g. green sawn timber), since further value adding is likely to take place outside the region, given current infrastructure. Milling benefits are likely to be concentrated in the major regional centre (Toowoomba).

Given the limited experience of farm forestry in the region, it is assumed that a forestry officer is employed to advise on establishment, maintenance and harvesting once it begins. There are three additional people involved in the marketing of farm forestry timber, either through a cooperative or as an extension of existing businesses. There is also assumed to be a sequestration credits trader and another official who monitors the credit providers and their enterprises. Incomes for these six people are treated as additional to current employment in the region. The payments for sequestration are presumed to come from outside the region.

3. RESULTS AND LIMITATIONS

The first results compare returns from the example farms for crops and/or livestock with those from a 10 ha timber-only plantation and are summarized in Table 3. As expected, there are no situations in which plantations are financially superior to existing land uses even, where there is no farming activity, when plantations are treated as a project with a conventional discount rate. To illustrate the sensitivity of the key variables, for plantations to compete with even basic beef production, would require halving the conventional discount rate (to 3 percent), halving the growth period for the trees (15 years) or a timber price increase of 60 percent to $80 per cubic metre.

Table 3. Returns from Current Land Uses and Timber Plantations Compared. Source: the Authors.

Farm Type	Farm Size (ha)	Off-farm income ($/yr)	Current Land Use	Change in income with plantations ($/ha)
Intensive crop farm (dryland)	500	0	Crops on fertile land	-$322
			Crops on marginal land	-$225
			Unused areas	-$72
Mixed farm	800	0	Crop-grazing rotations	-$220
Part-time mixed farm	180	$50,000	Crop-grazing rotations	-$185
Small-scale grazing	120	$70,000	Cattle breeding	-$85
Hobby farm	40	$70,000	Cattle breeding	-$56

The second step is to see if the conversion of farm land to sustainable forestry, starting some 30 years in the future after the first full plantation growth cycle, would result in an increase in on-farm returns. To simplify this, the analysis was based on a comparison of a 500 ha crop farm with fertile soils, to give the maximum returns, and a whole-farm plantation with annual harvesting and re-establishment. The result was that the annual net, after-tax income would increase from more than $62,000 to more than $91,000 per year. This illustrates that timber-only plantations could be the most profitable land use once a sustainable system was established. The next step was therefore to see if there might be a carbon price sufficient to encourage private landholders to move to a plantation system.

The results from the FullCAM simulation are summarised in Table 4. A number of growth rate scenarios were run for both species but most outcomes, as expressed in an annualised NPV, fell between $77 and $86/t$CO_2$-e. There are two main implications from this. First, as expected payments of this order would see little or no cropping land converted to plantations and so plantations would only displace low intensity grazing, or be established on land that currently has little agricultural activity on it. Second, within that range $83/ha was selected as the average payment to be the additional income injection within I-O tables.

Table 4: Sequestration and carbon value for two plantation scenarios. Source*:* Modified FullCAM scenarios.

Year	Price ($/$CO_2$-e)	White Gum (med. Growth)			Spotted Gum (high growth)		
		CO_2-e (t/ha)	Av. CO_2-e (t/ha)	Annual value ($/ha)	CO_2-e (t/ha)	Av. CO_2-e (t/ha)	Annual value ($/ha)
2011	8.4	0.29	12.76	107	0.29	13.6	114
2012	8.7	0.29	12.76	111	0.31	13.6	119
2013	9.1	0.31	12.76	116	0.36	13.6	123
-	-	-	-	-	-	-	-
2044	30.6	29.95	12.76	391	30.65	13.6	416
2045	31.9	0	12.76	407	0	13.6	433
		Annualised NPV ($/ha)		**79**			**84**

From the I-O tables, it appears that if low-intensity beef production was displaced by timber plantations, then in a steady-state, more than 35 years into the future, there would be an increase in gross regional output, value-added, household income and employment, as summarised in Table 5. Value added results are included because these are considered to be some indicator of the likely change in Gross Regional Product (Office of the Government Statistician, 2000). In the short run, expenditure on plantation establishment and maintenance, will partly offset the drop in beef production (Table 5) but establishment and maintenance is largely confined to the early years of the plantation cycle and for these species in marginal (for timber) areas, the maintenance regime is deliberately lean, with at most two prunings and one thinning. Post-planting weed control is expected to be spot spraying and then as the canopy closes, weed competition is expected to be minimal.

Table 5. Changes in annual regional output and employment in the steady state. Source: the Authors.

	Direct Effect	**Total Impact**	**Multipliers**
Plantation gross output ($/ha)	$1037	$1974	1.974
Beef gross output ($/ha)	*-$386*	*-$759*	*1.968*
Plantation value added ($/ha)	$752	$1227	1.631
Beef Value added ($/ha)	*-$162*	*-$345*	*2.134*
Household income: Plantation ($/ha)	$392	$618	1.577
Household income: Beef ($/ha)	*-$106*	*-$191*	*1.793*
Employment: Plantations (no./1000ha)	15	36	2.407
Employment: Beef (no./1000ha)	*-4*	*-12*	*2.718*

The establishment and then re-establishment of small-scale plantations on land with a relatively low opportunity cost would eventually result in an increase in regional output, average household income and regional employment. Once a steady state system was achieved, the net total impact of converting beef land to plantations would be increases in: gross output of $1215/ha of land converted to forestry; value-added of $882/ha; $427/ha; and employment of 24 people/1000ha (see Table 6). The problem is in the start-up phase, even though there is still considerable expenditure on establishing plantations. The net total impacts include decreases in: gross output of $262/ha of land converted; income of $94/ha; and employment of 7 people/1000ha (see Table 6).

Table 6. Annual regional output and employment (establishment phase). Source: the Authors.

	Direct Effect	**Total Impact**	**Multipliers Type II**
Plantation gross output ($/ha)	$340	$497	1.461
Beef gross output ($/ha)	*-$386*	*-$759*	*1.968*
Eucalypt Value added ($/ha)	$273	$354	1.295
Beef Value added ($/ha)	*-$162*	*-$345*	*2.134*
Household income: Plantation ($/ha)	$59	$97	1.646
Household income: Beef ($/ha)	*-$106*	*-$191*	*1.793*
Employment: Eucalypt (no./1000ha)	2	5	2.862
Employment: Beef (no./1000ha)	*-4*	*-12*	*2.718*

The temporal trends are illustrated in Figure 3, with an initial increase in total expenditure as timber plantation activity starts to substitute for beef (B/TS). In this scenario, the plantation establishment is staggered over the first 34 years, to reflect a gradual move to a sustainable system. Over time, the cumulative loss of annual beef production starts to show with an overall decline in regional expenditure as trees are planted but there is no recurring income from the beef. Carbon sequestration payments at an average of $83/ha (B/TS + C) offset this effect but would need to be at approximately $320/ha (a starting price of $32/t) to maintain the same level of output.

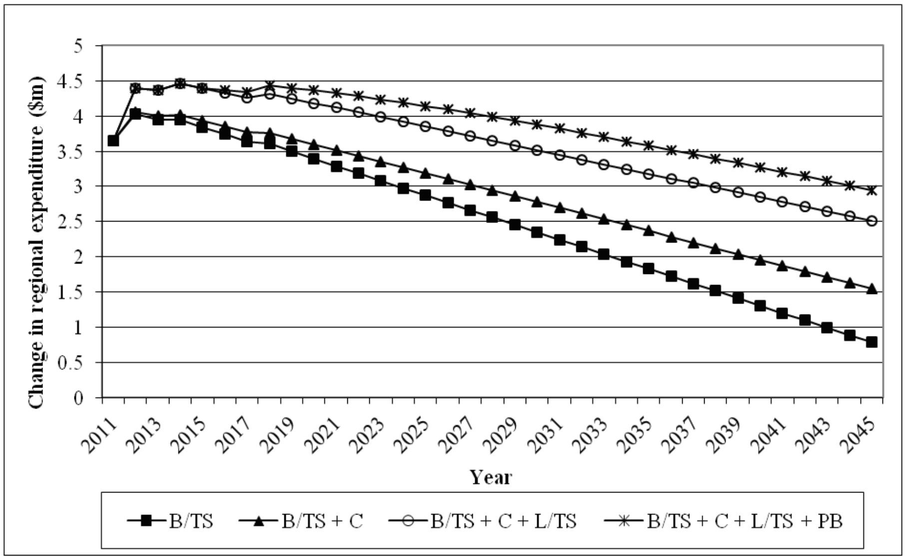

Figure 3. Direct regional expenditure under four land use scenarios. Source: the Authors

Other offsetting strategies during the transition period would include establishing plantations on the ley (currently unused for commercial production) areas, as identified in the spatial modelling and shown in the scenario B/TS + C + L/TS. Finally and additionally, if some grazing (PB = plantation beef) was maintained in plantations as B/TS + C + L/TS + PB, then direct regional spending would not fall below the current level until year 24. In this scenario, grazing commences in year 5 for those grazed prior to plantation establishment, after the stems are assumed to be robust enough to cope with stock contact. The stocking rate starts at 40 percent of that for the pasture land and declines by about 10 percent per year as trees demand more soil moisture at the expense of pasture. There is an increase in carrying capacity as each plantation is thinned in year 7, after which that capacity declines again with further growth and canopy closure. The plantation grazing, sequestration payments and planting of ley areas would reduce the overall impact but these results need to be qualified.

The results are a snapshot and the relationships between sectors may change, especially given the age of some of the data (1996-97) since the State Government ceased regular updates of its tables. There are no substitution effects and no supply constraints (Eiser and Roberts, 2002). Nor is there any consideration of the impacts on other regions or the nation in shifting resources. It is also possible that there will be greater 'leakages' out of the region with the smaller areas of farm forestry than would be the case with industrial-scale plantations (Crowley *et al.*, 2001 p. 41). Costs of harvesting may also be higher than assumed here, given the small area of many of the plantation sites. In addition, this is a long term prediction and bio-technological and planting and harvesting inputs for forestry may change considerably.

One of the major weaknesses of I-O analyses is the necessary assumption of limited change in production systems, which is heightened when considering long-term investments such as forestry. It may be that the development of a small-scale forestry sector would lead to the development of service industries somewhat different to those around industrial-scale timber production. There could, for example, be additional regionally-based advisers and contractors and some of those contractors might invest in high-technology harvesting equipment, as used in Nordic countries where small-scale forest owners fit in with the contractors' harvesting patterns. The adoption of such technology would in turn change the assumptions about labour requirements, with fewer people involved in logging and more in different forms of timber collection and transportation.

Another major area of uncertainty is the timber price, especially given climate change whereby hotter and drier conditions might suggest an overall decrease in timber supply in Australia. On the other hand many studies have concluded that global timber production is instead likely to increase (Sohngen *et al.,* 2001; Schjolden, 2004; Boisvenue *et al.,* 2006; Sohngen, 2008). Boisvenue *et al.* (2006) reviewed global literature on forest productivity and concluded that climatic change seemed to have a generally positive impact on forest productivity where water is not limited. Perez-Garcia *et al*. (1997) and Sohngen and Sedjo (2004) predicted increased timber supplies and falling timber prices. We therefore think it is reasonable to presume no imminent change in price.

4. DUAL FUNCTION FORESTRY AND REGIONAL IMPACTS

Studies of attitudes to small-scale forestry have shown that lack of profitability is considered by landholders to be a barrier to establishing plantations, especially those more dependent on agriculture for income (Harrison *et al.,* 1996; Cockfield, 2005; Herbohn *et al.,* 2005; Emtage *et al.,* 2007). This modelling suggests that a market for sequestration carbon could increase the incentives for landholders to establish small-scale plantations that have both timber and sequestration value. Even if the scheme lasted only 30 years, this could be sufficient to establish a system of small-scale plantations whereby, the profitability of a steady-state system could be sufficient to maintain an industry based solely on timber returns. The policy issue would be whether or not to rely solely on market signals to sustain this sub-sector or for governments to introduce harvesting limits and replanting requirements, as used in Sweden. Land tenure change to keep forestry going could be part of a long-term sequestration contract. This would change both the look of regional landscapes and the structure of regional economies.

There could however, be a relatively long period, once plantation establishment was completed and before harvest commenced, in which the GRP would be lower than in the current state, with various strategies examined above to mitigate those effects. These could be further mitigated by varying the payment schedules, perhaps following the expected increasing carbon price, though this then might reduce the early-stage incentive to establish plantations and would incur additional administrative costs in calculating benefits.

A further problem to getting plantations established is that both prospective growers and regional planners facilitating such an initiative may be wary of the stability of a scheme that depends on a reasonable degree of policy consistency over a long period, under potentially many governments. Some studies have shown that one of the highest rated barriers to establishing small-scale plantations is concern that government regulation will prevent the realisation of timber returns (Cockfield, 2005; Herbohn, *et al.,* 2005). Previously this was fuelled by regulatory restrictions on clearing and logging but there could be reasonable scepticism about governments' constancy to a trading or sequestration offset scheme over 35 years. Policy decisions go directly to the stimulation of demand for sequestration credits as demand will depend on initial price, the level of caps on emissions, enforcement and concessions to industries by way of free permits or exemptions. As an example of potentially extensive change, the Liberal-National Coalition (as at mid-2011), is committed to repealing the proposed carbon tax (and later emissions trading scheme) (a successor to the CPRS), and is yet to reveal what incentives will be provided to landholders to improve land practices as a part of a 'direct action' plan should those parties win government in 2013 or sooner.

Apart from legitimate concerns about policy settings and demand, landholders could also be reluctant to change the look of the landscape. The expansion of plantations in higher rainfall areas has caused some social concerns, with local people concerned about the loss of 'traditional' activities (farming and grazing) and a consequent loss of the rural cultures and local families and service industries (Tonts *et al.,* 2001; Williams, 2008; Williams, *et al.,* 2008). A social survey by Williams (2008) in Tasmania shows that cropping and grazing landscapes and activities are considered very acceptable by the majority of participants, while plantations are the less preferred option. It is however, large-scale plantations that seem to generate the most resistance (Sinclair Knight Merz, 1999; Capill, 2000; Tonts *et al.,* 2001) and small-scale plantations might be considered less threatening and intrusive.

For the study site (Hodgson Creek), the spatial analysis revealed that of the 256 identified plantation sites only 25 would be larger than 100ha. Nor are plantations likely to be on 'prime' farm land, an issue of concern in a region where there is extensive mining exploration. Plantations would be concentrated on more elevated, less fertile areas, near creeks and rivers and on hobby farms near major centres. Previous research has also shown that those with a low-dependency on agriculture are more favourably disposed to small-scale forestry (Cockfield, 2005; Emtage *et al.,* 2007). Therefore, some of these forest sinks might be located in 'hobby farm' areas where there would be little displacement of commercial farming.

5. CONCLUSIONS

This study combined spatial, financial, biomass and economic modelling to develop some scenarios for land use change. This modelling work is limited by the cost of developing and running I-O tables and acquiring and collating spatial data. The modelling of tree growth, biomass and sequestration is limited by the biophysical data available for inland regions and the general nature of the data that is available. Sequestration estimations will be refined over time and FullCAM is under revision. There will also be decisions on the inclusion or exclusion of carbon in litter and soil, as these were excluded here. Despite these limitations, the results show some general tendencies. As expected, the carbon price would need to be very high to compete with crops. Second, given the opportunity costs of switching managed pasture and crop land to plantations in medium rainfall agricultural areas, dual function forestry is likely to remain a relatively minor component of mosaic landscapes dominated by crops and managed pastures. There would be little threat to 'prime' agricultural land.

Third, if there was widespread adoption of plantation forestry there could be some significant medium term impacts on regional output and employment. On the other hand, the conversion of areas currently used for low intensity grazing or little used for agriculture could eventually increase regional output and value added. In the start-up period, the reduction in direct spending as a result of the loss of beef production could be partly offset by converting from a pastoral to a silvi-pastoral system and maximizing the conversion of land currently not used for agricultural activity. There are however, considerable barriers to the adoption of dual function forestry, including landholder scepticism of governments and concern about locking up land over such a long period. Nonetheless, a greenhouse gas mitigation scheme that included payments for sequestration does offer a one-off opportunity to change regional landscapes and to introduce an industry sub-sector that could boost regional output in the long run.

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