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The carbon credits and economic return of environmental plantings on a prime lamb property in south eastern Australia

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ABSTRACT

In Australia, an approved farm action under the Emissions Reduction Fund is for farmers to establish permanent tree plantations. For a livestock farmer who is considering establishing environmental plantings of trees for carbon sequestration, the question is 'what are the benefits and costs of growing trees instead of using that land to grow pasture to feed livestock?' In this research, the case study approach and the methods of farm management economics were applied to assess whether growing trees for carbon on part of a prime lamb case study farm in south-west Victoria could be a better use of resources than using that land to graze livestock. The question was investigated for a range of economic and environmental conditions over 25 and 100 years. A condition was that the trees provided no other benefit on farm and the required rate of return on marginal capital was 6% real (10% nominal). The results indicated that the price of carbon would need to be $AUD132/t CO_2e for growing trees solely for carbon sequestration to be a good investment. Alternatively, if the trees provided benefits in addition to carbon credits, such as shelter for vulnerable young lambs, the investment could be worthwhile to the business at a lower carbon price. Previous research has shown that shelter (in the form of trees, grasshedge rows and other man-made structures) can reduce lamb mortality by reducing wind chill at lambing, through reduced wind speed. The benefits to a farm system from growing trees for carbon depends on the reduction in wind speed the trees create, the weather conditions, the price of lambs, the establishment cost of the trees, the price of carbon, and transaction costs. The results of this research has shown that for the representative livestock farmer, growing trees for carbon is unlikely to be as profitable as alternative uses of their resources.

1. Introduction

The Australian Government has committed to reducing greenhouse gases (GHG) by 5% below the year 2000 amounts by 2020 (Hunt, 2013). One scheme designed to help meet this GHG target is the Emissions Reduction Fund (ERF), which provides incentives to land owners, businesses, community organisations and local and state governments to earn Australian Carbon Credit Units by storing or reducing GHG emissions. The ERF began on 1 July 2015 and builds on the previous Carbon Farming Initiative (CFI). All existing CFI projects approved prior to July 2015 were transferred to the new ERF and previous CFI methodologies continue to be available under the new scheme until they are varied. Participants of the ERF submit a price per tonne for projects that are accepted methods to reduce GHG emissions. The projects are assessed according to the offer price per tonne in a reverse auction process. The auction is held by the Clean Energy Regulator who purchases projects with the lowest cost. One way farmers can participate in the ERF, and previously the CFI, is through environmental plantings; whereby farmers grow trees for carbon. Farmers who grow trees for carbon can potentially earn Australian Carbon Credit Units to sell to the Australian Government, or to other parties.

Past research has considered the area of land that could be available for reforestation projects within the arrangements of the Kyoto Protocol (for example, Mitchell et al., 2012). Polgalse et al. (2013) investigated the area of Australia that could be available for planting new forests based on an estimate of currently cleared land. They concluded that there is insufficient economic incentive to motivate large scale environmental plantings, but their study was not at the farm level and did not consider the other benefits that trees can provide within a farming system.

The key question from the perspective of a farmer grazing livestock is: 'Am I better off using that land to grow trees rather than using the same land for my usual grazing activity?' Research has

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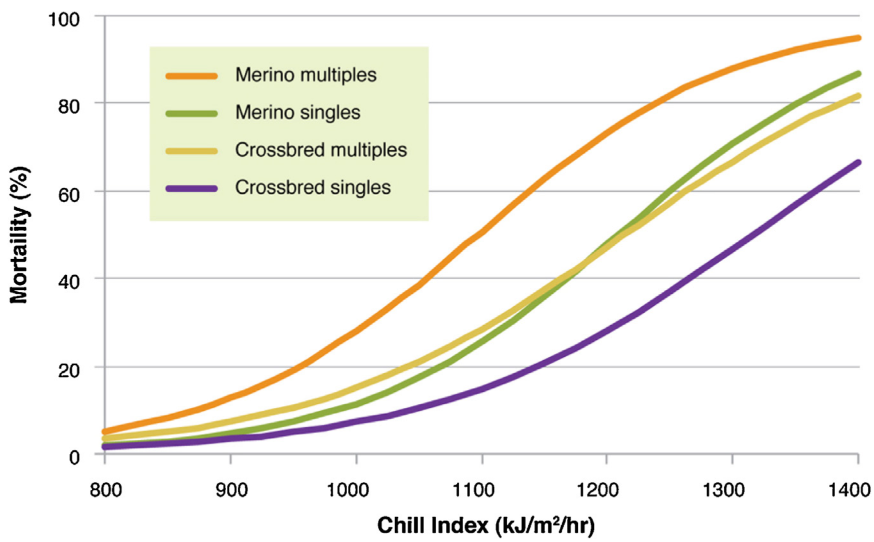

Fig. 1. Relationship between the chill index and the mortality of single and twin lambs born to merino ewes and crossbred ewes (Young et al., 2014, adapted from Donnelly, 1984).

shown that farmers who grow trees in an appropriate location and plantation design also derive other benefits for their farming business, through protection of their livestock from either extreme heat or cold. Marai et al. (2007) found that extreme heat affects production and reproduction traits. Trees that are grown to protect livestock from extreme heat events may reduce these affects. Trees that are grown to protect livestock from cold can reduce lamb mortality (Hume et al., 2011; Bird, 1998). However, trees grown in an orientation and density for protection from cold may not be as efficient for the protection from heat stress (DEPI, 2013) and vice versa. To protect against cold, shelter should aim to minimize wind speed (DEPI, 2013), whereas to protect against heat, the shelter should allow for the cooling effect of the wind. In practice, farmers will plant trees in a location and select species as part of a process that will take into account the environment and climate they farm in and the long term aims for their business. This will include consideration of the needs of current and future farming enterprises, topographical features on the farm, existing infrastructure (e.g. fencing/paddocks) and aesthetic aims. As the establishment of tree plantations is costly and to a large degree permanent, usually the aim will be to achieve multiple outcomes. Therefore, given the significant investment required in establishment and the longer term considerations for the farm, various other forms of shelter may have advantages. For example, grass hedgerows can provide similar wind speed protection with lower establishment costs (EverGraze, 2014). Land and Water Australia (2006) found that providing shelter using trees established through natural regeneration,[1] could be profitable (adequate return on capital), but it may take years for cumulative net cash flow to be positive (payback period). In contrast, grass hedgerows have been found to be profitable with a shorter financial break-even period in regions where lamb mortality is significantly reduced (Young et al., 2014). So, for a farmer to grow trees instead of grass hedgerows, the price of carbon must compensate for the higher establishment costs of the trees.

The proposition tested in this study was that a prime lamb farmer growing trees for carbon would benefit more than if the resources involved were used in some other way. This proposition was tested using the case study approach (Crosthwaite et al., 1997).

[1] Natural regeneration, does not include planting, it is the process of reintroducing vegetation to a site by naturally allowing seed, suckers or lignotubers to grow.

2. Method

2.1. Case study analysis

Use of case studies in farm economics is well established (Crosthwaite et al., 1997). Case study research aims to generalise to theory, or validate theory, unlike approaches that aim to generalise to the populations from which the sample is drawn. In the work reported here, the results from the case study analyses will either add support to explanations of current theory about farmer behaviour, or will not be consistent with theory and challenge accepted wisdom. The case study method is appropriate for this analysis, as survey data of large samples can only represent reality in a shallow way, whereas case studies can capture the full breadth and depth of all the important features of an actual farm (Malcolm et al., 2012).

2.2. The farm

A prime lamb enterprise located near Hamilton in south-west Victoria, Australia was selected as the case study farm. The business comprised 560 ha (400 ha on the home block and a 160 ha outblock), with an average stocking rate across the whole farm of 16.3 dry sheep equivalents (DSE)/ha. The flock comprised 3000 cross bred ewes (Coopworth Composite ewes: with 1000 of the ewes mated to a maternal sire and the remainder to a terminal sire). Lambing was in mid-July and weaning was in early December. The average annual rainfall was 730 mm and the farm was located in an area of very high wind chill during the month of lambing. The average July wind chill in unsheltered conditions in Hamilton is classed as very high (980–1000 kJ/m^2/h) (EverGraze, 2014).

Shelter that is located appropriately can reduce the speed of wind. Together, wind, rain and temperature make up chill index. Donnelly (1984) used the chill index of Nixon-Smith (1972) in a series of equations to describe the mortality of single and twin lambs born to pure Merino and cross-bred ewes (see Fig. 1). At a chill index greater than 900 kJ/m^2/h, the risk of lamb mortality increases significantly (Fig. 1), therefore shelter, which reduces wind speed, should reduce chill index and subsequently lamb mortality (Donnelly, 1984; Bird et al., 1984). Lambs that benefit the most from shelter are those with low birth-weights; usually twin/triplet born lambs (Bird et al., 1984; Pollard, 2006). Shelter can be in the form of grass hedgerows, artificial constructs, and trees and

Table 1
The type, median, 5th, 25th, 75th and 95th percentiles of input distributions used in the analysis.

Input costs/yields	Distribution type	P5	P25	P50	P75	P95
Lamb meat price (c/kg carcass weight, 45% dressing percentage)	Gamma	342	400	448	502	592
Skin price ($/extra lamb)	Pert	3.85	7.77	11.25	14.93	19.70
Mortality reduction if wind speed was reduced by 99%	Normal	46%	48%	50%	52%	54%
Mortality reduction if wind speed was reduced by 75%	Extvalue	29%	30%	32%	33%	36%
Mortality reduction if wind speed was reduced by 60%	Uniform	22%	23%	24%	25%	26%
Mortality reduction if wind speed was reduced by 50%	Uniform	18%	19%	20%	21%	22%
High carbon price ($/t CO_2e)	InvgaussAlt	15.00	18.05	22.00	28.55	45.00
Low carbon price ($/t CO_2e)	InvgaussAlt	8.00	8.94	10.00	11.56	15.00

Table 2
Assumptions used in the analysis.

Type of planting	Sub-question 1 Planting A Mixed species planting with greater height, but lower density planting	Sub-question 2 Planting B Mixed species planting, with trees that are not as tall, but greater density	Sub-question 3 Grass hedge rows	Sub-question 4 Mixed species planting
Area of shelter provided by 5.6 ha planted (ha)	72	54	56	No additional benefit to the farm system
Number of twin bearing ewes that could be carried	1290	970	1000	No additional benefit to the farm system
Conservative estimate of reduction in wind speed as a result of planting	60%	75%	75%	No additional benefit to the farm system
Best case estimate of reduction in wind speed as a result of planting	75%	99%	99%	No additional benefit to the farm system
Establishment costs tested ($/ha)	$1000, $2000 and $3200		$250	$1000, $2000 and $3200
Carbon prices tested ($/t CO_2e)	Two distributions were used, one with an average of $10 and the other with an average of $25			Breakeven carbon price was calculated

shrubs. Grass hedgerows are tall pasture species sown in rows about 10–15 cm apart and are normally about 1 m tall, which are allowed to grow rank during their reproductive phase in spring (McCaskill and Saul, 2008). Grass hedgerows do not require fencing, unlike trees. The benefits of shelter from grass hedgerows, or trees are expected to vary by the degree to which they achieve wind speed reduction that reduces the chill index and increases lamb survival (Broster et al., 2012; Young et al., 2014).

2.3. Research question and scenarios tested

The research question examined was 'will growing trees for carbon be the most beneficial use of the resources involved?' Answering this question is complex because there are a number of variables involved, including:

- The price of carbon
- The design of the environmental planting and the choice of plant(s)
- The growth rate of trees
- The establishment cost, subject to trees purchased, fencing required, labour required, and the ongoing costs (especially for a 100 year planning horizon)
- Whether there are other benefits for the farm business

Given there are a number of variables to consider, a number of sub-questions and scenarios were developed for the case study farm. The sub-questions were:

i. Is the farmer more profitable growing a selection of trees that provide protection (shelter) over a larger area so more ewes could be sheltered, but the reduction in wind speed is less, so a smaller reduction in lamb mortality is achieved? (Planting A)
ii. Is the farmer more profitable growing a selection of trees that provide protection (shelter) over a smaller area, but reduces wind speed to a greater extent and therefore achieve a greater reduction in lamb mortality? (Planting B)
iii. What is the expected return on extra capital invested if the farmer wanted to create shelter by growing a grass hedgerows for the purpose of reducing lamb mortality only, without the benefits of any income from ACCUs?
iv. What would the carbon price need to be for the farmer to earn 6.0% p.a. real return on the extra capital invested (equivalent to 10.0% nominal return when there is 3.8% p.a. inflation), if there were no other benefits from the trees for the farm business?

A 6.0% real return was used as the annual yield of 10-year Australian Bonds has averaged 3.8% real over the past five years (Reserve Bank of Australia, 2015). Bonds represent a relatively low risk investment compared with the share market, or real estate. A farmer considering alternate options about how to invest their money is likely to use bond yields, or bank interest rates as a minimum rate of return in their decision making. An additional 2.0% was included as a risk premium to bring the required rate of return to 6.0% real, as there is some risk associated with planting trees for carbon, but probably less so than alternatives such as early adoption of totally new technology.

2.4. The budget framework

For this analysis, the question is whether a farmer should do one activity over another activity; graze land, or plant trees on the land in question. A partial budget is an appropriate method when considering a change to only part of the farm system (Malcolm et al., 2005). The partial budget approach was used to assess the effects on farm profit and risk from establishing trees on land that is currently used for grazing. The extra income and extra costs associated with the change were estimated, and the return on the extra capital invested was calculated. In addition, the impact on cash flow was analysed. The effect of income tax was excluded from the analysis

Table 3
Marginal internal rate of return on extra capital under average conditions and prices based on a planning horizon of 25 years for different average carbon prices, estimates of wind speed reduction provided by the trees and establishment costs.

Wind speed scenario	Carbon price ($/t CO_2e)	Planting scenario	Establishment costs ($/ha)		
			$1000	$2000	$3200
Conservative estimate of expected wind speed reduction provided by the trees	$10	Planting A: 60% reduction in wind speed	4%	2%	0%
		Planting B: 75% reduction in wind speed	7%	5%	3%
	$25	Planting A: 60% reduction in wind speed	6%	4%	2%
		Planting B: 75% reduction in wind speed	9%	7%	4%
Best case estimate of expected wind speed reduction provided by the trees	$10	Planting A: 75% reduction in wind speed	14%	11%	8%
		Planting B: 99% reduction in wind speed	25%	21%	17%
	$25	Planting A: 75% reduction in wind speed	16%	13%	10%
		Planting B: 99% reduction in wind speed	27%	22%	18%

Table 4
Number of years to reach a positive cumulative net cash flow under average conditions and prices based on a planning horizon of 25 years or 100 years for different average carbon prices, estimates of wind speed reduction provided by the trees and establishment costs.

Wind speed scenario	Carbon price ($/t CO_2e)	Planting scenario	Establishment costs ($/ha)		
			$1000	$2000	$3200
Conservative estimate of expected wind speed reduction provided by the trees	$10	Planting A: 60% reduction in wind speed	25 years	Greater than 25 years	Greater than 25 years
		Planting B: 75% reduction in wind speed	14 years	15 years	18 years
	$25	Planting A: 60% reduction in wind speed	15 years	18 years	Greater than 25 years
		Planting B: 75% reduction in wind speed	10 years	13 years	15 years
Best estimate of expected wind speed reduction provided by the trees	$10	Planting A: 75% reduction in wind speed	9 years	10 years	11 years
		Planting B: 99% reduction in wind speed	6 years	7 years	8 years
	$25	Planting A: 75% reduction in wind speed	9 years	10 years	10 years
		Planting B: 99% reduction in wind speed	6 years	7 years	8 years

Table 5
Marginal internal rate of return on extra capital under average conditions and prices based on a planning horizon of 100 years for different average carbon prices, estimates of wind speed reduction provided by the trees and establishment costs.

Wind speed scenario	Carbon price ($/t CO_2e)	Planting scenario	Establishment costs ($/ha)		
			$1000	$2000	$3200
Conservative estimate of expected wind speed reduction provided by the trees	$10	Planting A: 60% reduction in wind speed	8%	7%	6%
		Planting B: 75% reduction in wind speed	11%	9%	8%
	$25	Planting A: 60% reduction in wind speed	9%	8%	7%
		Planting B: 75% reduction in wind speed	12%	10%	8%
Best case estimate of expected wind speed reduction provided by the trees	$10	Planting A: 75% reduction in wind speed	16%	14%	11%
		Planting B: 99% reduction in wind speed	26%	21%	18%
	$25	Planting A: 75% reduction in wind speed	17%	15%	12%
		Planting B: 99% reduction in wind speed	27%	22%	19%

as tax arrangements are unique to every farm business, and complex with taxable income averaging provisions over five years. The main purpose of the study was also to compare the relative profitability of different tree plantings. The impact of risk was included using @Risk (Pallisade, 2013), an add-in program for Excel, where probability distributions for key variables can be defined, leading to a range in possible outcomes (Table 1).

Extra income resulted from:

- Selling the carbon that was sequestered by the trees, as Australian Carbon Credit Units every 5 years. The price of carbon was based on probability distributions for two scenarios; one with a mean price of $AUD25, the other a mean price of $AUD10.
- Selling extra lambs, using a distribution for lamb mortality based on expected lamb mortality with, or without shelter at various wind speeds. The research behind McCaskill and Saul (2008) and McCaskill et al. (2010) was used to estimate the reduction in lamb mortality that could be expected if wind chill was reduced. That is, in July each year between 1997 and 2012, McCaskill et al. (2010) calculated the mortality of multiple lambs born to crossbred ewes for conditions in the open, or with shelter where lambs could seek areas with lower wind speeds. Using this information, the expected lamb mortality when shelter reduced wind speed by 99%, 75%, 60% and 50%, was estimated. These estimates were used in the present study to calculate the reduction in mortality from reducing wind speed by this amount (99%, 75%, 60% and 50%), and a probability distribution was fitted around these results (Table 1).

Extra costs resulted from:

- Capital costs associated with establishing the trees, or grass hedgerows, which depends on the price of the trees, the cost of planting, and the cost of permanent fencing. Three establishment costs were considered for the growing trees option; $1000/ha, $2000/ha and $3200/ha. The different amounts reflected whether the farm could use the direct-seeding method, or required ripping and mounding of the soil, the planting of tube stock and the costs of fencing. It was assumed that establishing a grass hedgerow would cost $250/ha. The estimates used in this analysis are supported by previous studies (Polglase et al., 2013; Young et al., 2014).
- Auditing costs associated with establishing an environmental planting, which were based on Swainson (2013). It was assumed that the initial cost would be $5000. Sharpe (2012) also estimated that initial accreditation and legal advice would cost $5000. According to the Clean Energy Regulator (2014), some sequestration projects may be exempt from continuing audits if they

are estimated to sequester less than 2500 t of carbon annually, thus it was assumed that there were no ongoing costs for this planting.

- Income foregone; the opportunity cost of using land to plant trees instead of grazing livestock.
- The costs associated with rearing the extra lambs, including animal health, freight and cartage and selling costs.
- The cost of caring for the trees, repairs and maintenance of fencing and the labour associated with managing those trees.

2.5. Model inputs

The assumptions specific to each of the research questions are given in Table 2. It was assumed that the planting follows rules described in the 2012 Carbon Farming Methodology Determination (Dreyfus, 2012). Further, it was assumed that the trees were grown to maximise shelter benefits, that is, they were planted in a position that would have the correct orientation to the prevailing winds at lambing time, and have coverage that is low to the ground at lamb height. This required the use of permanent fencing for the tree plantation.

2.6. Wind speed reduction from shelter

The height and density of the trees alter the extent of the shelter zone (Bird, 1998). For this study, the level of protection was 10 times the height of the tallest tree in the planting based on assumptions used by EverGraze (2014). The level of reduction in wind speed used in the analysis was based on findings from Bird et al. (1992) and EverGraze (2014). It was also assumed that the protection was the same across the paddock. Although this is a simplifying assumption, two reductions in wind speed were tested; a conservative case and a best case. It was also assumed that a mixed species planting would begin to offer some protection three years after establishment and full protection after four years (Hume et al., 2011; Johnson and Brandle, 2009).

2.7. Stocking rate

The sheltered paddocks were designed as 'maternity wards', which is a paddock of concentrated shelter where ewes are held during lambing and the ewes have no choice but to lamb in a sheltered environment (Robertson et al., 2012). This could lead to an increased stocking rate in the 'maternity ward'. Robertson et al. (2012) considered a stocking intensity of 16 ewes/ha and 30 ewes/ha, and found the survival of twin lambs born was reduced at the higher stocking rates. Alexander et al. (1983) calculated that 18 ewes/ha would be the ideal stocking rate. Thus, 18 ewes/ha was used in this study.

2.8. Carbon credits

Under the ERF (previously CFI), there is an approved method for quantifying carbon sequestration by permanent environmental plantings of native species using the CFI reforestation modelling tool. This tool was used to estimate the location-specific carbon sequestration rate and amount likely to be achieved on the case study farm over time, for a mixed species environmental planting. It was assumed that both planting A and planting B sequestered the same amount of carbon. Further, it was assumed the Australian Carbon Credit Units earned would be 5% lower than what was estimated to occur, as the government takes 5% as a hedge against the risk of sequestered carbon being released back into the atmosphere from unforseen events, such as bush fire. Payments for Australian Carbon Credit Units were made every five years, up to year 15. Currently, 15 years is the maximum time that credits can be claimed (Clean Energy Regulator, 2013).

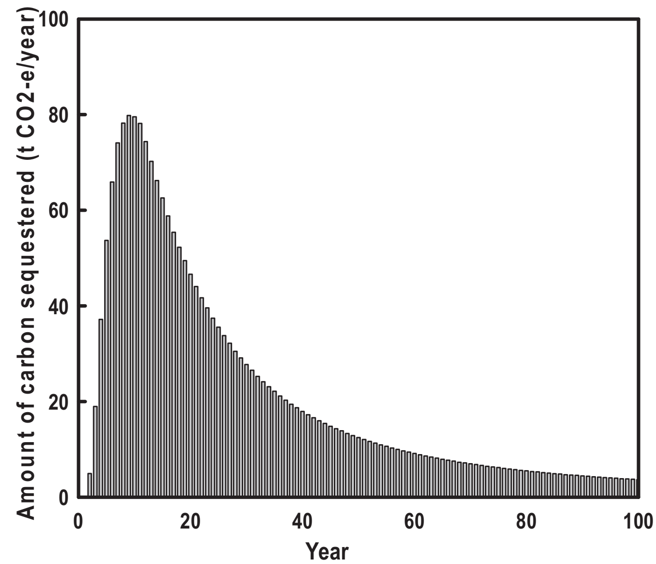

Fig. 2. Annual amount of carbon sequestered in an environmental planting established on 5.6 ha of a case study farm in western Victoria.

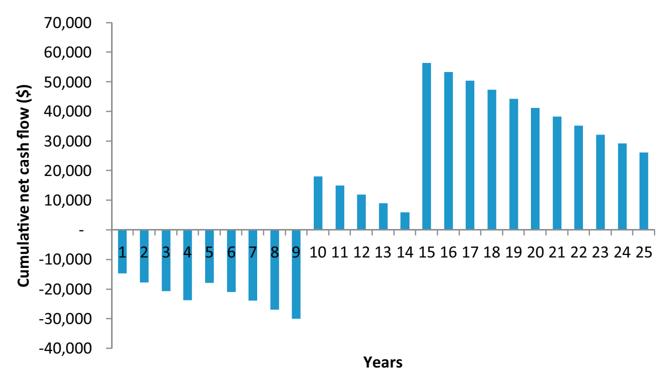

Fig. 3. Cumulative net cash flow based on establishing an environmental planting on 5.6 ha for 25 years.

2.9. Planning horizon

Under the previous arrangements, one of the rules for establishing an environmental planting was that it needed to be permanent and remain for at least 100 years. If a farmer wished to cancel their project before 100 years and remove the trees, they would need to return credits that had been issued based on the prevailing market price. Under the new ERF, proponents of sequestration projects can nominate a 25 or 100-year permanence period. Projects with a 25-year permanence period will have a 20% discount applied to the number of credits issues that would have been issued under a 100-year period. Thus two planning horizons were considered for this study; 25 years and 100 years.

3. Results

Using the reforestation modelling tool, the cumulative amount of carbon sequestered over time for both plantings analysed is presented in Fig. 2. The accumulated carbon sequestered was 1305 and 2158 t CO_2e at 25 years and 100 years, respectively.

Table 6
Marginal internal rate of return on extra capital and number of years to reach a positive cumulative net cash flow under average conditions and prices based on a planning horizon of 25 years for a grass hedgerow for different average carbon prices, estimates of wind speed reduction provided by the trees and establishment costs.

Wind speed scenario	Marginal internal rate of return	Years to reach a positive cumulative net cash flow
Conservative reduction in wind speed (wind speed reduced by 75%)	26%	6
Best case reduction in wind speed (wind speed reduced by 99%)	59%	4

Table 7
Carbon price required for the case study farmer to earn 6% real return on the extra capital invested.

	Carbon price required (\$/t CO_2e)	
Establishment cost (\$/ha)	Tree planting established for 25 years	Tree planting established for 100 years
\$1000	\$132	\$163
\$2000	\$146	\$177
\$3200	\$163	\$194

3.1. *Establishing an environmental planting which also provides shelter*

Two types of plantings were considered with both assumed to qualify under the ERF, but they differed in the amount of wind speed reduction and in the area of land sheltered, and therefore the number of ewes that could be stocked on the sheltered paddock. For either planting, a farm business could earn a positive return on the extra capital invested. However, the size of the return varied subject to the assumptions about wind speed, the cost of establishing the trees and to a lesser extent, the carbon price (Table 3). This equated to a return on marginal capital ranging from 0% to 27%. The reduction in wind speed was more important and had a greater influence on return on capital than carbon price. For example, considering a scenario where the establishment cost of trees was \$2000/ha and there was a 75% reduction in wind speed, the return on marginal capital was 7% under a carbon price distribution with a mean of \$25/t CO_2e. The return on marginal capital reduced to 5% when a carbon price distribution with a mean of \$10/t CO_2e was used. For the same establishment cost (\$2000/ha) and with a carbon price based around a mean of \$25/t CO_2e, a reduction in wind speed from 75% to 99% increased return on marginal capital from 7% to 22%. Not surprisingly then, for the two types of plantings considered, which qualified under the ERF, the planting that had the greatest reduction in wind speed, but provided protection over a smaller area (Planting B) performed better economically and financially than Planting A, which offered shelter to more ewes, but with less wind speed reduction and less reduction of lamb mortality.

The number of years that the extra capital invested would take to be repaid by the cash flows generated by the change is presented in Table 4. The time taken to repay borrowed capital ranged from 6 years to greater than 25 years.

Assuming the farmer maintained the planting for 100 years, the return on the extra capital invested increased slightly compared to if the trees were maintained for 25 years (Table 5). However, this assumes the reduction in lamb mortality occurred every year for the 100 years, which may not be the case in practice.

3.2. *Planting a grass hedgerow instead of trees for shelter to lambing ewes and their lambs*

Planting a grass hedgerow to provide shelter to ewes and their lambs could earn a higher return on the extra capital invested than either of the environmental planting options, however, this would not qualify for the ERF. Under the conservative reduction in wind speed (a 75% reduction in wind speed), an average return on marginal capital of 26% was generated by the investment in hedgerows. Under the best case scenario (a 99% reduction in wind

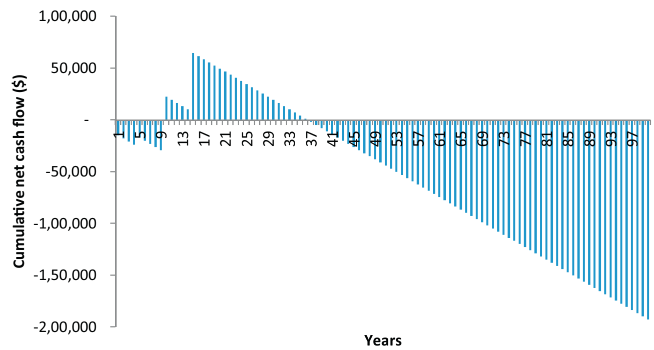

Fig. 4. Cumulative net cash flow based on establishing an environmental planting on 5.6 ha for 100 years.

speed), a 59% return on marginal capital was expected. Establishing grass hedgerows could also be repaid in less than 10 years for all scenarios (Table 6).

3.3. *Establishing an environmental planting without any other benefits for the farm*

The carbon price required to earn 6.0% real return (10.0% nominal, with 3.8% inflation), without any other benefits for the farm was greater than \$100/t CO_2e for the three establishment costs tested (Table 7). Further, the required carbon price was higher if the planting remained for 100 years (Table 7).

If a carbon price of \$132/t CO_2e was achieved, the capital could be repaid by year 10 (Figs. 3 and 4). The cash flows are intermittent as the payment for carbon stored in trees was only expected in years 5, 10 and 15.

4. Discussion

Growing trees for carbon is not expected to be the best use of resources under the likely carbon prices. The analysis reported here does not support the original proposition. The first ERF auction was held in April 2015, where the average price per tonne of abatement was \$13.95/t CO_2e. The results from this research show that in order for trees grown for carbon sequestration to earn a real return of greater than 6%, and without any additional farm benefits from the trees, a carbon price in excess of \$100/t CO_2e is required. This is significantly more than the price established at the ERF auction. Further, it is also significantly more than the EU carbon price. At the time of writing, the European carbon price was \$8.72/t CO_2e (€6/t CO_2e) (Hill, 2014).

If the case study farmer were growing trees for carbon sequestration and also for reduced lamb mortality, then an environmental planting could be profitable. However, this depends on the reduction in wind speed from the plantings. The greater the reduction in wind speed, the greater the decrease in wind chill index and subsequent positive effects on lamb survival benefiting the farm system. This concurs with the results of Broster et al. (2012) and Young et al. (2014). Growing trees that offer a reduced area of protection, but a greater decrease in wind speed has the potential to earn more than 10% return on extra capital invested. However, planting grass hedgerows (which would not qualify for the ERF) would be more profitable than planting trees. This is because of the high establishment costs associated with planting trees and the expectation that carbon price will be low and that similar benefits of lamb survival were achieved. Young et al. (2014) also found that planting grass hedgerows could be profitable for a sheep producer, but depended on where the farm was located, the associated weather conditions and consequently, the degree to which lamb mortality could be reduced. The investment in trees is also expected to take longer to earn a positive cumulative net cash flow, compared with the time taken to earn a positive cumulative net cash flow from growing grass hedgerows.

The results from the analysis that included farm co-benefits to carbon credits could also be considered optimistic, as it was assumed that lamb mortality decreased every year with the trees compared with no trees. In practice, lamb mortality may not decrease every year because the benefit of trees depends on the weather during lambing and the reduction in chill varies between years (Broster et al., 2012). Robertson et al. (2011) found the increase in survival from trees will be small if the weather was mild during lambing. The Bureau of Meteorology and CSIRO (2014) predict that the temperature in Australia will increase in future, with more hot days and fewer cold days. So, the benefits of trees in providing shelter from the cold may be less in the future than what was assumed in this study, particularly for the 100 year scenario.

This analysis has shown that there are some key factors that farmers need to account for when considering whether to establish an environmental planting including the:

- Weather (temperature, rainfall and wind speed, which impact on wind chill index).
- Reduction in wind speed caused by the trees/shelter design and consequently, the reduction in lamb mortality that can be achieved.
- Income foregone on the area that is planted to trees.
- Cost of establishing the planting and maintenance of the planting and fences.
- Area protected by the trees and the number of twin bearing ewes that can be sheltered.

Previous research has found that the effectiveness of trees on reducing lamb mortality is also dependent on factors such as the breed of sheep, reproduction rate, proportion of twins, current lamb mortality, time of lambing, the existing climate, and the extent of wind speed reduction from the shelter. Broster et al. (2012) reported considerable variability in the reduction in wind speed and chill index for similar reasons. This research has highlighted the complexity and uncertainties of determining the benefits and costs of establishing an environmental planting. A further important consideration is the issue of permanence and how long the farmer elects to maintain the environmental planting. Under the ERF, a 25 or 100 year permanence period can be chosen. However, the risk for a farmer is if they decide to harvest the trees before the end of the contract period (25 years or 100 years), as they would be required to replace the offset credits earned up to that time.

The analysis reported here also demonstrates the importance of evaluating a change on a case-by-case-basis. The location of the planting, the area protected and the expected wind speed with and without trees will affect the outcome. Carbon sequestration from environmental plantings also varies across regions and is influenced by geography as well as rainfall (Centre for International Economics, 2015). In general, tree plantings in higher rainfall regions, such as the farm analysed in this study, sequester more carbon than in lower rainfall regions. In such lower rainfall areas, an even higher carbon price would be required for a real return of 6% p.a. Sharpe (2012) also explored whether environmental plantings were profitable and concluded that carbon credit projects can be a feasible and financially attractive option for landowners in some circumstances. As Sharpe (2012) said, landowners need to understand the costs and risks involved before undertaking an environmental planting. There may also be other benefits farmers may consider when planting trees, beyond the economic benefits from shelter and carbon credits. These include the use of tree plantations for aesthetic reasons, as wildlife corridors and for habitat creation, for the control of erosion and the protection of soils and crops. These benefits were not quantified in this study, but farmers will trade off additional perceived benefits against the expense of establishment and lower returns from tree plantations.

5. Conclusion

For a farmer to earn a reasonable return from participating in the ERF through establishing an environmental planting, the trees would need to be selected (for density and height) and planted in a position that would generate the greatest reduction in wind speed. The farm would also need to be located in an area with a high to extreme wind chill index. If the trees reduced the wind chill index, through reducing wind speed, this could decrease lamb mortality and reward the farmer with a reasonable return on the extra capital invested to plant the trees. Whether it is the best use of resources available will depend on the establishment costs, the price of carbon, the price of lambs, the weather, and the wind chill index before trees and after trees, which affects the lamb survival and hence the number of extra lambs sold. The proposition tested in this study that a prime lamb farmer growing trees for carbon would benefit more than if the resources were used in some other way, was rejected based on the carbon prices examined. However, the consideration of other benefits from trees to the whole farm will also be important in making the final decision.

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References

Alexander, G., Stevens, D., Mottershead, B., 1983. Problems in the accurate recording of lambing data. Aust. J. Exp. Agric. 23, 361–368.
Bird, P.R., Lynch, J.J., Obst, J.M., 1984. Effect of shelter on plant and animal production. Anim. Prod. Aust. 15, 270–273.
Bird, P.R., Bicknell, D., Bulman, P.A., Burke, S.J.A., Leys, J.F., Parker, J.N., Van Der Sommen, F.J., Voller, P., 1992. The role of shelter in Australia for protecting soils, plants and livestock. Agrofor. Syst. 20, 59–86.
Bird, P.R., 1998. Tree windbreaks and shelter benefits to pasture in temperate grazing systems. Agrofor. Syst. 41, 35–54.

Broster, J.C., Robertson, S.M., Dehaan, R.L., King, B.J., Friend, M.A., 2012. Evaluating seasonal risk and the potential for windspeed reductions to reduce chill index at six locations using GrassGro. Anim. Prod. Sci. 52, 921–928.
Bureau of Meteorology and CSIRO, 2014. State of the Climate Report [Online]. Available at http://www.bom.gov.au/state-of-the-climate/documents/state-of-the-climate-2014_low-res.pdf?ref=button (verified 12th November 2014).
Centre for International Economics, 2015. The Business Case for Carbon Farming: Improving Your Farm's Sustainability: Workshop Manual. Kondinin Information Services, Perth, Australia.
Crosthwaite, J., MacLeod, N., Malcolm, B., 1997. Case studies: theory and practice in agricultural economics. In: Vanclay, F., Mesiti, L. (Eds.), 'Sustainability and Social Research'. Centre for Rural Social Research—Charles Sturt University, Wagga Wagga, Australia.
Clean Energy Regulator, 2014. Auditing eligible offsets projects [Online]. Available at https://www.cleanenergyregulator.gov.au/Carbon-Farming-Initiative/Auditing-eligible-offsets-projects/Pages/default.aspx) (verified 23rd April 2015).
Clean Energy Regulator, 2013. Carbon Farming Initative workshop: from plan to practice –slides; environmental plantings [Online]. Available at http://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0CC0QFjAD&url=http%3A%2F%2Fwww.cleanenergyregulator.gov.au%2FCarbon-Farming-Initiative%2FFact-sheets-FAQs-and-guidelines%2FPublications%2FDocuments%2FFrom%2520Plan%2520to%2520Practice%2520workshop%2520presentation.docx&ei=kmxJVfT6JoaOmwWYzIHgAw&usg=AFQjCNHCk_pJLvC3b57wiOMZ9p7wKmQ7ww&sig2=76HplqGAVpEfIhTtB7l1kg&bvm=bv.92291466,d.dGY (verified 23rd April 2015).
DEPI, 2013. Sheep Guidelines for the provision of shelter [Online]. Available at: http://www.depi.vic.gov.au/__data/assets/pdf_file/0016/228301/Fact-sheet-sheep-shelter-artwork-for-the-web.pdf. (verified 12 November 2014).
Donnelly, J.R., 1984. The productivity of breeding ewes grazing on lucerne or grass and clover pastures on the Tablelands of Southern Australia. III Lamb mortality and weaning percentage. Aust. J. Agric. Res. 35, 709–721.
Dreyfus, 2012. Carbon Farming (Quantifying carbon sequestration by permanent environmental plantings of native tree species using the CFI Reforestation Modelling Tool) Methodology Determination 2012 [Online]. Available at: http://www.comlaw.gov.au/Details/F2012L01340 (verified 12 November 2014).
EverGraze, 2014. Shelter improves lamb survival [Online]. Available at: http://www.evergraze.com.au/library-content/hamilton-key-message-shelter-improves-lamb-survival/ (verified 12 November 2014).
Hill, J.S., 2014. European carbon price set to rise to €23/t between 2021 and 2030 [Online]. Available at: http://cleantechnica.com/2014/09/02/european-carbon-price-set-rise-e23t-2021-2030/ (verified 2nd February 2015).
Hunt, G., 2013. The Coalition Government's plan to tackle climate change, reduce emissions and reduce pressure on electricity prices. Paper to the Carbon Market Institute Workshop. Melbourne.
Hume, I., Ebberbach, P., Condon, J., 2011. Shrub belt hedges for shelter and recharge control. EverGraze research note [Online]. Available at: http://www.evergraze.com.au/wp-content/uploads/2013/10/Evergraze+Exchange+shrubs.pdf (verified 12 November 2014).
Johnson, H., Brandle, J., 2009. Shelterbelt design. [Online] Available at: http://www.depi.vic.gov.au/agriculture-and-food/farm-management/soil-and-water/erosion/shelterbelt-design (verified 4th February 2015).
Land and Water Australia, 2006. Extension note 3: Using natural regeneration to establish shelter on wool properties. [Online] Available at: http://lwa.gov.au/files/products/land-water-and-wool/ef061121/ef061121.pdf (verified 12 November 2014).
Malcolm, B., Makeham, J., Wright, V., 2005. The Farming Game—agricultural Management and Marketing. Cambridge University Press, Melbourne.
Malcolm, B., Ho, C.K.M., Armstrong, D.P., Doyle, P.T., Tarrant, K.A., Heard, J.W., Leddin, C.M., Wales, W.J., 2012. Dairy directions: a decade of whole farm analysis of dairy systems. Aust. Agribus. Rev. 20, 39–58.
Marai, I.F.M., El-Darawany, A.A., Fadiel, A., Abdel-Hafez, M.A.M., 2007. Physiological traits as affect by heat stress in sheep—a review. Small Rumin. Res. 71, 1–12.
McCaskill, M.R., Behrendt, R., Clark, S., 2010. EverGraze: hedges and climate change reduce lamb chill. In: Proceedings of the 51st annual conference of the Grassland Society of Southern Australia ', Grassland Association of Southern Australia Inc.: Echuca, Vic, pp. pp. 175–180.
McCaskill, M.R., Saul, G.R., 2008. Perennial grass hedges provide shelter at lambing. [Online] Available at http://www.evergraze.com.au/wp-content/uploads/2013/06/EverGraze-Action-hedges-A4.pdf (verified 23rd April 2015).
Mitchell, C.D., Harper, R.J., Keenan, R.J., 2012. Current status and future prospects for carbon forestry in Australia. Aust. For. 75, 200–212.
Nixon-Smith, W.F., 1972. 'The forecasting of chill risk ratings for new born lambs and off shears sheep by the use of a cooling factor derived from synoptic data.'. In: Working Paper No. 150. Bureau of Meterology, Canberra.
Polglase, P.J., Reeson, A., Hawkins, C.S., Paul, K.I., Siggins, A.W., Turner, J., Crawford, D.F., Jovanovic, T., Hobbs, T.J., Opie, K., Carwardine, J., Almeida, A., 2013. Potential for forest carbon plantings to offset greenhouse emissions in Australia: economics and constraints to implementation. Clim. Change 121, 161–175.
Pallisade, 2013. '@Risk—risk analysis and simulation add-in for Microsoft Excel version 6.'. Pallisade Corporation, Newfield, New York.
Pollard, J.C., 2006. Shelter for lambing sheep in New Zealand: a review. N. Z. J. Agric. Res. 49, 395–404.
Reserve Bank of Australia, 2015. 'Capital Market Yields –Government Bonds –Monthly –F2.1′, in Statistical tables—Interest rates, http://www.rba.gov.au/statistics/tables/index.html (accessed 07.09.15.).
Robertson, S.M., Friend, M.A., Broster, J.C., King, B.J., 2011. Survival of twin lambs is increased with shrub belts. Anim. Prod. Sci. 51, 925–938.
Robertson, S.M., King, B.J., Broster, J.C., Friend, M.A., 2012. The survival of lambs in shelter declines at high stocking intensities. Anim. Prod. Sci. 52, 497–501.
Sharpe, F., 2012. Carbon forestry opportunities in the CFI. Presentation to the Carbon Farming Conference Dubbo [Online]. Available at: http://www.google.com.au/url?url=http://www.carbonfarmersofaustralia.com.au/_literature_112913/Carbon_Farming_Conference_2012_-_Freddy_Sharpe&rct=j&frm=1&q=&esrc=s&sa=U&ei=xMxiVKz5JeXYmAW-vIJQ&ved=0CBcQFjAB&sig2=zR3yeqyGdLbHnQS4ltiTKA&usg=AFQjCNFd09GAh73XhRri8H9IkZcjkY0whw (verified 12 November 2014).
Swainson, (2013) Environmental plantings webinar transcript [Online]. Available at http://www.cleanenergyregulator.gov.au/Carbon-Farming-Initiative/events/Pages/transcript-plantings-webinar.aspx (verified 12 November 2014).
Young, J.M., Saul, G., Behrendt, R., Byrne, F., McCaskill, M., Kearney, G.A., Thompson, A.N., 2014. The economic benefits of providing shelter to reduce the mortality of twin lambs in south western Victoria. Anim. Prod. Sci. 54, 773–782.