Assessing South Australian carbon offset supply and cost

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Executive Summary

This report presents research that fills knowledge gaps related to how much carbon sequestration supply to offset carbon emissions might be available, at what carbon price and from what land use and management change, in South Australia (SA). It provides estimates of carbon offset supply amounts that could be economically viable at various price points for a set of agreed Emissions Reduction Fund (ERF) and prospective non-ERF methods. The geographic focus of this work is areas of South Australia predominantly used for intensive agriculture. Estimates of annual and cumulative carbon supply over a 100 year horizon for 2020 plantings were produced for relevant areas. We considered the economic method consistent with previous related economics literature, which assumes carbon credits for 100 years and a requirement to keep land covered in trees for 100 years. We also calculated how conservative ERF rules, that credit only the first 25 years of carbon sequestration, but require permanent land use change for 100 years, change the economics of carbon supply. All costs relevant to an economically oriented landholder were accounted for. This includes cost of establishing and maintaining carbon plantings, and the opportunity cost foregone from the previous land use.

Carbon supply from ERF methods

Two currently available ERF methods to supply carbon that can be implemented across broad swathes of SA were evaluated: revegetation with Mallee monocultures and revegetation with Environmental Plantings. An additional ERF method, human induced regeneration, was also evaluated for permanently ceasing the mechanical or chemical destruction, or suppression of forest regrowth. This method is relevant to small areas of land holdings (≈ 35,000ha) that have permits to allow the destruction of Mallee regrowth via heavy rolling and grazing on long (up to eight years) intervals.

We found that the overall potential supply from environmental methods would be large at high carbon prices under the base case scenario assumptions of a 100 year crediting period (consistent with academic literature), current climate, agricultural profitability growth on current trend and a discount rate of 5 percent. For example, at a carbon price of \$200 /tCO_2e, over two gigatonnes of CO_2e could be sequestered over a 100 year period. Whilst a carbon price in this range is unlikely and the trade-off involved with this level of supply would also likely be unacceptable, we present it for completeness to allow understanding of the true physical potential for SA agricultural lands to sequester carbon. This level of supply would involve revegetation of approximately 8.5 million hectares, and would displace in the order of \$58 billion (present value) in direct agricultural activity over a 100 year period.

Economically viable supply first occurred at a more realistic price of approximately \$50 /tCO_2e, but still significantly higher than recent ERF auction prices (≈ \$11-13 /tCO_2e). At this price 130 MtCO_2e of abatement cumulatively and 4 MtCO_2e annually would be possible by 2050 (an amount of annual abatement equal to about 15% of South Australia's 2015 total emissions). This would involve displacing 316,000 ha of agricultural production worth \$80 million annually over the 30 year period from 2020 to 2050.

The Mallee ERF revegetation method was found to provide relatively expensive abatement compared to Environmental Plantings. This is possibly primarily because this methodology is only applicable in areas receiving less than 600 mm of rainfall, and so areas with high (potential) carbon yields are excluded under ERF eligibility requirements.

Significant supply was only estimated to be possible at prices above \$100 /tCO_2e with Mallee revegetation methods. For example, at \$125 /tCO_2e ≈ 79 MtCO_2e was estimated to be economically viable over the 100 year permanence period option, which does not involve 20 percent discounting like the 25 year option. Most supply with this method was realised within 30 years. For example, at a price of \$150 /tCO_2e ≈ 150 MtCO_2e would be available over 30 years in comparison to 158 MtCO_2e of abatement over 100 years.

When considering a 25 year crediting period, consistent with current ERF protocols, carbon supply calculated under a conventional methodological approach of a 100 year crediting period appear optimistic. For both Mallee and Environmental Plantings, the carbon price at which supply is initiated increased significantly (16 percent for Mallee plantations and 10 percent for Environmental Plantings). An important outcome from the consideration of a 25 year crediting period was the significant decline in the amount of lowest cost abatement opportunities for the Environmental Plantings method. For example, under a 100 year crediting period, at $42 /tCO_2e approximately 49 MtCO_2e was available over the 100 year permanency period. Under a 25 year crediting period consistent with the ERF, only 4 MtCO_2e is available at $42 /tCO_2e. Such significant decline in lowest cost abatement results in a marked increase in the carbon price required to abate South Australia's residual emission in 2050 of 12.7 MtCO_2e. Under 100 year crediting a carbon price of up to $70 /tCO_2e would initiate enough land use change to carbon forestry to abate residual emission in 2050, however under a 25 year crediting period this increases $157 /tCO_2e, a 124 percent increase.

Distinct regional differences in potential to supply and cost of supply were evident. The South East of South Australia offers the greatest amount of relatively low cost carbon from Environmental Plantings by far. There may, however, be trade-offs in loss of groundwater recharge from establishing large areas of Environmental Plantings in this region. Other regions also offered some lower cost opportunities which are predominantly quite localised and tend to arise where there are combinations of relatively higher carbon yields and/or relatively less opportunity cost.

The human induced regeneration option evaluated applies to small areas of land holdings (≈ 35,000 ha) that have permits to allow the destruction of Mallee regrowth via heavy roller. Current practice is to roll and graze such properties on intervals such as once every eight years. Whilst this represents a niche opportunity, it does potentially provide a significant economically viable abatement option ≈ 5.5 to 6 MtCO_2e over a 100 year period. Local expert opinion is that grazing in such circumstances is substantially less productive than more standard sheep grazing in similar geographic areas. Thus, 25 percent of the average agricultural opportunity costs of sheep grazing enterprises in the region of the eligible land parcels being investigated was our default assumption. With this assumption, economically viable abatement begins at $21 /tCO_2e yielding ≈ 130,000 /tCO_2e over a 100 year period. Our estimate of viable supply grew substantially to ≈ 3.8 MtCO_2e over 100 years at a price of $50 /tCO_2e.

Sensitivity of supply estimates to key assumptions

Supply estimates were found to be sensitive to variations in a number of key assumptions. The effect of a higher discount factor, representative of landholder reticence (or hurdle) to supply was significant. It was greatest for the Mallee supply option where an approximate 94 percent reduction in supply was estimated at a price of $125 /tCO_2e when comparing a 10 to a 5 percent discount rate scenario. The impact was less radical, but still significant, for Environmental Plantings where at a carbon price of $100 /tCO_2e held constant each year over the 100 year horizon had the effect of the 10 percent rate relative to a 5 percent rate, was a supply decline of ≈ 21 percent.

Because the Environmental and Mallee planting options compete for land with agriculture, higher agricultural productivity implies higher opportunity cost and less willingness of economically oriented landholders to supply carbon at any given price. The effect of increasing agricultural productivity at both 1.5 and 3 percent per annum was considerable compared to the base case assumption of no growth. For example, for Mallee plantings, at a carbon price of $75 /tCO_2e under the 1.5 percent scenario supply declined by ≈ 35 percent from the base scenario. The effect was more radical for Environmental Plantings where at a carbon price of $100 /tCO_2e supply was reduced by ≈ 48 percent. We did not consider changes in carbon farming productivity though they could offset agricultural productivity growth effects somewhat.

The effect of varying establishment cost by ± 25 percent on supply was smaller than estimated effects of varying discount rates and agricultural profitability. However, at higher carbon price points for Environmental Plantings the sensitivity of carbon supply estimates was significant. For example, for Mallee plantings, at a carbon price \$100 /tCO_2e 25 percent higher establishment cost decreased supply by ≈ 27 percent. For Environmental Plantings, the effect of 25 percent higher establishment cost was less: at a carbon price of \$100 /tCO_2e supply was ≈ 10 percent less than in the base case scenario.

Our base case assumption was current climate. Three additional climate change scenarios were also evaluated. An assumption of mild warming and drying had a moderate effect on supply of abatement. For example, for Mallee plantings at \$100 /tCO_2e a reduction by 21 percent from base case historic climate abatement was estimated. In contrast under severe warming and drying scenarios, abatement potential was estimated to drastically decrease in comparison to a historical climate scenario. For example, for Environmental Plantings at \$100 /tCO_2e the reduction in abatement for severe warming relative current climate was estimated to be ≈ 38 percent over the 100 year permanency period.

Carbon Supply from Non-ERF methods

We also estimated the potential to supply carbon, and the cost of such supply, for several methods which are not currently ERF methods, but that could be advocated for by South Australia. One was rangeland regeneration for the large area of land in the northern agricultural and southern pastoral zones, generally used for extensive livestock grazing (primarily sheep). The area is not eligible for inclusion in existing ERF revegetation methodologies as these areas often incorporate existing remnant native vegetation, and the vegetation type does not satisfy Kyoto protocol conditions of 20 percent canopy cover at two metres in height. Despite this, these areas represent potential as carbon abatement options through the exclusion of livestock grazing. We found that low cost abatement potential from the study area is limited due to a combination of low carbon sequestration rates and moderate agricultural opportunity costs. The majority of the abatement potential for this option occurs at prices of \$100 /tCO_2e or above. Still some (around 9.5%) of the area was found to be potentially available at prices below \$50 tCO_2e.

Another non-ERF method considered was grassy woodland regeneration in the Mt Lofty Ranges. This involves allowing the natural regeneration of originally occurring open woodland on currently cleared land. The method is not ERF compliant as the revegetation is sparse and does not meet the 20 percent canopy cover at two metre height conditions of the Kyoto Protocol. Despite zero establishment costs applying to this method, supply of abatement was still estimated to be relatively expensive. At \$50 /tCO_2e ≈ 1.7 MtCO_2e is available over the 100 year permanency period from this method with ≈ 7,300 ha available for restoration at this price.

Some landholders in the areas where this method applies (e.g. peri-urban lifestyle property owners) may be less commercially oriented and not value forgone agricultural opportunity cost. To assess the opportunity that this may present, modelling was also conducted considering zero opportunity cost[1]. This resulted in some much lower cost supply opportunities. For example, at \$22 /tCO_2e, supply ≈ 1.4 MtCO_2e over the 100 year permanency

[1] Fencing costs were also excluded as they are by no means prerequisite and are at the discretion of the landholder. Production systems not involving livestock would not require fencing and temporary fencing could be erected as is common in rotational grazing systems.

period was estimated to be available with this assumption. An additional consideration is that the areas considered for this option have high biodiversity conservation value. The benefits of combining carbon and biodiversity benefit was beyond the scope of this study, however should be investigated to provide a more comprehensive assessment of the land use change economics.

The final non-ERF method considered was restoration of drooping sheoak ecosysems on Kangaroo Island identified as a conservation priority by the Government of South Australia. This method provided the most expensive abatement opportunituies of the non-ERF methods examined, primarily due to low sequestration rates and moderate agricultural opportunity costs. The lowest cost abatement from this method was supplied at \$112 /tCO_2e, with ≈ 1.2 MtCO_2e in abatement over the 100 year permanency period.

Conclusion

This analysis supports work at National level (e.g. Bryan *et al.*, 2014) suggesting that conversion from agriculture to carbon plantings is not likely to be economically viable for most South Australian landholders at carbon prices below approximatley \$50 /tCO_2e. This finding is also consistent with outcomes of ERF auctions where supply of carbon plantings from land in South Australia was near zero at prices in the range \$11-13 /tCO_2e. This finding is further exacerbated if considering current ERF regulations that stipulate a 25 year crediting period and 100 year permanency period. The result of such a condition increases the cost of lowest cost abatement by up to 16 percent and could reduce supply by up to 90 percent at the corresponding carbon price.

The analysis discovered a number of niche opportunities where supply may be possible at prices closer to \$20 /tCO_2e, a level much closer to ERF auction prices and voluntary market prices that are now approaching \$17-18 /tCO_2e (O'Connor *et al.*, 2019, Energetics, 2017). The areas and volumes of carbon that represent potentially economically viable supply from these opportunities are small as a percentage of the total agricultural area of South Australia and potential sequestration. Still, in absolute magnitude they represent significant areas (tens to hundreds of thousands of hectares), sequestration (hundreds to millions of tonnes of CO_2e), and carbon payments (tens to hundreds of millions of dollars). Key examples include highly targeted low opportunity cost rangeland destocking opportunities in northern pastoral areas; highly targeted natural regeneration of grassy woodlands in relatively high carbon yielding areas and where land owner preferences are such that they don’t expect compensation for opportunity cost of forgone agricultural production; and cessation of Mallee rolling in targeted areas that represent very low opportunity cost and relatively high carbon yields. Providing landholders in such context information about these opportunities and facilitating low transaction cost ERF application process support may assist private landholders to realise these opportunities.

The second part of the reporting for this project will outline some further opportunities. These involve plantings that produce potential for carbon payments and additional benefits that have value to the landholders who undertake the plantings such enhanced agricultural productivity or reduced cost of water treatment through avoiding sediment and nutrient loading and consequent water treatment costs. The authors note that carbon plantings may provide more than one co-benefit simultaneously and in addition to those presented in this report, and these could conceivably lower the cost of abatement if benefits such as soil conservation and amenity value in addition to water quality, pollination service and carbon could be combined and stacked. However, for this report these benefits were considered singularly in conjunction with carbon benefit and results can be seen in Connor *et al.* (2019), Summers *et al.* (2019a) and Summers *et al.* (2019b).

1 Introduction

How much carbon supply might be available at what carbon price and from what land use and management change in South Australia (SA) has not previously been well documented. Prior to this research the Government of South Australia (GoSA) was working from one 2015 report. The report included an assertion that converting 37 percent of the eligible land base in the State to carbon forestry by 2020 could offset 12.7 $MtCO_2e$ annually and 139 $MtCO_2e$ cumulatively by 2050 (Hewson *et al.*, 2015). The report further asserted that in a scenario with rapid improvements in energy efficiency, electrification of transport/industry and low carbon electricity generation, emissions of 12.7 $MtCO_2e$ annually by 2050 could be possible down from 27.6 $MtCO_2e$ in 2015. Thus the inference is that carbon farming could offset SA emissions completely by 2050 (Figure 1).

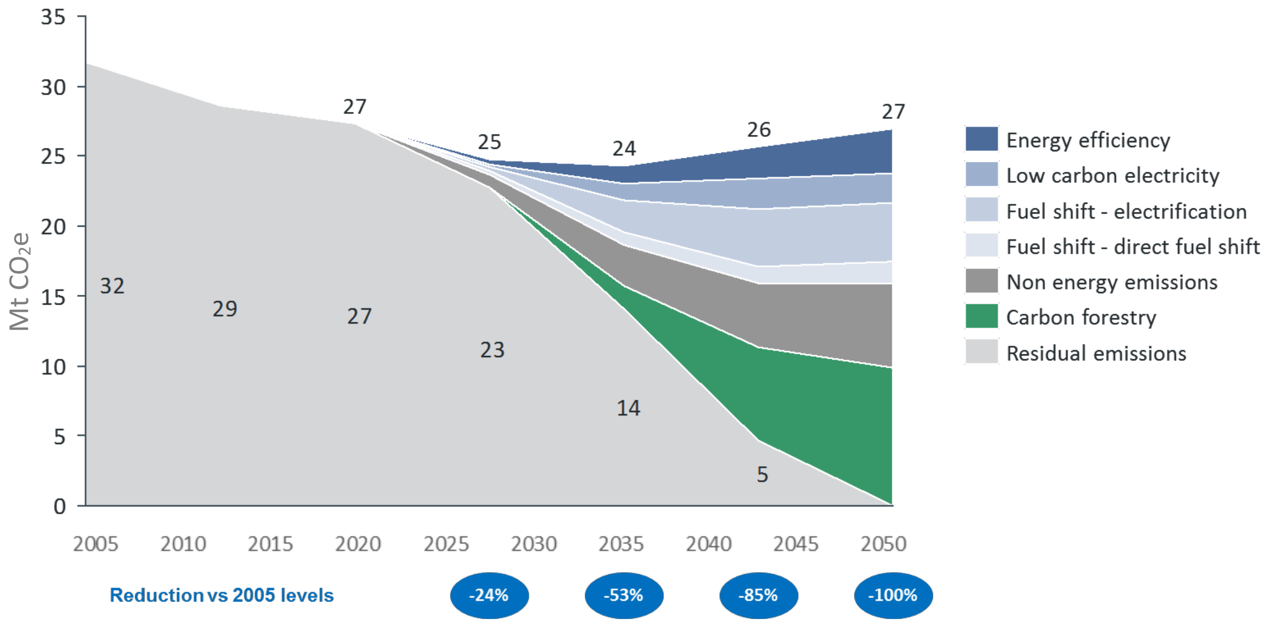


Figure 1: Emissions reduction pathways for South Australia 2005-2050 (Hewson *et al.*, 2015).

Carbon price, land use and management change, and costs required to induce this offset supply was not documented by Hewson *et al.* (2015). It is evident that results drew on CSIRO modelling (Bryan *et al.*, 2014) of potential carbon supply from Australia's agricultural landscape. That modelling suggested that little to no carbon supply would be economically viable at prices below \$50 /tCO_2e in SA, with supply increasing at higher prices under several future carbon market development scenarios (Bryan *et al.*, 2014).

To fill the fundamental gap in carbon budget and economic knowledge in SA, this report presents estimates of carbon offset supply that could be economically viable at various price points. The estimates of supply response to carbon prices presented here are consistent with what would be expected from economically motivated landholders. Specifically, we account for how such landholders would require compensation for costs of establishing new plantings and the costs of forgoing current agricultural returns to change from current agricultural land use to carbon forestry. To place results in context we compare potential offset supply to emissions from SA; present regionally disaggregated supply; and test sensitivity of modelled supply to variations in key assumptions about outcome drivers.

2 Objectives, scope and methods overview

2.1 Objectives

The overall objective of this reporting was to evaluate potential for carbon sequestration supply from South Australian agricultural and rangelands based offset options (not livestock options) for a set of agreed Emissions Reduction Fund (ERF) and prospective non ERF methods in the short, medium and long-term. More specific objective were to produce:

a) Estimates of tonnes of CO_2e supply possible across SA agricultural and range land for each of the agreed ERF and prospective non-ERF methods;
b) Estimates of the costs per tonne CO_2e abatement and how it increases as less costly opportunities are exhausted;
c) Identification (but not quantification) of key potential negative and positive environmental and economic implications;
d) Accounting for offset supply and cost implications of NRM planning constraints that may preclude some ERF or other methods in some locations; and
e) Quantitative assessment of supply reductions/increases arising from key supply uncertainties including: land holder preferences, adoption reticence and policy factors, scientific uncertainty and natural variability such as climate.

2.2 Spatial extent of carbon supply study area

Broadly, the study area for this research is the non-continuous 98,424,000 ha of land in SA (Figure 2). More specifically this study focuses on the reforestation of areas of the State predominantly used for intensive agricultural areas (i.e. areas cleared for broad acre cropping and grazing) which encompass approximately 11 percent of SA's area. Agricultural production across the State is carried out on land interspersed by areas of remnant revegetation and urban land uses. Agricultural production is dominated by cereal cropping, beef and sheep grazing with isolated areas of high-value irrigated horticulture and agriculture (Bryan *et al.*, 2014). In 2015/2016 the gross value of agriculture production from SA was $6.2 billion and the most important commodities, based on gross value, were wheat, cattle, sheep and lambs, and wine.

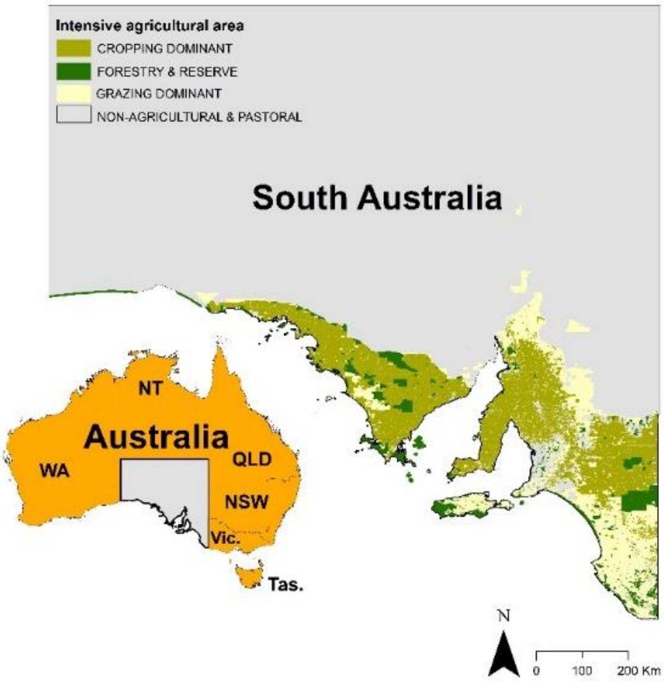


Figure 2: South Australian study area and current land use categories.

2.3 Methods overview

2.3.1 Carbon modelling

Full details of technical carbon supply work appear in the report entitled *Technical Estimation of Carbon Supply Data and Methodology Report* (Settre *et al.*, 2019). A brief overview of these methods are provided here.

The project considered both ERF, and non-ERF methods. Non-ERF methods were included as possible future scenarios that might become eligible for inclusion in the ERF. An overview of the ERF methods and non-ERF methods included, including their geographic extent, and the methods by which carbon sequestration potential of these methods was determined, was as follows.

Emissions reduction fund methods

Three ERF methods from the vegetation management sector and one ERF method from the agricultural sector were modelled. The ERF method from the agricultural sector was later excluded for economic analysis, and so is not discussed further here. The ERF methods included in this report are summarised in Table 1. Each ERF method prescribes a range of on-land activities called *project mechanisms* that can be undertaken to earn Australian Carbon Credit Units (ACCUs). The methods and the subsequent project mechanisms considered in this project are also shown in Table 1.

Table 1: Outline of Emissions Reduction Fund methodologies considered

Sector	ERF method	Project mechanism
Vegetation management	Reforestation by environmental or Mallee plantings	Mallee revegetation*
		Mixed environmental planting revegetation*
	Human-induced regeneration of a permanent even-aged native forest	The exclusion of livestock and the taking of reasonable steps to keep livestock excluded*
		The management of the timing, and the extent, of grazing
		The management, in a humane manner, of feral animals
		The management of plants that are not native to the project area
		The implementation of a decision to permanently cease the mechanical or chemical destruction, or suppression, of regrowth*
Agriculture	Estimating sequestration of carbon in soils using default values	Increasing biomass yields through sustainable intensification*
		Retaining crop residue in field rather than burning or bailing*

**= considered in this project*

For the ERF methods, carbon supply in each eligible area for implementation was estimated. ERF methods and project mechanisms have strict eligibility requirements (Table 2). Using generalised land use mapping data (DPTI, 2016) in ArcGIS, eligible land for each project mechanism was determined based on land use characteristics, current native vegetation cover and annual rainfall.

Table 2: ERF eligibility requirements.

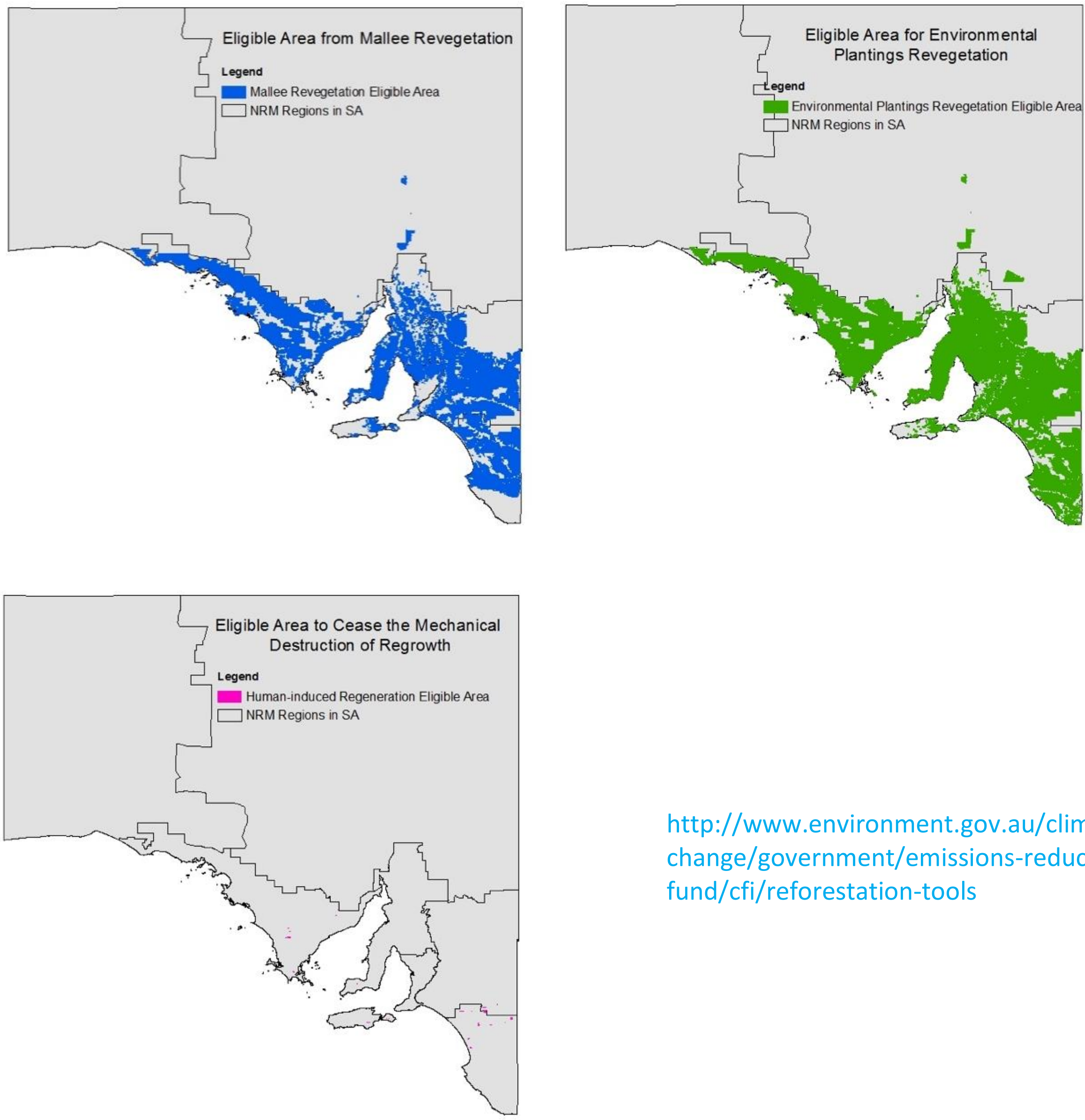
ERF Method	Project mechanism	Eligibility requirements
Reforestation by environmental or Mallee Plantings	Mixed environmental planting revegetation	• Land must not contain woody biomass that would need to be cleared for revegetation to occur, except in the case of prescribed weed species • Land must be clear of forest cover for at least five previous years • Trees on project land must be the potential to attain a height of 2 m and a crown cover of at least 20%
	Mallee revegetation	• In addition to all as above, Mallee plantations must only be established in regions with long-term average rainfall of 600 mm/year or less
Human-induced pegeneration of a Permanent even-aged native forest	The implementation of a decision to permanently cease the mechanical or chemical destruction, or suppression, of regrowth.	• Land is not conservation land • Land must have been used or managed in a way that suppressed the development of forest cover either through livestock grazing, feral animals, plants not native to the area, or mechanical or chemical destruction/suppression of regrowth • Land did not have forest cover at any time during the baseline period (e.g. before stock exclusion occurred)
Estimating Sequestration of Carbon in Soils Using Default Values	Increasing biomass yields through sustainable intensification	• Land must be agricultural land which has been cropped, grazed or fallowed at least once in the previous five years • Land must have deficient soil that can be improved by undertaking two specified management actions
	Retaining crop residue in field rather than burning or bailing	• Land must be agricultural land which has been cropped, grazed or fallowed at least once in the previous five years • No burning or bailing can occur on land more than once every five years while the area is under crops

Sources: DoE (2015b), DoE (2015a) & Frydenberg (2017)

The total area eligible for each ERF method project mechanism by NRM Region is presented graphically in Figure 3.

A sample grid of 10 km intervals was applied across SA. Sample points falling within eligible land were identified. Within the gridded intervals, eligible areas were identified based on current land use and rainfall requirements prescribed by the ERF methods. The ERF land use restrictions prevent the inclusion of urban areas, regional townships, and currently existing vegetated areas, among others. In ArcGIS, shapefiles of these areas were created and then excluded from analysis. The remaining eligible areas were identified and a shape file of eligible land was created for each of the ERF method investigated. Sample points within non-eligible land but within the nominal agricultural zone were also noted for future analysis. More detail is given in *Technical Estimation of Carbon Supply Data and Methodology Report* (Settre *et al.*, 2019).

The Full Carbon Accounting Model (FullCAM), the model used to construct Australia's national greenhouse gas emissions account for the land sector, was applied at a 10 km intervals across the study area (Figure 2) resulting in 100 year annual and cumulative carbon sequestration estimates for eligible land (Figure 3) for each ERF methodology. For soil carbon estimates, the 2015 version of the Federal Government's Carbon Farming Initiative Mapping Tool (CFI Mapping) was used to estimate sequestration.



http://www.environment.gov.au/climate-change/government/emissions-reduction-fund/cfi/reforestation-tools

Figure 3: Geographical extent of the eligible areas associated with each of the ERF methodologies included in the economic analysis.

Non-ERF methodologies

Three non-ERF methods were developed and modelled in this project, all classified as vegetation management or human induced revegetation: a) Drooping Sheoak restoration on Kangaroo Island; b) grassy woodlands restoration in Mount Lofty Ranges; and c) carbon sequestration in the southern Rangelands/northern agricultural zone (

Table 3).

Table 3: Proposed Non-ERF methods included.

Sector	Proposed non-ERF method	Proposed project mechanism	What makes it non-ERF?	Relevance to SA
Vegetation management	Revegetation of Drooping Sheoak on Kangaroo Island	*Casuarina* forest revegetation	Does not meet 20% cover at 2 m condition (sparsely populated)	Conservation priority
	Grassy Woodlands Regeneration in the Mount Lofty Rangers	*Eucalyptus* woodlands natural regeneration measures	Does not meet 20% cover at 2 m condition (sparsely populated)	Conservation priority
	Carbon Sequestration in the Southern Rangelands	Environmental plantings in sandy soil, moderate to low rainfall zones	Has existing native remnant vegetation, does not meet 20% cover at 2 m condition	Large area of land

Applicable areas for non-ERF methods considered in this project are shown in Figure 4. The non-ERF methods were selected on a criteria based on existing conservation targets and applicability to SA. The non-ERF methods developed do not meet requirements under the current legislation due to inability to reach 20% forest cover at 2 m and also due to their placement outside of eligible land uses.

To the greatest degree possible, the same procedure to determine eligible land and identify sample points was applied to the non-ERF methods as was to the ERF methods described above (*Carbon Physical Supply Estimation Methods*). However, because there is no eligibility requirements placed on the non-ERF methods, the area estimates were approximated from the ERF eligible areas.

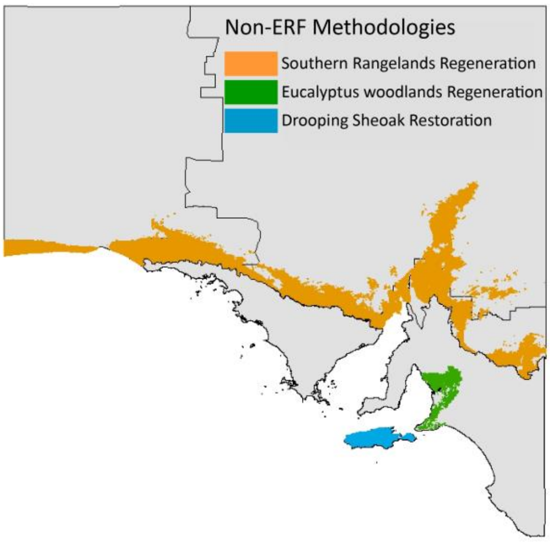


Figure 4: Geographical extent of the eligible areas associated with each of the non-ERF methodologies included in the economic analysis

For the sake of comparability to the ERF methods, it was advantageous to use existing tools where possible. The 2016 version of FullCAM was used for *Drooping Sheoak restoration* and *grassy woodlands restoration* methods. Results were outputted as cumulative carbon sequestration over a project timeframe of 100 years. FullCAM technical specifications are provided in DoEE (2016).

For carbon sequestration in the southern Rangelands, a different model developed by Hobbs *et al.* (2016) was used to estimate carbon storage in native tree species at 25, 45 and 65 year intervals from establishment.

2.4 Carbon supply economics

Following estimation of carbon annual and cumulative supply across the study area (Figure 2), point estimates were up scaled to area estimates of carbon sequestration supply over a 100 year horizon for 2020 plantings. The economic cost of supplying carbon was then calculated by sample point. Two components of cost were accounted for: a) costs of establishing and maintaining carbon plantings; and b) the opportunity cost foregone from the previous land use. The net present value of all costs involved were compared to the net present value of carbon sequestration for a range of carbon prices. The amount of additional supply value greater economically viable at each price point was then calculated to trace economic supply curves for each method. Details of economics methods and data are provided in Regan and Connor (2019).

To deal with the long investment horizon (100 years) net present value methods were applied which involves discounting all future costs and returns: the formulas applied are described Regan and Connor (2019). To account for the 100 year permanence and 25 year crediting period consistently with the ERF method, only carbon values for the first 25 years were counted. However, the land use change is required to stay in place and opportunity cost is charged for the entire 100 years. This difference results in about 25% higher cost per CO_2e than results when 100 years of carbon credit value are considered.

3 Findings

Consistent with past academic literature, economic supply was calculated for a 100 year permanency period carbon plantation that credited carbon sequestration for the full 100 year period (e.g. Connor *et al.*, 2016; Bryan *et al.*, 2015). i.e. In every year of the 100 year period the land holder received a payment for the carbon sequestered in that year. However, under the Australian Government's current policy for the ERF, a 25 year crediting period is stipulated. As such a 100 year crediting period assumption provides an optimistic estimate of carbon supply.

Under current ERF regulations, only the first 25 years of sequestration is compensated but land must stay in trees for 100 years (a 25 year crediting period and 100 year permanency period). To evaluate economic implications of this current regulation, we also calculated the price of carbon required for returns from switching land from farming to carbon necessary to cover all costs over 100 years. This includes opportunity costs and uncompensated sequestration that occurs in years 26 to 100 of the permanency period. Section 3.1 provides a comparison of expected carbon sequestration supply for all of SA calculated two ways: 1) with the 100 year crediting period used in previous peer reviewed literature,; and 2) with the ERF 25 year crediting period required in actual ERF contracts. Estimates of carbon supply at varying carbon price points by SA Natural Reource management (NRM) region are provided in section 3.2 for the 100 crediting period and 3.3 for the 25 year crediting period. Other results (sections 3.4 – 3.7) are for 100 year crediting period.

3.1 ERF Methodologies

3.1.1 State-wide abatement from combined Mallee and Environmental Plantings ERF methodologies 100 year crediting period

Mallee and Environmental Plantings methods are applicable across nearly all of SA's cropping and grazing areas. The results from the eligible areas for the two methodologies is a good approximation to overall state supply possible from ERF revegetation methods. Results of carbon supply analysis for the two methods (choosing the least cost of the two on land eligible for both) shows that considerable amounts of carbon abatement is available from the South Australian landscape.

The lower curve in Figure 5 shows supply with 100 year crediting with further base case scenario assumptions of current climate, stable agricultural profitability and a discount rate of 5 percent. This shows[2]:

- At a carbon price of \$200 /tCO_2e, representing an extreme high price upper bound, over two giga tonnes of CO_2e could be sequestered over a 100 year period (Figure 5).
- This level of supply would involve revegetation of approximately 8.5 million hectares and would displace in the order of \$58 billion (present value) in direct agricultural activity over a 100 year period.
- At the last round current ERF price of ≈ \$12 /tCO_2e no land in SA is economically viable for carbon forestry.
- When all establishment and opportunity costs are considered the first economically viable options occur at \$38 /tCO_2e. At this price ≈ 9.3 MtCO_2e of abatement could be achieved by 2050.

[2] Calculations are based on year 0 = 2020

- Carbon abatement potential increases significantly at prices over \$40 /tCO_2e.
- At \$50 /tCO_2e ≈ 130 $MtCO_2e$ of abatement could be achieved by 2050.
- This amount of revegetation would occupy ≈ 316,000 ha and displace \$1.2 billion Net Present Value (NPV) in agricultural activity over the 30 year period to 2050.
- Modelling provided in previous reporting (Hewson *et al.*, 2015; Figure 1) indicates that in an optimistic emissions reduction scenario, for SA to reach zero net emissions in 2050, 12.7 $MtCO_2e$ offset would be required from carbon forestry. Our results show that at a price \$50 /tCO_2e ≈ 4 $MtCO_2e$ of abatement could be expected in 2050.
- This is approximately one third of the abatement required to offset emissions of 12.7 $MtCO_2$.
- It is not until prices reach approximately \$70 /tCO_2e that residual emission in 2050 could be negated by carbon forestry abatement.
- Under a 25 year crediting period the first available supply shifts from \$38 /tCO_2e to \$42 /tCO_2e.
- While the price at which first supply is available is effected significantly, the carbon supply at each price point is significantly reduced. For example, at \$42 /tCO_2e supply is reduced 49 $MtCO_2e$ to 4 $MtCO_2e$ over the 100 year period, a reduction of approximately 91 percent.
- At higher carbon process the scale of the difference declines, however is still significant. For example at \$100 /tCO_2e supply is reduced by 1105 $MtCO_2e$ over the 100 year period to 766 $MtCO_2e$, a reduction of 30 percent.

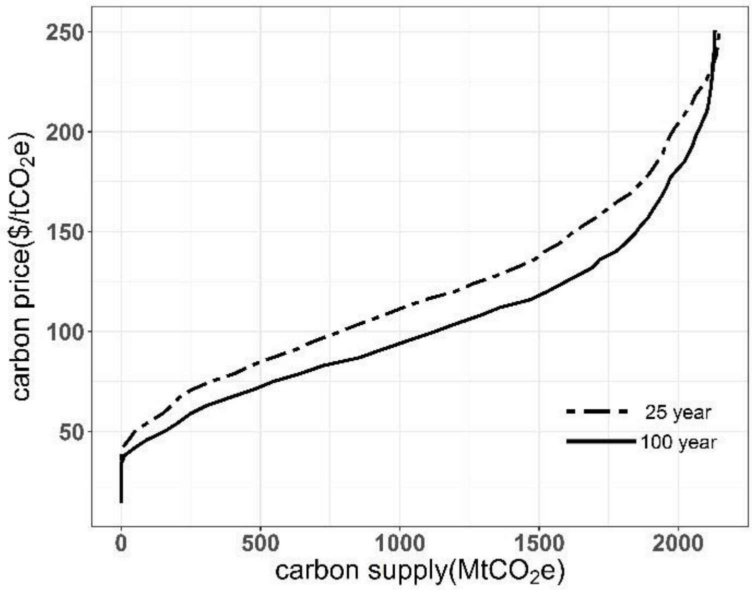


Figure 5: State-wide carbon abatement potential environmental revegetation ERF methodology to a price of \$250 /tCO_2e.

In terms of abating residual emissions of 12.7 $MtCO_2e$ in 2050 through Environmental Plantings, a carbon price of up to \$157 /tCO_2e would be required. This is a 124 percent increase on the 100 year crediting method, which calculated a price of \$70 tCO_2e.

3.1.2 Mallee monoculture revegetation 100 year credit period

Potentially economically viable supply with the Mallee monoculture ERF revegetation method at various price points is presented in Figure 6 for a 100 year crediting period. Results indicate that this is a relatively expensive abatement option compared to Environmental plantings. One explanation is that under the ERF planting rules, this methodology cannot be used in areas above 600 mm of rainfall, excluding many high productivity areas with high carbon yields.

Under the base case scenario of current climate, stable agricultural profitability and a discount rate of 5 percent we found the following:

- Nearly 800 M/tCO_2e of supply is possible at a price of \$250/ /tCO_2e.
- Supply of abatement begins at \$75 /tCO_2e delivering ≈ 1.43 MtCO_2e over a 100 year period. The areas where this occurs are very low opportunity cost land on the northern Adelaide plains and have the potential to already be salt affected further limiting suitability.
- Very small amounts of abatement are available for the Mallee ERF methodology at prices below \$100 /tCO_2e.
- As can be seen in Figure 6 tThe increase in supply of abatement from this planting methodology is slow with no significant increase in abatement below a price of \$100 /tCO_2e.
- At a price of \$125 /tCO_2e ≈ 79 MtCO_2e could be achieved over the 100 year permanency period.
- Abatement potential rises steeply between prices of \$125 /tCO_2e and \$150 /tCO_2e. At \$150 /tCO_2e ≈ 158 MtCO_2e of abatement over 100 years becomes viable.
- When considering the 30 year time horizon to 2050, the results show relatively little change in the achievable abatement totals when compared to the 100 year permanency period. For example at \$150 /tCO_2e FullCAM modelling shows ≈ 150 MtCO_2e would be available over 30 years in comparison to 158 MtCO_2e of abatement over 100 years. This is a function of the s-shaped plantation growth curves, with the majority of carbon sequestration occurring in the first 40 years of a plantations lifetime.
- If relying on this ERF methodology to abate residual emissions of 12.7 MtCO_2e in 2050 an extremely high carbon price of \$190 /tCO_2e would be required.

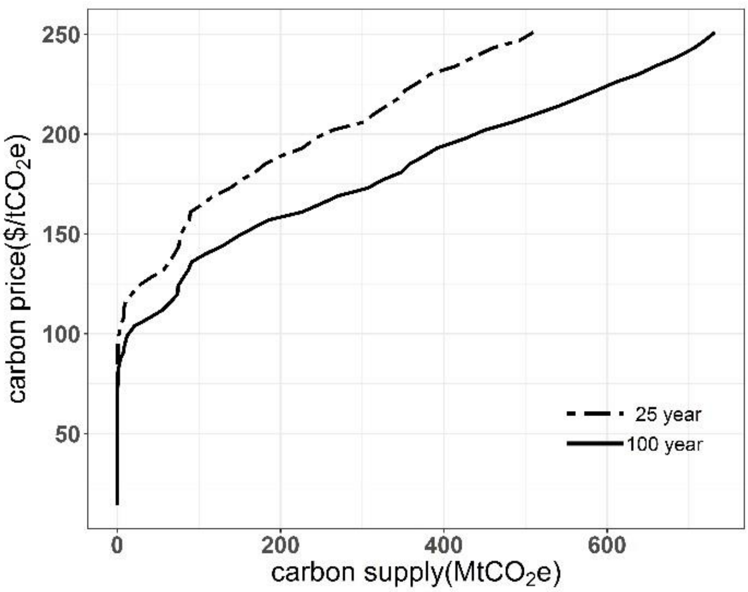


Figure 6: State-wide carbon abatement potential from Mallee monoculture revegetation ERF methodology to prices up \$250 /tCO_2e.

3.1.3 Mallee monoculture revegetation 25 year credit period

As can be seen in Figure 6 supply of abatement from Mallee revegetation becomes more expensive under the 25 year crediting period. Results show that:

- Under the 25 year crediting period the price at which supply is initiated increases from $75 /t$CO_2$e to $87 /t$CO_2$e (a 16 percent increase).
- In addition, supply at any given price point is significantly reduced. For example, at a carbon price of $100 /t$CO_2$e state-wide supply under a 100 year crediting period is approximately 12 MtCO_2e over the 100 year permanency period. When considering the 25 year ERF crediting period, supply at this carbon price is reduced to 1.6 MtCO_2e over the same period, a decline of 86 percent.
- In terms of abating residual emissions of 12.7 MtCO_2e in 2050 through Mallee plantations, a carbon price of up to $353 /t$CO_2$e would be required. This is an 85 percent increase on the 100 year crediting method, which calculated a price of $190 t$CO_2$e.

3.1.4 Environmental plantings methodology 100 year credit period

Environmental plantings were found to be a relatively cheaper source of abatement from afforestation compared to Mallee plantings with the 100 year crediting assumption. The majority of the abatement potential outlined in analysis of combined method supply consists of abatement from this methodology. So much so that the supply curve for Environmental Plantings is barely discernibly different than the curve for joint supply from both Environmental and Mallee plantings (Figure 5).

Under the base case scenario of current climate, stable agricultural profitability and a discount rate of 5 percent we found the following:

- Supply becomes available at a significantly lower price than Mallee monocultures. At a price of $38 /t$CO_2$e ≈ 9.3 Mt$CO_2$e of abatement becomes available.
- As shown in Figure 5 supply increases steadily at prices over $38 /t$CO_2$e. At $50 /t$CO_2$e ≈ 130 Mt$CO_2$e of cumulative abatement would be available to 2050.
- As outline above, for SA to abate residual emission in 2050 and achieve net zero emission in that year, a carbon price of ≈ $70 /t$CO_2$e would be required.
- At $50 /t$CO_2$e ≈ 316,000 ha would be more profitable under Environmental Plantings than current land use, with an opportunity cost of 1.2 billion in agricultural activity over the 30 year period to 2050. The majority of this land is located in the South East of SA and displaces land currently utilised for grazing.

3.1.5 Environmental Plantings methodology 25 year credit period

Similarly to Mallee plantings, the consideration of a 25 year crediting period significantly reduces the supply from Environmental Plantings.

- Under a 25 year crediting period the first available supply shifts from $38 /t$CO_2$e to $42 /t$CO_2$e.
- While the price at which first supply is available is affected significantly, the carbon supply at each price point is significantly reduced. For example, at $42 /t$CO_2$e supply is reduced 49 MtCO_2e to 4 MtCO_2e over the 100 year period, a reduction of approximately 91 percent.
- At higher carbon process the scale of the difference declines, however is still significant. For example, at $100 /t$CO_2$e supply is reduced by 1105 MtCO_2e over the 100 year period to 766 MtCO_2e, a reduction of 30 percent.

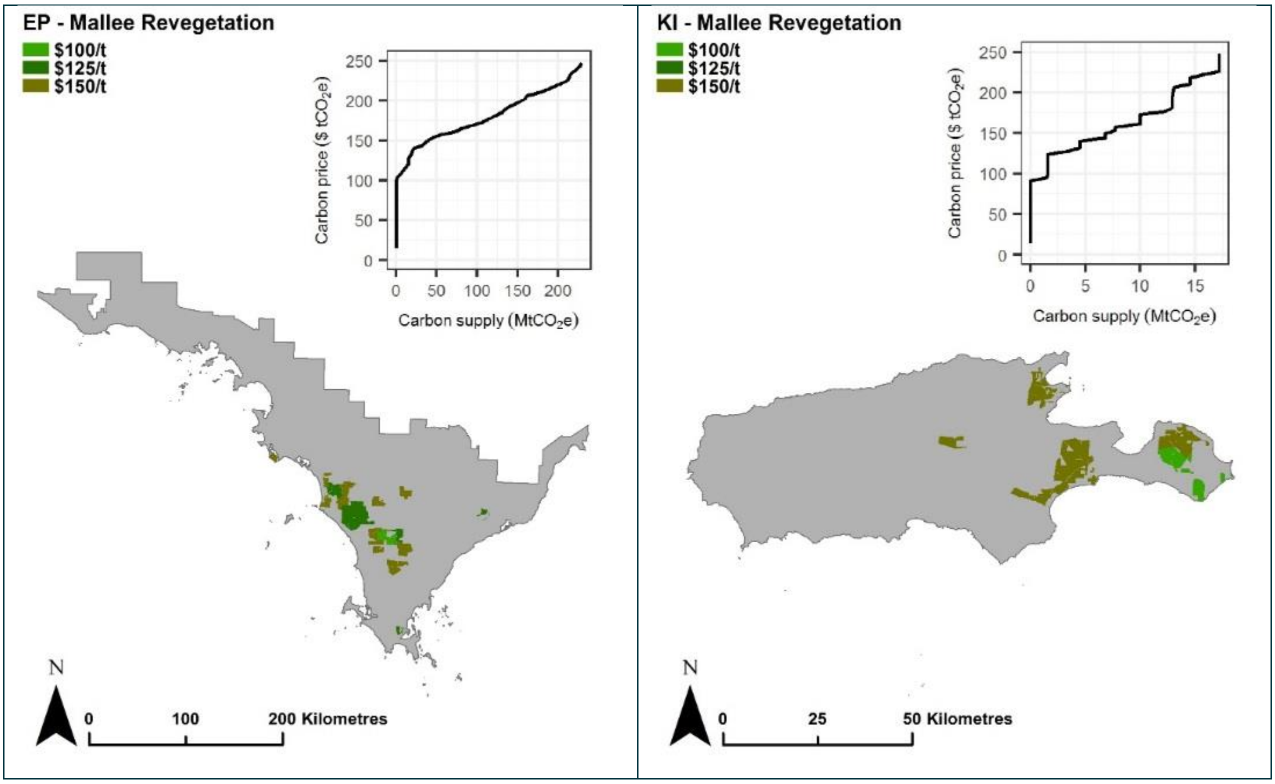
- In terms of abating residual emissions of 12.7 $MtCO_2e$ in 2050 through Environmental Plantings, a carbon price of up to \$157 /tCO_2e would be required. This is a 124 percent increase on the 100 year crediting method, which calculated a price of \$70 tCO_2e.

3.2 ERF Mallee and Environmental Planting results by NRM region 100 year credit period

We found distinct regional difference across South Australian NRM regions in potential for economically viable carbon supply with the 100 year crediting assumption. These are illustrated in Figure 7 for Mallee revegetation and in Figure 8 for Environmental Plantings.

Key findings with respect to NRM region disaggregated supply estimates for Mallee plantings include that:

- The greatest potential for supply from Mallee plantings is in the Mt Lofty Ranges, the South East, and the Eyre Peninsula.
- More relatively lower cost Mallee planting opportunities exist in higher rainfall and thus more carbon productive areas including parts of the Mt Lofty Ranges, the South East, and the south eastern part of the South Australian Murray-Darling Basin (SAMDB).
- The greatest potential for supply from Environmental Plantings are in the Mid North and Yorke Peninsula, the South East, the SAMDB, and the Eyre Peninsula.
- More relatively lower cost environmental planting opportunities exist in the South East, and the south eastern part of the SAMDB.
- Lower cost opportunities are quite local context specific and tend to arise where there are combinations of relatively higher carbon yields and or relatively less opportunity cost.
- The South East offers the greatest amount of relatively low cost carbon from Environmental Plantings by far. There may, however, be trade-offs in loss of groundwater recharge from establishing large areas of Environmental Plantings in this region.



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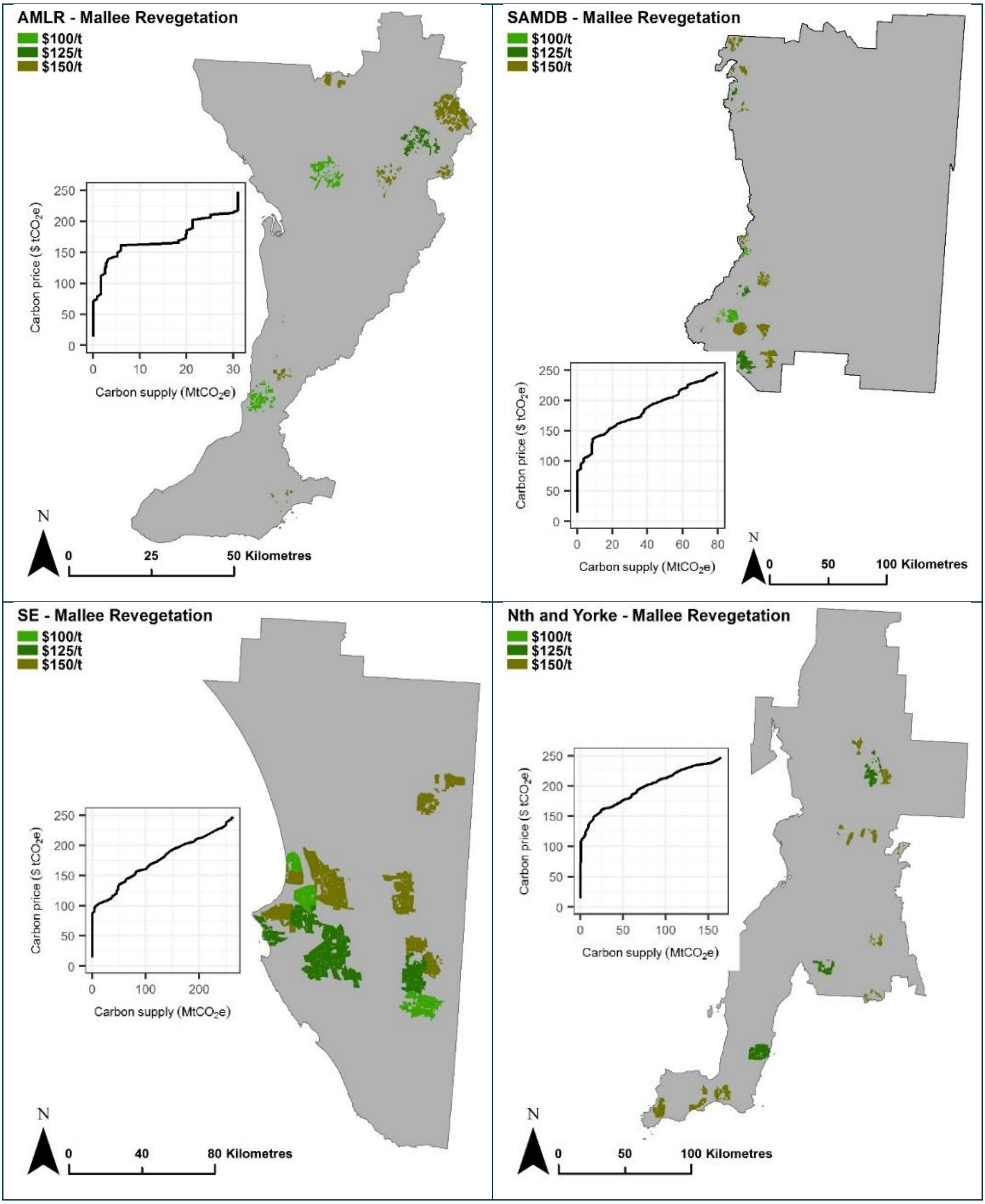
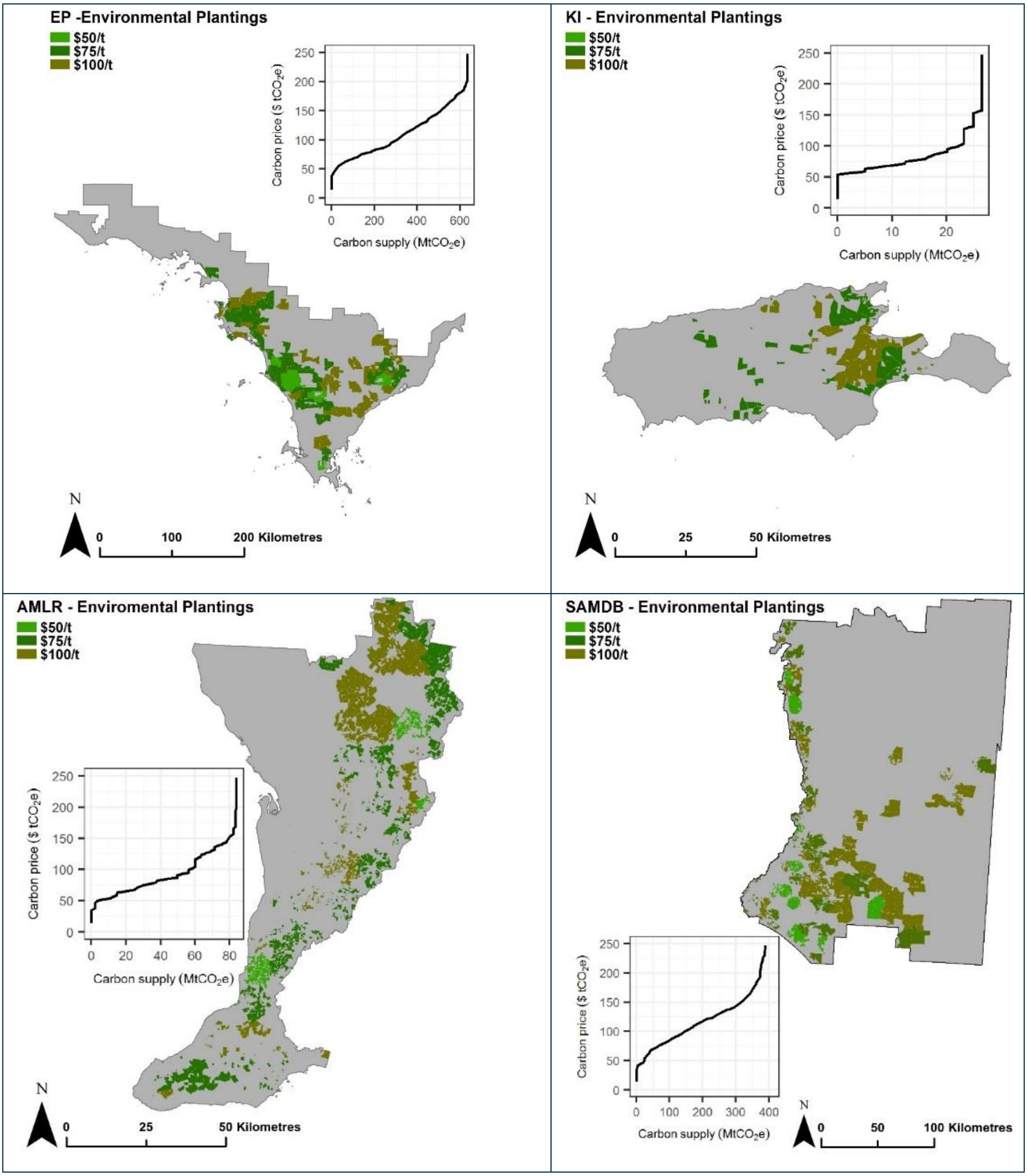


Figure 7: Potential for Carbon Supply over 100 years by ERF Mallee Method by SA NRM Region.



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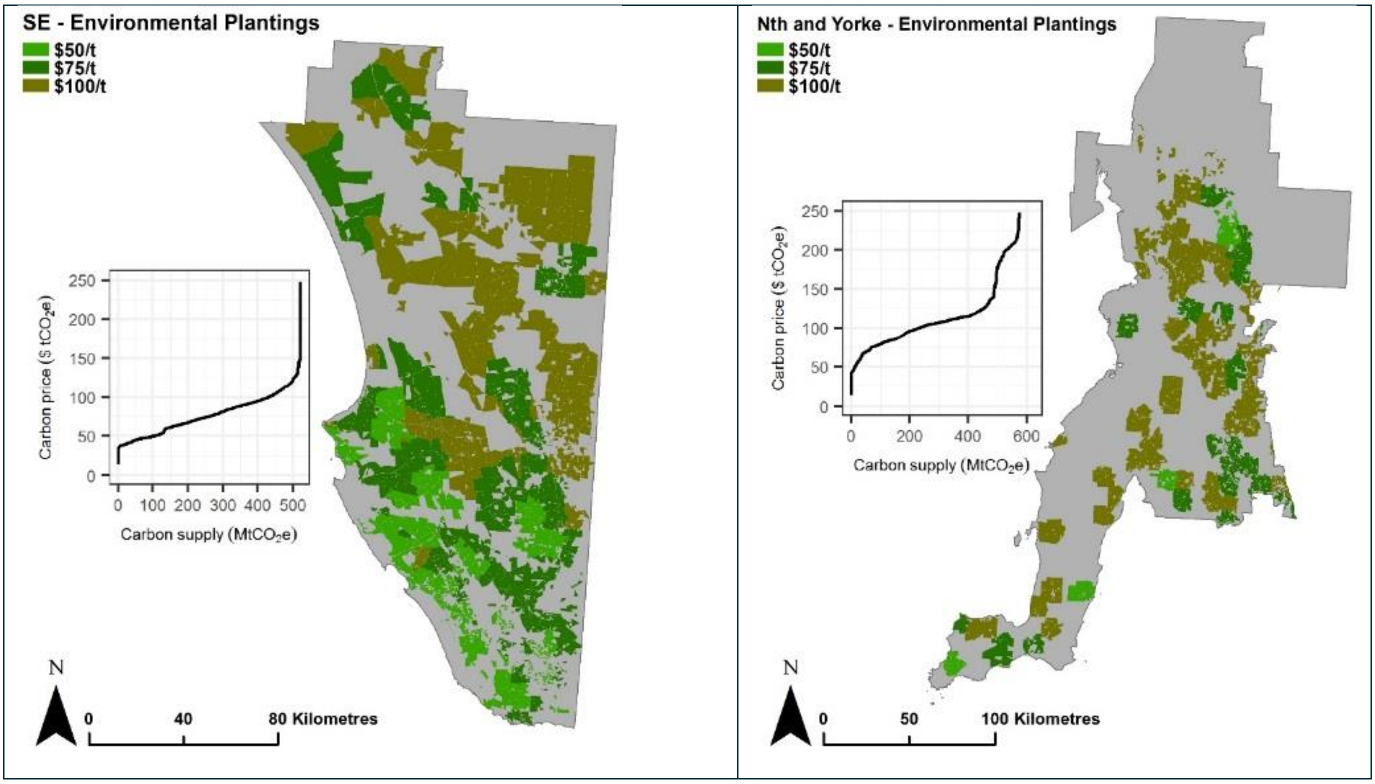


**Verticality of the supply curve indicates supply saturation. I.e. all eligible land is available.*

Figure 8: Potential for Carbon Supply over 100 years from ERF Environmental Planting Method by SA NRM Region.

3.3 ERF Mallee and Environmental Planting Results by NRM region 25 year credit period

As can be seen from Figure 9 and Figure 10 idiosyncratic differences emerge in the sequestration potential between the two crediting period examples across NRM regions. In all situations supply is reduced in the 25 year scenario.

3.3.1 Mallee monoculture revegetation

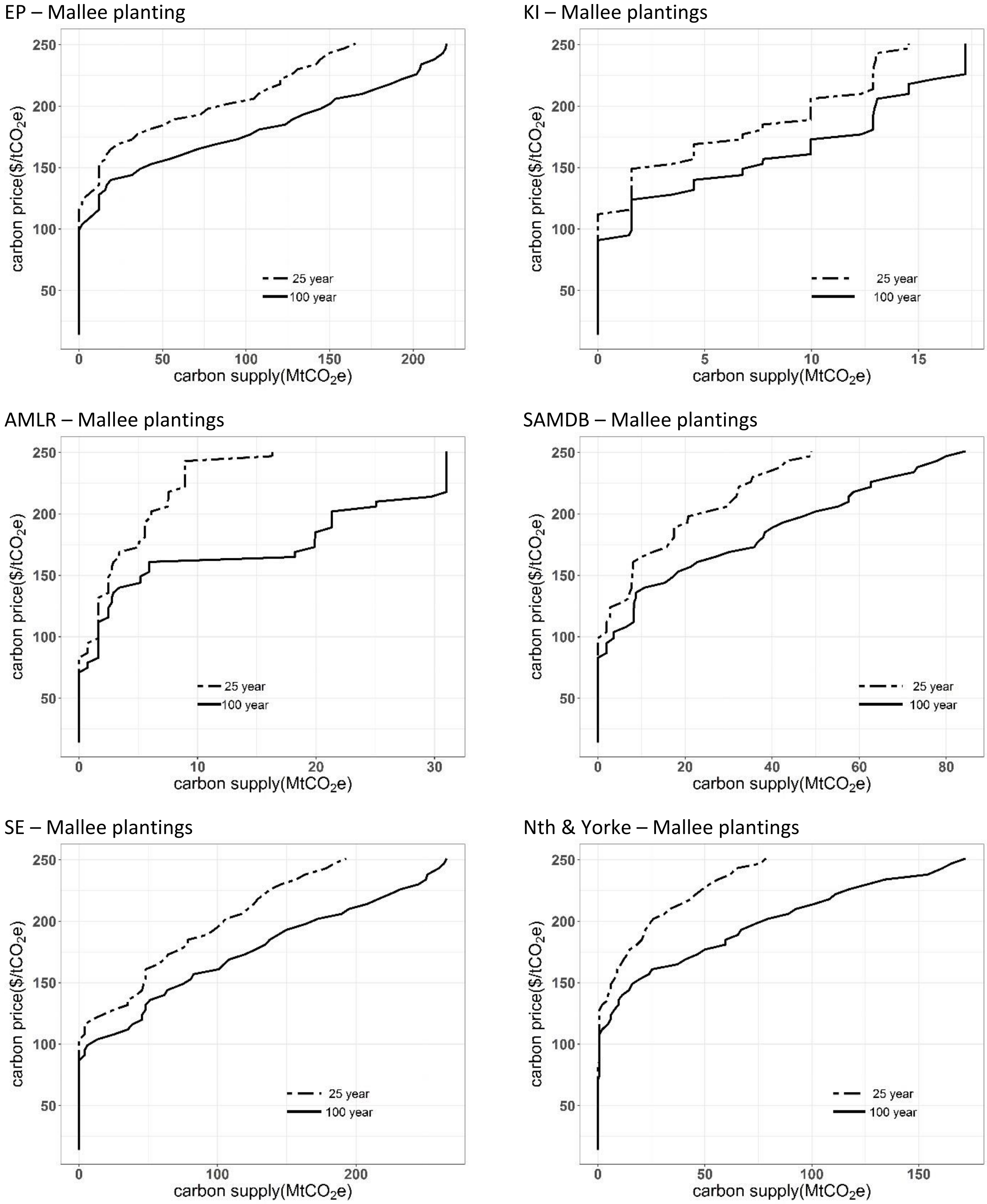


Figure 9: Supply curve comparing ERF mandated 25 year crediting period and a 100 year crediting period for a 100 year permanency period Mallee carbon planting by NRM region.

3.3.2 Environmental Plantings

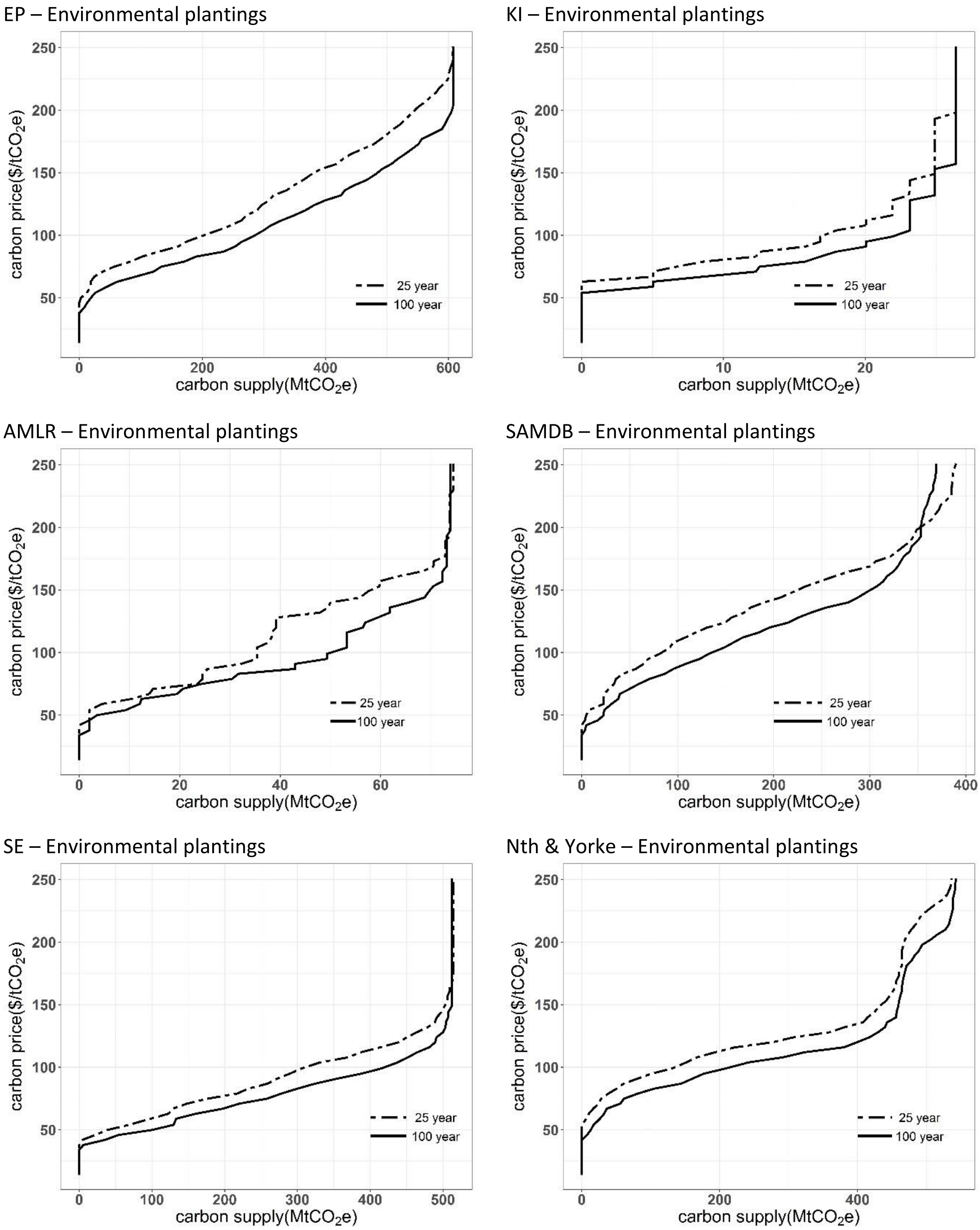


Figure 10; Supply curve comparing ERF compliant 25 year crediting period and a 100 year period for a 100 year permanency period environmental carbon planting by NRM region.

3.3.3 Human induced revegetation

This methodology, in contrast to the initial two ERF methodologies (Environmental and Mallee plantings) does not require the establishment of new forestry plantations. It was therefore seen as a potential low-cost abatement option. The methodology relates to the implementation of a decision to permanently cease the mechanical or chemical destruction, or suppression, of forest regrowth.

This methodology was applied to small area of land holdings (≈ 35,000ha) that have permits to allow the destruction of Mallee (*Eucalyptus* Sp.) regrowth via heavy rolling. As such this methodology represented a niche, but potentially significant economically viable abatement option of ≈ 5.5 to 6 $MtCO_2e$ over a 100 year period.

The economic modelling of supply presented difficulties in accounting for opportunity cost. The land is utilised for grazing, however, anecdotal evidence suggests it provides poor nutrition to sheep when grazed. Despite this, the fact that landholders continue with this land management practice shows the cessation of the practice would represent some opportunity cost.

In order to investigate this more fully, the economic modelling was performed using 25 percent to 100 percent of the average agricultural opportunity costs of sheep grazing enterprises in the region of the eligible land parcels being investigated.

For 100 percent regional sheep grazing opportunity cost, the results show that:

- If 100 percent opportunity cost is considered supply of abatement begins at a price of \$27 M/tCO_2e. At this price a very small amount of abatement is supplied over a 100 year period ≈ 100,000 tCO_2e.
- At \$50 /tCO_2e ≈ 1.9 $MtCO_2e$ of abatement could potentially be achieved over the 100 year permanency period.
- If the GoSA wanted to achieve the full abatement potential from this category of land, a carbon price of ≈ \$98 /tCO_2e would be required, if full opportunity costs were considered and compensated for.

For 25 percent regional sheep grazing opportunity cost, the results show that:

- Consideration of a lower opportunity costs improves the economics of this abatement option considerably. Supply of abatement begins at \$21 /tCO_2e. Only small abatement amounts are achievable at this price with ≈ 130,000 /tCO_2e over a 100 year period being potentially available.
- At \$50 /tCO_2e however supply almost doubles to ≈ 3.8 $MtCO_2e$ over 100 years.
- If the GoSA wanted to achieve the full abatement potential from this category of land, a carbon price of ≈ \$80 /tCO_2e would be required.
- Some areas in the analysis appear resistant to land use change and require high carbon prices for land use change to occur. The results from these areas was not driven so much by agricultural opportunity cost as by extremely low modelled carbon sequestration rates for the revegetation. In these locations, maximum modelled sequestration rates from regrowth are less than 1 tonne per year compared to the lowest cost location that has a maximum sequestration rate of over 3 tonnes per year.

3.4 Sensitivity of ERF methodology supply to varying assumptions

3.4.1 Discount rates

Several discount rate scenarios were tested. Evidence from the literature demonstrates that landholders often require higher than breakeven financial yields from new enterprises to compensate for risk when considering land use change to permanent forest cover. We approximated this effect by using higher than commercial cost of money discount rates in NPV calculations of supply. As can be seen from Figure 11 and Figure 12, the addition of higher discount rates decreases supply for both Mallee and Environmental plantings. Table 4 summarises the effect of higher discount rate on carbon abatement supply.

Table 4: Carbon abatement potential ($MtCO_2e$) to 2050 for Mallee monocultures and Environmental plantings between the prices of \$50 -\$150 /tCO_2e and using 3 different discount rates in the economic analysis.

	Discount rate		
	5%	*10%*	*15%*
Mallee Monocultures			
\$50 /tCO_2e	0	0	0
\$75 /tCO_2e	0.7	0	0
\$100 /tCO_2e	12	0	0
\$125 /tCO_2e	74	4	0
\$150 /tCO_2e	149	31	0
Price to abate residual 2050 emissions	***\$190***	***N/A***	***NA***
Environmental Plantings			
\$50 /tCO_2e	130	38	3.53
\$75 /tCO_2e	460	297	138
\$100 /tCO_2e	928	735	370
\$125 /tCO_2e	1332	844	429
\$150 /tCO_2e	1554	844	429
Price to abate residual 2050 emissions	***\$70***	***\$83***	***\$103***

Mallee monoculture revegetation

Key findings:

- The effect of the increased discount rate on supply from Mallee monocultures was considerable (Figure 11).
- Using a 10 percent rate increases the price required initiate supply from \$75 /tCO_2e to \$125 /tCO_2e.
- An approximate 94 percent reduction in supply is seen at a price of \$125 /tCO_2e when comparing a 10 to a 5 percent discount rate scenario.

- If a 15 percent rate is used in the analysis no supply would be generated under a price of $150 /t$CO_2$e.
- When considering a carbon price that would deliver abatement of residual emission in 2050, under a 5 percent discount rate and price of $190 /t$CO_2$e would be needed to supply 12.7 MtCO_2e. If considering a 10 or 15 percent discount rates in the analysis, it is not possible to deliver the required abatement in 2050 at prices less than $200 /t$CO_2$e.

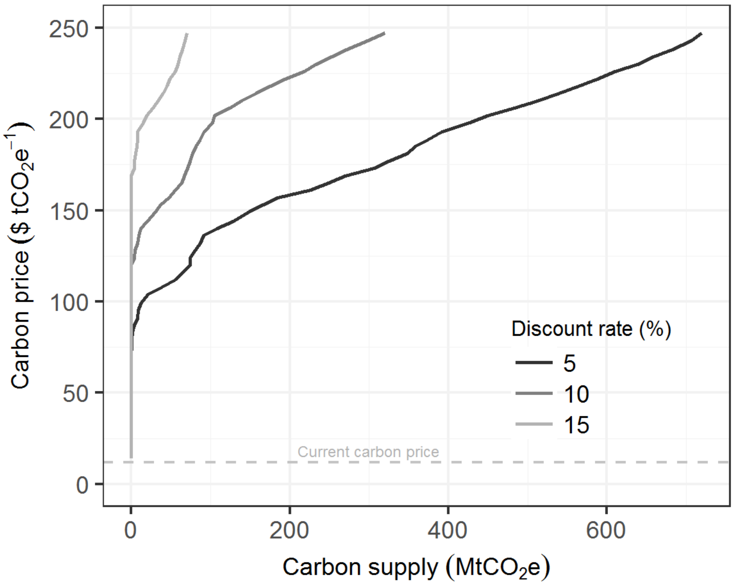


Figure 11: Effect of increased discount rate on the economics of abatement supply from Mallee monoculture revegetation.

Environmental Plantings

Key findings:

- Similarly to Mallee monocultures the effect of higher discount rates in the economic analysis on carbon supply was considerable.
- At a carbon price of $50 /t$CO_2$e supply under a 10 percent discount rate declined by 70 percent from 130 MtCO_2e to 38 MtCO_2e by 2050.
- At a carbon price of $100 /t$CO_2$e the effect of the 10 percent rate was still significant by not as pronounced. Supply at this price declined by ≈ 21 percent from 928 MtCO_2e by 2050 to 735 MtCO_2e.
- At a carbon price of $150 /t$CO_2$e supply to 2050 declined by ≈ 46 percent from 1.55 Gt CO_2e to 844 MtCO_2e.
- Under the assumption of a 10 percent discount rate the carbon price that would deliver abatement of residual emission in 2050 increased by ≈ 18 percent from $70/t$CO_2$e to $83 /t$CO_2$e.
- The effect of a 15 percent discount rate in the economic analysis was also considerable.
- At a carbon price of $50 /t$CO_2$e supply under a 15 percent discount rate declined by ≈ 97 percent compared to a 5% discount rate from 130 MtCO_2e to 3.53 MtCO_2e.
- At a carbon price of $100 /t$CO_2$e the effect of the 15 percent discount rate was to reduce supply to 2050 by ≈ 60 percent to 370 MtCO_2e compared to the 5 percent scenario.
- At a carbon price of $150 /t$CO_2$e supply declined by ≈ 72 percent to 429 MtCO_2e of abatement by 2050.
- Under the assumption of a 15 percent discount rate the carbon price that would deliver abatement of residual emission in 2050 increased by ≈ 47 percent to $103 /t$CO_2$e.

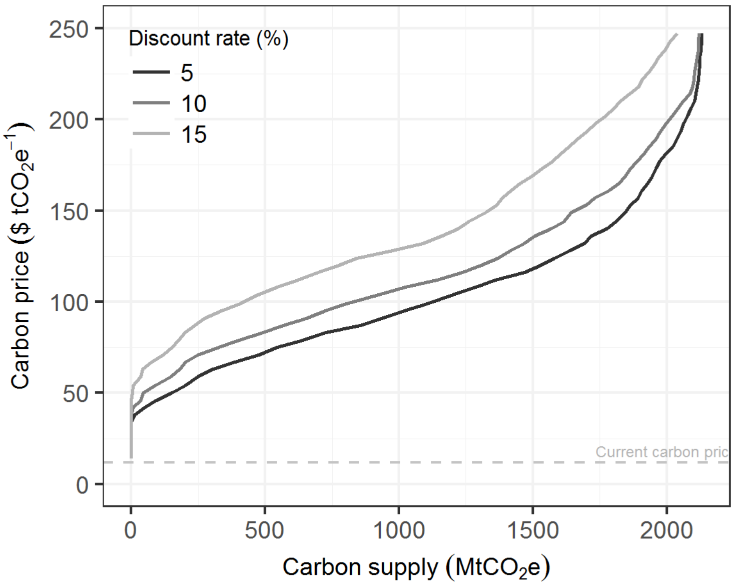


Figure 12: Effect of increased discount rate on the economics of abatement supply from Environmental Plantings.

3.4.2 Agricultural profitability

Population growth, demographic changes increasing demand for food and adoption of new technologies will have impacts on future agricultural profitability. Because carbon forests such as Mallee and Environmental Plantings compete for land with agriculture, higher agricultural productivity implies higher opportunity cost and less willingness of economically oriented landholders to supply carbon at any given price. As outlined in Settre *et al.* 2019, several scenarios were investigated to assess the impact of changing agricultural profitability on potential carbon supply in South Australia. Whilst new technologies could also enhance carbon sequestration or the costs of carbon/Environmental Plantings, this possibility is not tested in our analysis. However, we do test the related issue of sensitivity to planting cost.

The effect of increased agricultural profitability over the 100 year permanency period for South Australia can be seen in Figure 13. The effect of increasing agricultural productivity at both 1.5 and 3 percent per annum has a considerable effect on the supply of abatement from both of these ERF methods.

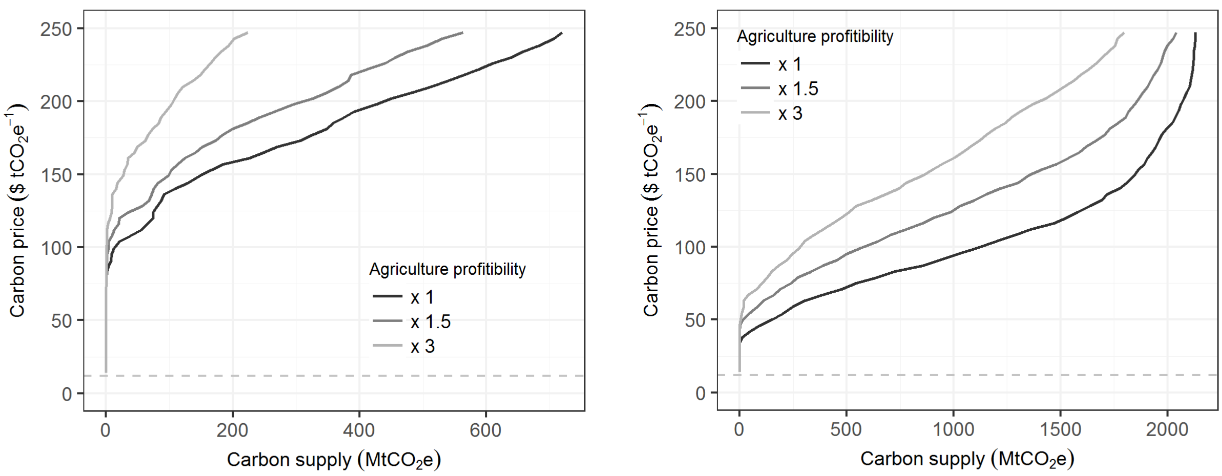


Figure 13: Sensitivity of Environmental (left) and Mallee ERF method supply to future agricultural profitability growth assumptions (x 1 = current productivity, x 1.5 = 1.5% annual growth, x 3 = 3% annual growth).

Mallee monoculture revegetation

The effect of increasing agricultural profitability on abatement supply to 2050 can be seen in Table 5.

For the 1.5 percent agricultural profitability multiplier it is evident that:

- The effect of projected possible increase in agricultural profitability on abatement supply from Mallee monocultures was considerable.
- At a carbon price of \$75 /tCO_2e under the 1.5 percent scenario supply declined by ≈ 35 percent from the base scenario of no change in agricultural profitability from 720,000 /tCO_2e to ≈ 470,000 /tCO_2e by 2050.
- At a carbon price of \$100 /tCO_2e under the 1.5 percent scenario supply declined by ≈ 80 percent 12 MtCO_2e to ≈ 2.5 MtCO_2e by 2050.
- At a carbon price of \$150 /tCO_2e under the 1.5 percent scenario supply declined by ≈ 55 percent from the base scenario of no change in agricultural profitability from 149 MtCO_2e to 66 MtCO_2e.

For the 3 percent agricultural profitability multiplier it is evident that:

- Under a 3 percent agricultural profitability multiplier zero abatement is achieved until carbon prices reach ≈ \$104 /tCO_2e.
- At \$125 /tCO_2e ≈ 6 MtCO_2e is available. This is decline in abatement potential of ≈ 92 percent.
- At \$150 /tCO_2e ≈ 18 MtCO_2e is available when compared the base scenario of no change in agricultural profitability. This is a reduction in supply of ≈ 88 percent.

Table 5: Carbon abatement potential (MtCO_2e) to 2050 for Mallee monocultures and Environmental plantings between the prices of \$50 -\$150 /tCO_2e considering increasing agricultural profitability of growth 1.5 and 3 percent per annum.

	Agricultural profitability multiplier (% per annum growth)		
	0%	1.5%	3%
Mallee Monocultures			
\$50 /tCO_2e	0	0	0
\$75 /tCO_2e	0.72	0.47	0
\$100 /tCO_2e	12	2.4	0
\$125 /tCO_2e	74	26	6
\$150 /tCO_2e	149	66	18
Price to abate residual 2050 emissions	**\$190**	**NA**	**NA**
Environmental Plantings			
\$50 /tCO_2e	130	14	4.5
\$75 /tCO_2e	460	205	90
\$100 /tCO_2e	928	478	237

$125 /tCO$_2$e	1332	839	438
$150 /tCO$_2$e	1554	1146	732
Price to abate residual 2050 emissions	**$70**	**$91**	**$119**

Environmental Plantings

For the 1.5 percent agricultural profitability multiplier, it is evident that:

- In a similar manner as for Mallee monocultures, the effect of projected possible increase in agricultural profitability on abatement supply from Environmental Plantings was considerable.
- At a carbon price of \$50 /tCO_2e supply was reduced by ≈ 90 percent with abatement supply declining to 14 MtCO_2e by 2050.
- At a carbon price of \$100 /tCO_2e supply was reduced by ≈ 48 percent with abatement declining from 928 MtCO_2e under the base scenario to 478 MtCO_2e by 2050.
- At a carbon price of \$150 /tCO_2e supply was reduced by ≈ 26 percent. Abatement potential by 2050 declined from 1.55 Gt CO_2e to 1.1 Gt CO_2e.
- Under this scenario, the carbon price that would deliver abatement of residual emissions in 2050 increased by ≈ 30 percent to \$91 /tCO_2e.

For the 3 percent agricultural profitability multiplier, it is evident that:

- At a carbon price of \$50 /tCO_2e supply was reduced by ≈ 97 percent with abatement supply declining to 4.5 MtCO_2e by 2050.
- At a carbon price of \$100 /tCO_2e supply was reduced by ≈ 74 percent with potential abatement declining from 928 MtCO_2e under the base scenario to 237 MtCO_2e by 2050.
- At a carbon price of \$150 /tCO_2e supply was reduced by ≈ 53 percent to 732 MtCO_2e by 2050.
- Under this scenario, the carbon price that would deliver abatement of residual emissions in 2050 increased by ≈ 70 percent to \$119 /tCO_2e.

3.4.3 Establishment costs

Results from the literature (Paterson and Bryan, 2012) indicated that plantation establishment costs can have a significant effect on abatement supply. In order to test this in our modelling, and given the levels of variability and levels of uncertainty surrounding establishment costs outlined in Settre *et al.* 2019, we tested 2 establishment cost scenarios of 75 percent and 125 percent of the base scenario. The results are presented in Figure 14.

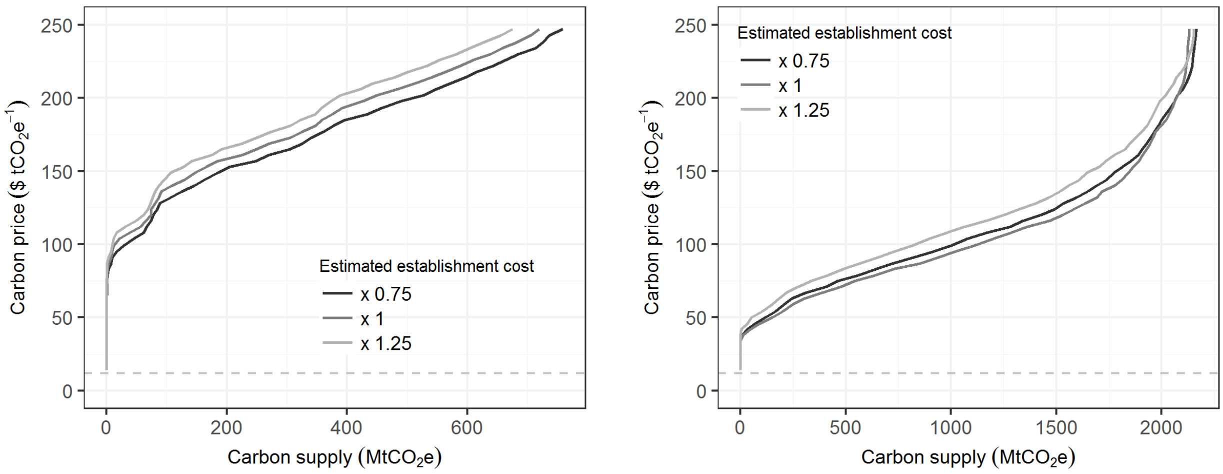


Figure 14: Effect of establishment cost assumption on carbon abatement supply from Mallee (left) and Environmental (right) ERF revegetation methods (x 0.75 = 75%, x 1 = 100%, x 1.25 = 125% of baseline assumed cost, respectively).

The effect of varying establishment cost by ± 25 percent had an overall smaller effect on supply from when compared to discount rate and agricultural profitability. However, at higher carbon prices for Environmental plantings the sensitivity of carbon supply estimates was more significant.

Mallee monoculture revegetation

One sensitivity analysis explored how economically viable carbon abatement through the Mallee method varied with differing assumptions about establishment cost. We found that:

- For Mallee monoculture revegetation the reduction in establishment costs reduced the carbon price required to initiate abatement supply \$75 /tCO_2e to \$67 /tCO_2e.
- In addition to decreasing the carbon price required for abatement supply to begin a reduction in establishment costs increased supply at key price points when compared to the base scenario. For example at a carbon price \$100 /tCO_2e supply increased by 122 percent from ≈ 13 MtCO_2e to ≈ 30 MtCO_2e over the 100 year permanency period.
- The effect of the reduced establishment cost was not uniform however and had the largest effect at relatively low carbon prices. For example at \$150 /tCO_2e the increased abatement from lower establishment costs declined to ≈ 26 percent, increasing supply from ≈ 158 MtCO_2e to ≈ 200 MtCO_2e over the 100 year permanency period.
- An increase in establishment cost of 25 percent increased the carbon price required for abatement supply to begin from \$75 /tCO_2e to \$79 /tCO_2e.
- The effect of increased establishment costs was not as pronounced as the corresponding decrease in establishment costs at lower carbon prices.
- At a carbon price \$100 /tCO_2e supply decreased by ≈ 27 percent from 13 MtCO_2e to ≈ 10 MtCO_2e over the 100 year permanency period.
- At \$150 /tCO_2e supply decreased by ≈ 28 percent from ≈ 158 MtCO_2e to ≈ 114 MtCO_2e over the 100 year permanency period.

ENVIRONMENTAL PLANTINGS

One sensitivity analysis explored how economically viable carbon abatement through the Environmental Plantings method varied with differing assumptions about establishment cost. We found that:

- For Environmental Plantings the reduction in establishment cost has no effect on the price at which supply of abatement began, however it did increase the supply available.
- At \$38 /tCO_2e, carbon supply increased by ≈ 78 percent from ≈ 7 MtCO_2e to ≈ 11 MtCO_2e over the 100 year permanency period.
- The magnitude of the effect of decreased establishment costs diminishes quickly however. At a carbon price of \$100 /tCO_2e supply is ≈ 10 percent higher than the base case scenario.
- At \$150 /tCO_2e there is a small difference of ≈ 4 percent in potential carbon abatement between the base scenario and the decreased establishment cost scenario.
- An increase in establishment cost of 25 percent increased the carbon price required for abatement supply to begin from \$38 /tCO_2e to \$42 /tCO_2e.
- The increased establishment costs had a significant effect on carbon abatement at key price points.
- At \$50 /tCO_2e the effect of increased establishment costs was to decrease supply by ≈ 56 percent, reducing supply to ≈ 52 MtCO_2e over the 100 year permanency period.
- In a similar manner to the decreased establishment costs scenario the effect of the changed establishment costs reduced at higher carbon prices.
- At a carbon price \$100 /tCO_2e supply decreased by ≈ 18 percent to ≈ 866 MtCO_2e.
- This result indicates that in locations that require higher carbon prices for environmental planting to be profitable, establishment costs are not likely to be the main driver of the economics. Instead, in these locations the economics are determined by a combination of low carbon sequestration rates and high establishment costs.

3.4.4 Climate change

Climate change is a recognised risk to carbon abatement supply from revegetation. We investigated the risk posed by future climate change to abatement in SA by calculating effects to supply under several potential climate futures scenarios. The climate change scenarios investigated are outlined in Table 6. The results for Mallee monoculture revegetation and environmental planting for the 100 year permanency period are presented in Figure 16 and for supply to 2050 in Table 7.

To investigate the effects of climate change we sourced data from an alternative model of carbon sequestration developed by Hobbs *et al.* (2016). This model is an allometric model derived from direct measurements of biomass from plantations in SA. This model was run for the sample point previously modelled in FullCAM across SA over several climate change scenarios adapted from Bryan *et al.* (2011) as outlined in Table 6 describing assumed changes in temperature, rainfall and evaporation to the year 2070. Specific details of climate change modelling can be found in Regan and Connor (2019).

Table 6: Climate change scenarios used in sensitivity analysis.

Climate Change Scenario	Temperature	Potential evaporation	Rainfall
CC0 Baseline	Historic	Historic	Historic
CC1 Mild warming & drying	+1°C	+3%	-5%
CC2 Moderate warming & drying	+2°C	+6%	-15%
CC3 Severe warming and drying	+4°C	+8%	-25%

In general, the impact of climate change, in terms of percentage change from base line climate, on abatement supply was most pronounced at the lower carbon. Our results indicate that many of the lower cost abatement supply options will shift in to a medium cost category. At higher carbon prices, the reduction in abatement supply is less pronounced, again in terms of percentage change, however the reduced abatement supply in terms of $MtCO_2e$, is pronounced and significant. The results of the modelling on carbon sequestration rates is shown in Figure 15.

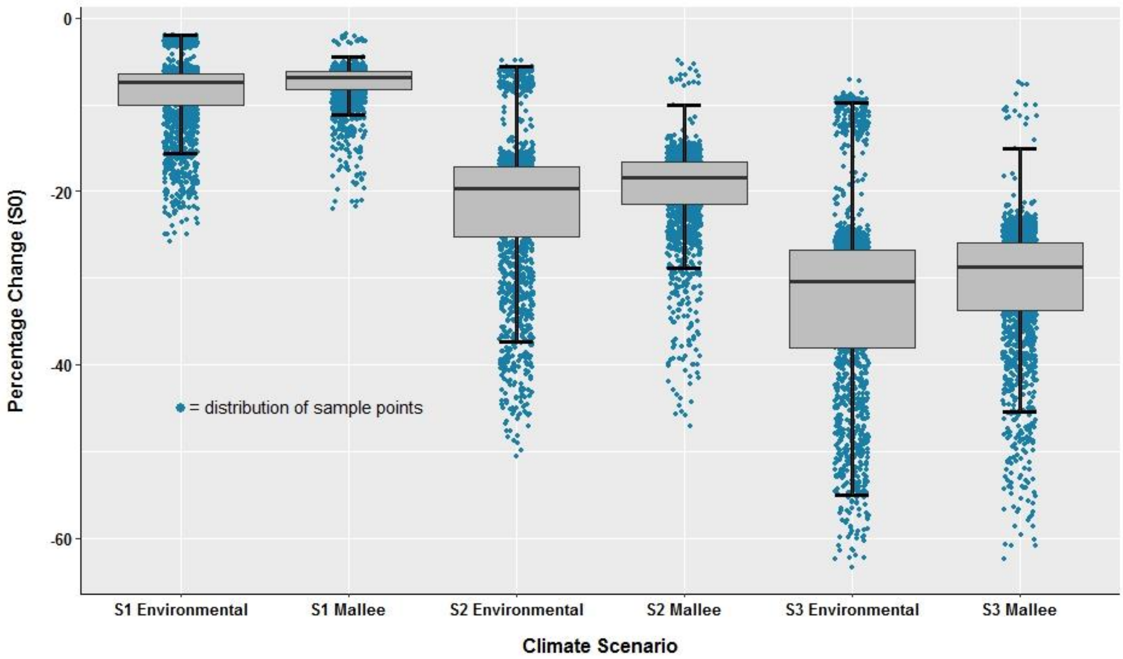


Figure 15: Percentage change in sequestration rates for three climate change scenarios for all sample points in the study area

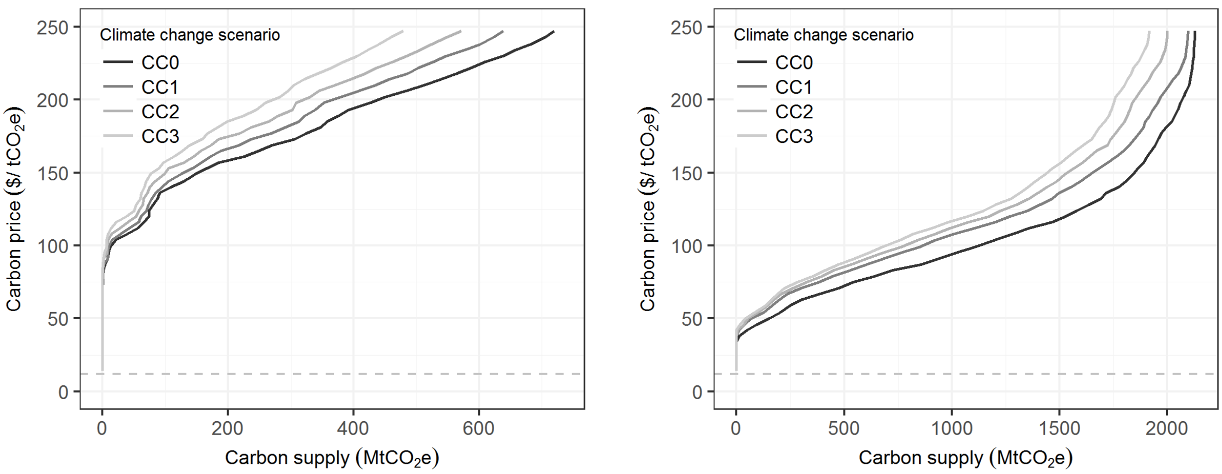


Figure 16: Effect of climate change scenarios on the supply of abatement from Mallee (left) and Environmental ERF revegetation method carbon supply (right) (CC0 = current climate, CC1 = mild warming and drying, CC2 = moderate warming and drying, CC3 = severe warming and drying).

Mallee monoculture revegetation

We tested how economic viability of plantings with the Mallee method varied from our baseline for a mild warming and drying climate scenario. We found that:

- Climate change scenario one, mild warming and drying had a moderate effect on supply of abatement from Mallee vegetation. Under this climate scenario supply was calculated to begin at ≈ \$79 /tCO_2e. At this price supply from Mallee revegetation is estimated to be ≈ 0.7MtCO_2e over the 100 year permanency period.
- At \$100 /tCO_2e supply is reduced by ≈ 21 percent over the 100 year permanency period compared to base climate to ≈ 9.5 MtCO_2e.
- At \$150 /tCO_2e supply is reduced by ≈ 15 percent compared to base climate to ≈ 126 MtCO_2e over the 100 year permanency period.

When considering supply to 2050, significant reductions in abatement could be expected under a mild warming and drying scenario (Table 7):

- At \$100 /tCO_2e ≈ 6.2 MtCO_2e is available to 2050 under climate scenario one. This equates to a 48 percent reduction in abatement potential when to 2050 when compared to the baseline climate scenario.
- For residual emissions in 2050 (12.7 MtCO_2e) to be abated from Mallee monocultures requires a carbon price of \$234 /tCO_2e, which is ≈ 23 percent higher than under the baseline climate scenario.

We also tested how economic viability of plantings with the Mallee method varied from our baseline for a moderate warming and drying climate scenario. We found that:

- Under a moderate warming and drying climate change scenario supply of abatement would not occur below a price of \$83 /tCO_2e.
- At \$100 /tCO_2e ≈ 7 MtCO_2e of abatement could achieved over the 100 year permanency period, a reduction of ≈ 41 percent when compared to the baseline climate scenario.
- At \$150 /tCO_2e supply is reduced by ≈ 34 percent compared to baseline climate to ≈ 98 MtCO_2e over the 100 year permanency period.

When considering supply to 2050, significant reductions in abatement could be expected under a moderate warming and drying scenario. These scale of reduced abatement to 2050 is outlined in Table 7:

- At \$100 /tCO_2e ≈ 5 MtCO_2e is available to 2050 under climate scenario two. This is ≈ 60 percent less than under baseline climate scenario.
- At \$150 /tCO_2e ≈ 66 MtCO_2e is available to 2050 under climate scenario two. This is ≈ 56 percent less than under baseline climate scenario.

Finally, we tested how economic viability of plantings with the Mallee method varied from our baseline for a severe warming and drying climate scenario. We found that:

- Under sever warming and drying scenarios abatement potential is further decreased in comparison to historical climate scenario.
- Supply of Mallee revegetation in this scenario would not occur below a price \$87 /tCO_2e.
- At that price supply could be expected to be less than 1 MtCO_2e over the 100 year permanency period
- At a high carbon price of \$150 /tCO_2e supply was calculated to be ≈ 49 percent lower than the baseline climate scenario, supplying ≈ 76 MtCO_2e of abatement over the 100 year permanency period.

When considering abatement supply to 2050, the effect of severe warming and drying has pronounced effect on sequestration:

- At a price of $125 /tCO$_2$e abatement supply is reduced by ≈ 68 percent when compared to baseline climate scenario to ≈ 4 MtCO$_2$e to 2050.
- At a price of $125 /tCO$_2$e abatement was calculated to be ≈ 54 percent lower than baseline climate supplying ≈ 34 MtCO$_2$e to 2050.
- At a very high price of $150 /tCO$_2$e abatement was calculated to be ≈ 65percent lower than baseline climate supplying ≈ 52.5 MtCO$_2$e to 2050.

Table 7: Carbon abatement potential (MtCO$_2$e) to 2050 for Mallee monocultures and Environmental plantings between the prices of $50 -$150 /tCO$_2$e under historical and three climate change scenarios.

	Climate Scenario			
	Historical climate	CC1	CC2	CC3
Mallee Monocultures				
$50 /tCO$_2$e	0.0	0.0	0.0	0.0
$75 /tCO$_2$e	0.7	0.0	0.0	0.0
$100 /tCO$_2$e	12.0	6.2	4.7	3.9
$125 /tCO$_2$e	74.0	45.3	38.3	34.3
$150 /tCO$_2$e	145.0	83.9	65.8	52.5
Price to abate residual 2050 emissions ($ /tCO$_2$e)	**$190**	**$234**	**$246**	**N/A**
Environmental Plantings				
$50 /tCO$_2$e	130.0	58.6	45.5	36.6
$75 /tCO$_2$e	460.0	323.2	282.0	248.1
$100 /tCO$_2$e	928.0	721.3	657.8	590.7
$125 /tCO$_2$e	1332.0	1149.3	1056.9	1001.9
$150 /tCO$_2$e	1554.0	1398.3	1315.5	1255.0
Price to abate residual 2050 emissions ($ /tCO$_2$e)	**$70**	**$79**	**$83**	**$87**

Environmental Plantings

We tested how economic viability of plantings with the Environmental Plantings varied from our baseline for a mild warming and drying climate scenario. We found that:

- Despite environmental planting being eligible to be established in high rainfall areas of SA, notionally less susceptible to the effects of climate change, the effects of mild warming and drying was considerable, especially at lower carbon prices.

- At a price of \$50 /tCO_2e abatement was calculated to be reduced by ≈ 55 percent from ≈ 153 MtCO_2e to ≈ 69 MtCO_2e over the 100 year permanency period.
- At \$100 /tCO_2e the reduction in abatement was less pronounced, however still significant reducing supply by ≈ 23 percent to ≈ 850 MtCO_2e over the 100 year permanency period.
- Considerable supply is still achievable at higher carbon prices, for example at \$150 /tCO_2e supply is reduced by 11 percent compared to baseline climate to ≈ 1.65 giga tones of abatement over the 100 year permanency period.

When considering abatement supply to 2050, similarly to Mallee revegetation, supply reduction was most pronounced at lower prices (Table 7).

- At \$50 /tCO_2e abatement supply was reduced by ≈ 55 percent compared to baseline climate to ≈ 59 MtCO_2e to 2050.
- At high carbon prices the reduction was less pronounced under mild warming and drying. For example, at \$150 /tCO_2e ≈ 1.4 giga tonnes of abatement is potentially available to 2050.
- The price at which residual emissions in 2050 of 12.7 MtCO_2e would be offset, increased under this climate scenario by ≈ 12 percent to \$79 /tCO_2e.

We also tested how economic viability of plantings with the Environmental Plantings method varied from our baseline for a moderate warming and drying climate scenario. We found that:

- Again the effect of moderate drying and warming was more pronounced at lower carbon prices.
- At a price of \$50 /tCO_2e abatement was reduced by ≈ 66 percent from ≈ 154 MtCO_2e to ≈ 53 MtCO_2e over the 100 year permanency period.
- At \$100 /tCO_2e the reduction in abatement was less pronounced. Moderate warming and drying reduced supply by ≈ 31 percent to ≈ 762 MtCO_2e over the 100 year permanency period.
- Considerable supply is still achievable at higher carbon prices, for example at \$150 /tCO_2e ≈ 1.5 giga tonnes of abatement could be achieved over the 100 year permanency period.
- The price at which residual emissions in 2050 of 12.7 MtCO_2e would be offset, increased under this climate scenario by ≈ 18 percent to ≈ \$83 /tCO_2e.

Finally, we tested how economic viability of plantings with the Environmental Planting method varied from our baseline for a severe warming and drying climate scenario. We found that:

- Under climate scenario CC3 supply from Environmental Plantings begins at \$46 /tCO_2e. At this price ≈ 1.5 MtCO_2e would be available over the 100 year permanency period.
- At a price of \$50 /tCO_2e abatement under severe warming and drying was ≈ 73 percent lower than baseline climate reducing from ≈ 154 MtCO_2e to 42 MtCO_2e over the 100 year permanency period.
- At \$100 /tCO_2e the reduction in abatement was less pronounced reducing supply by ≈ 39 percent to ≈ 675 MtCO_2e over the 100 year permanency period.
- When considering abatement supply to 2050 considerable supply could still be achieved even under a severe warming and drying with ≈ 1.25 GtCO_2e available at \$150 /tCO_2e.
- The price at which residual emissions in 2050 (12.7 MtCO_2e) would be offset, increased under this climate scenario by ≈ 24 percent to \$87 /tCO_2e

3.5 Non-ERF methods

3.5.1 Rangeland regeneration

The rangeland regeneration method involves vegetation management of a large area of land in the northern agricultural zone and southern pastoral zone. The area is generally used for extensive livestock grazing, primarily sheep. The area is not eligible for inclusion in existing ERF revegetation methodologies as these areas often incorporate existing remnant native vegetation, and the vegetation type does not satisfy Kyoto protocol conditions of 20% canopy cover at two metres in height. Despite this, these areas represent potential as carbon abatement options through changed management practices. i.e. the exclusion of livestock grazing.

The results presented for this methodology should be interpreted with several caveats. The geographical extent of the underlying land use for each cell was difficult to ascertain without more detailed spatial analysis, which was beyond the scope of this study. For example, if the primary agricultural activity in a cell was grazing, exactly how much of that cell is in reality used for the assigned agricultural enterprise, as opposed to remnant vegetation, salt pan or unused land was not able to be confirmed. Therefore, the results presented should not be interpreted as necessarily applying to the entire spatial extent of a cell or the study area as a whole. Instead the results indicate the likely price at which the land that is available in any cell is more profitable under regeneration for carbon sequestration than the agricultural land use assigned to it.

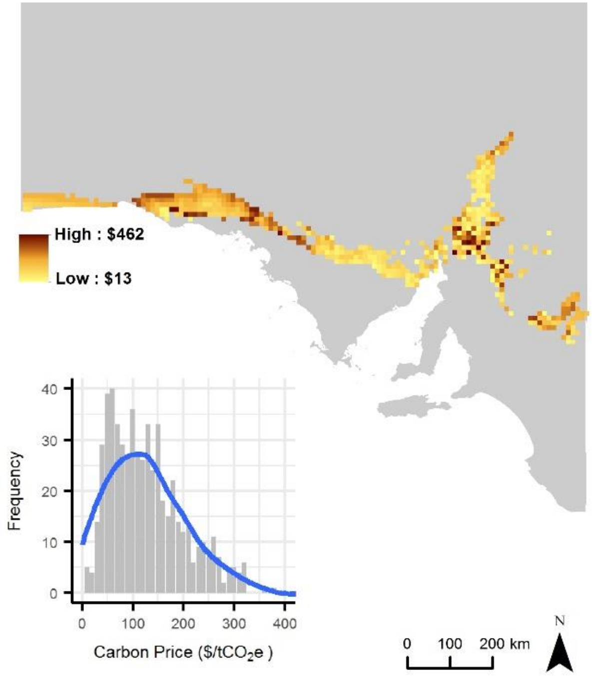


Figure 17: Carbon prices (S tCO_2e) required for natural regeneration for carbon sequestration to be more profitable than existing agricultural practice in the rangelands of South Australia.

As seen in Figure 17 low cost abatement potential from the study area is limited due to a combination of low carbon sequestration rates and relatively high current agricultural opportunity costs. As a result the majority of the abatement potential supply occurs at prices of \$100 /tCO_2e or above. Despite this, significant areas of supply are potentially available at prices below \$100 /tCO_2e (Figure 18). Our results indicate that ≈ 9.5 percent of the study area would potentially be available for sequestration purposes at \$50 /tCO_2e or below.

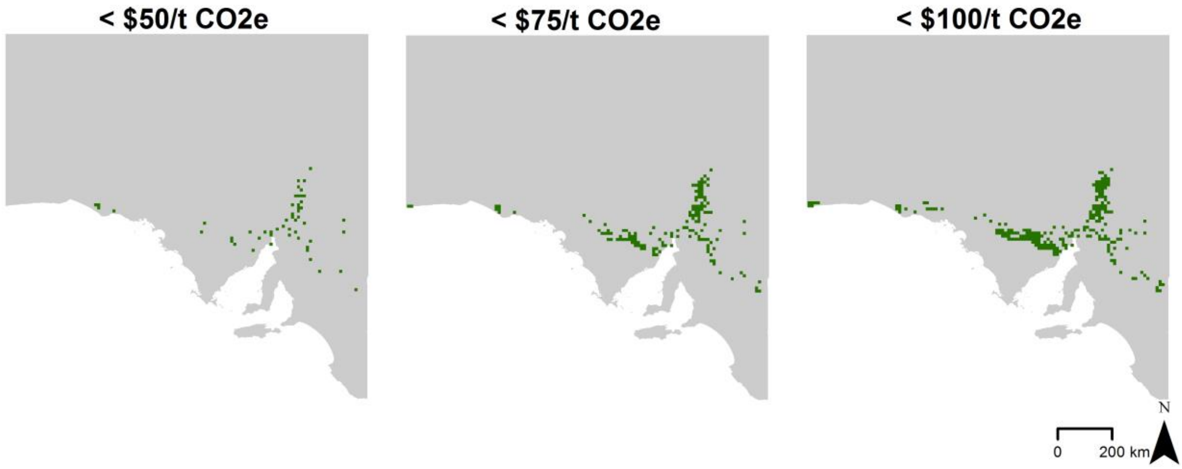


Figure 18: Rangeland areas profitable for natural regeneration for carbon sequestration at $50, $75 and $100 /t$CO_2$e.

The rangelands and pastoral areas of the state could potentially be a significant source of abatement supply due to the vast areas involved. However, quantifying the carbon sequestration totals is problematic with currently available data. Previous research (Dean *et al.*, 2015) has shown some opportunity exists for carbon sequestration from destocked rangelands in New South Wales at $10 /t$CO_2$e. However, this research was conducted on temperate grasslands, not xeric shrublands as exist in SA. As a result the opportunity costs and carbon sequestration rates may differ markedly. In order to quantify the opportunity for abatement from rangelands and pastoral zones specialised data collection (primarily satellite) and analysis will be required.

3.5.2 Grassy woodlands regeneration in the Mt Lofty Ranges

Grassy woodland regeneration in the Mt Lofty Ranges involves the natural regeneration of currently cleared land back to a natural state of open woodland. This method is not ERF compliant as the revegetation is sparse and does not meet the 20 percent canopy cover at two metre height conditions of the Kyoto Protocol.

Potential carbon supply from this method at $50, $100 and $150 /t$CO_2$e over the 100 year permanency period are mapped in Figure 19.

Key findings are that:

- Despite zero establishment costs applying to this method due to it relying on natural regeneration, supply of abatement from this methodology is still relatively expensive.
- Supply begins at $38 /t$CO_2$e, supplying ≈ 0.6 Mt$CO_2$e over the 100 year permanency period.
- At $50 /t$CO_2$e ≈ 1.7 Mt$CO_2$e is available over the 100 year permanency period.
- At higher carbon prices significantly more abatement becomes available.
- At $125 /t$CO_2$e ≈ 9.2 Mt$CO_2$e is available over the 100 year permanency period.
- At $150 /t$CO_2$e ≈ 15 Mt$CO_2$e is available over the 100 year permanency period.
- In terms of the area of land returned to a woodland state, at $38 /t$CO_2$e ≈ 3,200 ha would be available for restoration to grassy woodland.
- At $50 /t$CO_2$e ≈ 7,300 ha would be available for restoration to grassy woodland.
- At $100/t$CO_2$e ≈ 10,600 ha would be available for restoration to woodland.

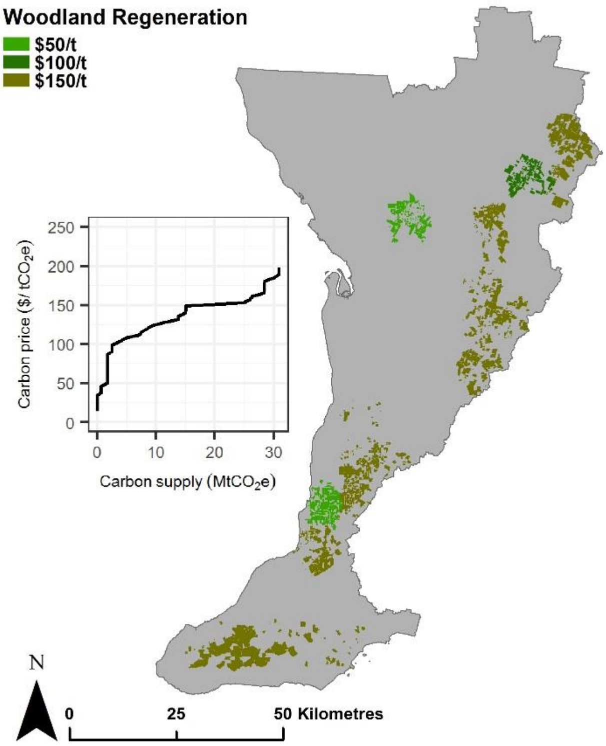


Figure 19: Potential for carbon supply from grassy woodland restoration in the Mt. Lofty Ranges.

Much of the area investigated is in peri-urban areas predominated by small land holdings where commercial agriculture is less intensive or is no longer the primary income for the landholder. As such, landholder attitudes may have shifted from an agriculture focus to a lifestyle focus. As a result lower cost opportunities may exist for land to be converted from current land use to restored grassy woodlands than indicated by the economic results considering full agricultural opportunity costs. To examine this, modelling was conducted that considered zero opportunity cost of the land noting that this is an optimistic assumption and implies that landholders ignore the "lost option" cost of not being able to return the land to agriculture and being "locked in":

- As would be expected without the consideration of opportunity cost, abatement supply begins at lower prices.
- Supply of abatement begins at \$22 /tCO_2e, supplying ≈ 1.4 MtCO_2e over the 100 year permanency period.
- At \$50 /tCO_2e ≈ 37 MtCO_2e is available over the 100 year permanency period. Assuming no change in the South Australia's emissions over the 100 year period 2020 – 2120, this figure equates to ≈ 1.4 percent of the emissions.
- While there is no suggestion that all land in the study area would be available at zero opportunity costs, the modelling highlights that significantly lower cost opportunities exist where landholder and conservation objectives meet. While these opportunities appear niche, considerable carbon abatement and conservation outcomes may be achievable. Further work is needed to quantify the size of these opportunities.

Although this methodology is expensive when considering carbon supply independently, the areas have high biodiversity conservation and amenity value.

The benefits of combining carbon, biodiversity and amenity benefit was beyond the scope of this study, however should be investigated to provide a more comprehensive assessment of the land use change economics.

3.5.3 Revegetation of drooping sheoak on Kangaroo Island

The restoration of drooping sheoak ecosysems on Kangaroo Island was identified as a conservation priority by DEW. Two establishment modes were considered: natural regeneration and replanting. The results (The supply *curves appear 'stepped' as opposed to smooth due the sampling density and the coarseness of underlying data on Kangaroo Island (KI). Due to the underlying FullCAM modelling data being quite homogenous, several sampling points become available at the same time giving a stepped function as opposed to them becoming available at intervals which would result in a smooth curve.*

Figure 20) show that supply from the regeneration (both natural regeneration and replanting) of Drooping Sheoak vegetation on Kangaroo Island is an expensive niche carbon abatement opportunity based on carbon supply in isolation. An explanation for the expensive nature of the supply from this methodology is the reduced carbon yield from this vegetation type. When compared to the environmental planting FullCAM modelling, the carbon yield from *Casuarina* sp. is in the order of half that of the Environmental Plantings.

Natural regeneration

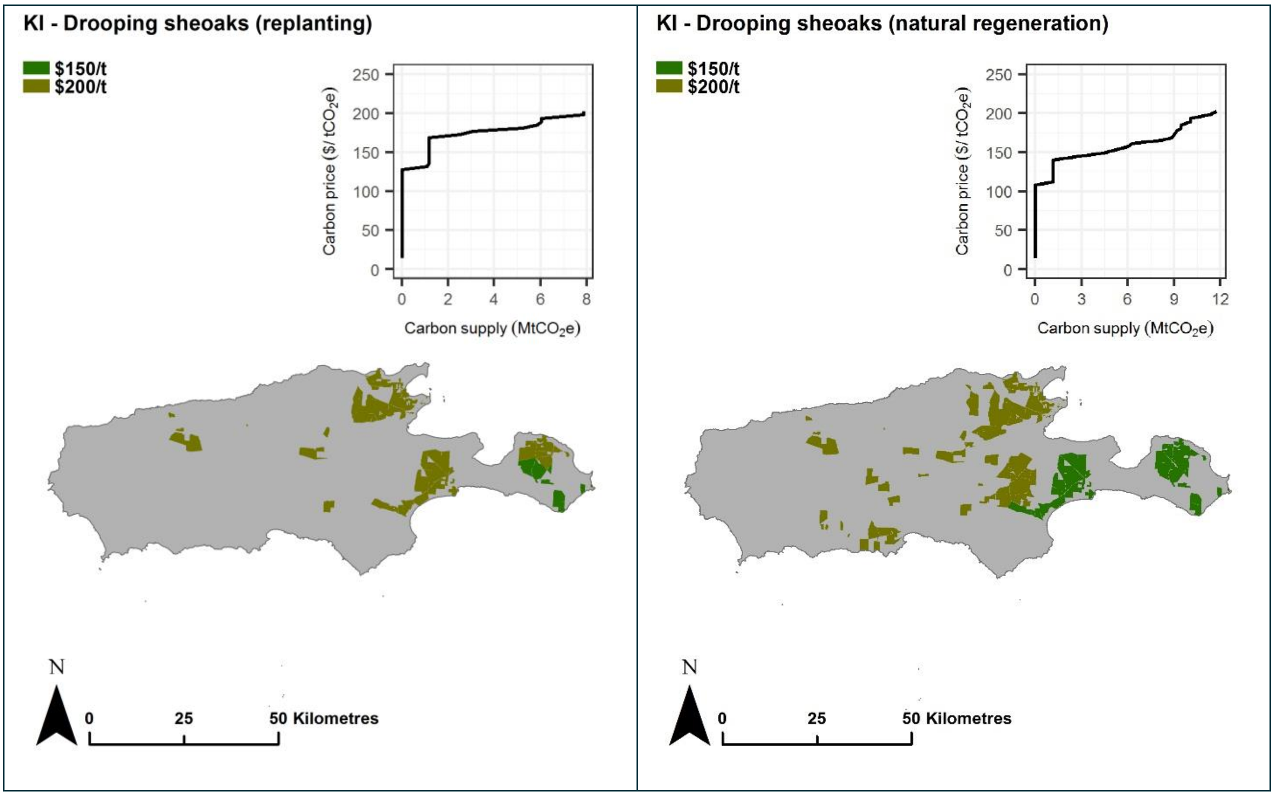
Key findings with respect to the economics of supply through natural generation were that:

- Supply of abatement begins at $112 /t$CO_2$e, with ≈ 1.2 Mt$CO_2$e being available at this price over the 100 year permanency period.
- Not until extremely high carbon prices are reached are any significant levels of supply available.
- For example, at a carbon price of $150 /t$CO_2$e ≈ 4.5 Mt$CO_2$e being available at this price over the 100 year permanency period.
- At a carbon price of $200 /t$CO_2$e ≈ 12 Mt$CO_2$e of abatement would be available over the 100 year permanency period.

Replanting

Key findings with respect to the economics of supply through replanting were that:

- The results showed the replanting sheoak vegetation was the highest cost option for this vegetation type, with no supply below $130 /t$CO_2$e due to the addition establishment costs.
- At $132 /t$CO_2$e ≈ 1.1 Mt$CO_2$e of abatement would be available over the 100 year permanency period.
- At $150 /t$CO_2$e ≈ 1.5 Mt$CO_2$e of abatement would be available over the 100 year permanency period.
- At a high carbon price of $200 /t$CO_2$e ≈ 7.9 Mt$CO_2$e of abatement would be available over the 100 year permanency period.
- The supply curves appear 'stepped' as opposed to smooth due the sampling density and the coarseness of underlying data on Kangaroo Island.



The supply curves appear 'stepped' as opposed to smooth due the sampling density and the coarseness of underlying data on Kangaroo Island (KI). Due to the underlying FullCAM modelling data being quite homogenous, several sampling points become available at the same time giving a stepped function as opposed to them becoming available at intervals which would result in a smooth curve.

Figure 20: Potential for carbon supply over 100 years from drooping sheoak from replanting (left) and natural regeneration (right).

3.6 NRM consistency – Groundwater

In addition to carbon sequestration and co-benefits outlined in Connor *et al.* (2019), Summers *et al.* (2019a), Summers *et al.* (2019b), carbon plantings may contribute to or detract from other NRM objectives. Deep rooted perennial vegetation carbon plantings have the potential to effect ground water reserves (DEWNR, 2017). This can provide a positive co-benefit in areas where rising ground water tables have the potential to salinise soil. However, it can also affect economically important groundwater resources that support irrigated agriculture or ground water dependent ecosystems. In such a case consideration may need to be given as to the suitability of carbon plantings in those areas. To begin addressing this issue DEWNR (2017) developed a guide to carbon plantings in SA that included spatial data on areas of high risk of ground water interception from carbon plantations (Figure 21).

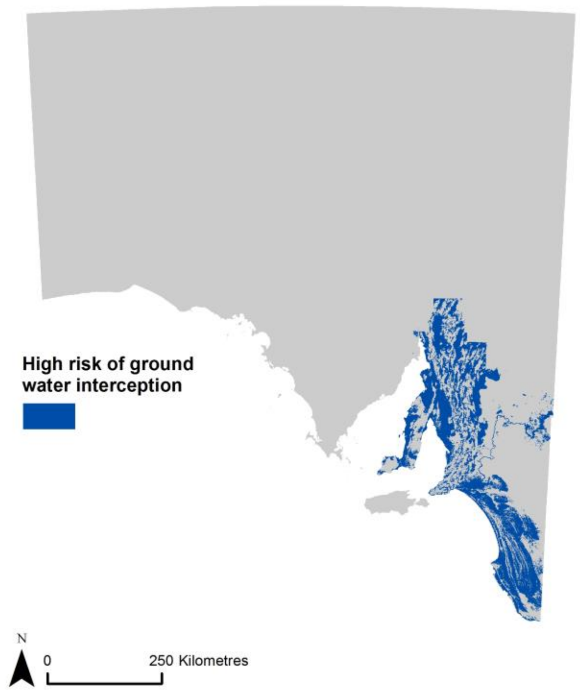


Figure 21: Areas of South Australia where a high risk of ground water interception exists from deep rooted carbon plantings. Note that the Eyre Peninsula and Kangaroo Island have yet to be included in this dataset.

We incorporated this data into the analysis of carbon supply in order to understand the effect of excluding high risk areas for ground water from potential carbon supply. In this analysis we exclude all areas presented in Figure 21 from supply which accounts for ≈ 2.13 million hectares of ERF eligible land. The analysis considered Environmental Plantings only as much of the area shown in Figure 21 is in areas receiving 600 mm annual rainfall or higher, excluding Mallee revegetation as an option in those areas. The reduction in supply as a result of excluding those areas can be seen in Figure 22.

In a scenario where high risk areas are excluded, many high productivity areas are excluded from supply, having modest effects on potential abatement from Environmental Plantings over the 100 year period across SA. The exclusion of these areas would, however, disproportionately reduce abatement from the lowest cost supply options. For example:

- At \$50 /tCO_2e the total state abatement potential from Environmental Plantings is ≈ 154 MtCO_2e over the 100 year permanency period. Exclusion of high risk ground water extraction areas would reduce supply by ≈ 10 MtCO_2e over the 100 year permanency period (≈ 6.5 percent). This is due to the exclusion of large areas in the South East, where ≈ two-thirds (2/3rds) of the abatement at this price point is located.
- Conversely, the proportionate loss of abatement is less pronounced at higher carbon process. For example, at \$100 /tCO_2e total state abatement potential from Environmental Plantings is ≈ 1.1Gt CO_2e over the 100 year permanency period. Exclusion of high risk ground water extraction areas would reduce supply by ≈ 32 MtCO_2e over the 100 year permanency period (≈ 2.8 percent).

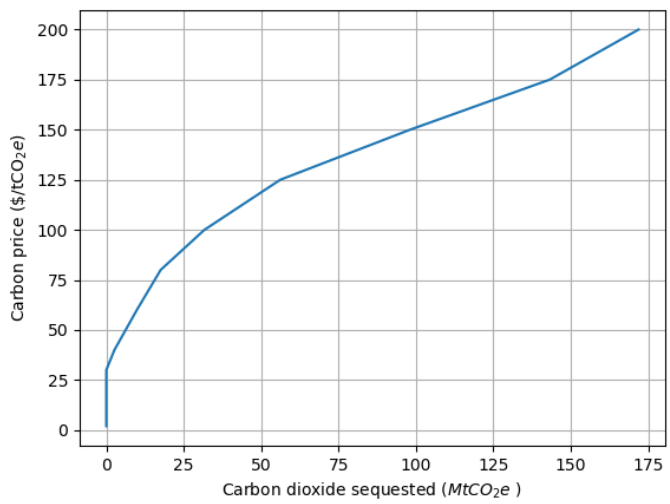


Figure 22: Supply curve showing reduction in supply from Environmental Plantings if areas at high risk of ground water interception are excluded from the analysis.

There are several caveats on these results. Some of the areas displayed in Figure 21 would be areas where groundwater interception would be of benefit in reducing soil salinisation threat. However, data on area of risk of dry land salinisation was not available for incorporation in to the analysis. In addition to ground water interception carbon plantings may hold benefit for other NRM priorities such as soil stabilisation, habitat restoration or flood mitigation. Areas where NRM priorities and favourable carbon economics intersect hold promise as a niche, but substantial carbon abatement supply opportunity. To fully understand the size and spatial distribution of this opportunity will require more detailed and finer resolution analysis. This was beyond the scope of this project but is worthy of further investigation.

4 Conclusions

This report presents research that fills knowledge gaps related to how much carbon sequestration supply to offset carbon emissions might be available, at what carbon price and from what land use and management change, in South Australia (SA). It provides estimates of carbon offset supply amounts that could be economically viable at various price points for a set of agreed Emissions Reduction Fund (ERF) and prospective non-ERF methods. The geographic focus of this work is areas of South Australia predominantly used for intensive agriculture. Estimates of annual and cumulative carbon supply over a 100 year horizon for 2020 plantings were produced for relevant areas.

The findings from the analysis supports previous work at National level (e.g. Bryan *et al.*, 2014) suggesting that conversion from agriculture to carbon plantings is not likely to be economically viable for most South Australian landholders at carbon prices below approximatley \$50 /tCO_2e. This finding is also consistent with outcomes of ERF auctions where supply of carbon plantings from land in South Australia was near zero at prices in the range \$11-13 /tCO_2e. This finding is further exacerbated if considering current ERF regulations that stipulate a 25 year crediting period and 100 year permanency period. The result of such a condition increases the cost of lowest cost abatement by up to 16 percent and could reduce supply by up to 90 percent at the corresponding carbon price.

The analysis discovered a number of niche opportunities where supply may be possible at prices closer to \$20 /tCO_2e, a level much closer to ERF auction prices and voluntary market prices that are now approaching \$17-18 /tCO_2e (O'Connor *et al.*, 2019, Energetics, 2017). The areas and volumes of carbon that represent potentially economically viable supply from these opportunities are small as a percentage of the total agricultural area of South Australia and potential sequestration. Still, in absolute magnitude they represent significant areas (tens to hundreds of thousands of hectares), sequestration (hundreds to millions of tonnes of CO_2e), and carbon payments (tens to hundreds of millions of dollars). Key examples include highly targeted low opportunity cost rangeland destocking opportunities in northern pastoral areas; highly targeted natural regeneration of grassy woodlands in relatively high carbon yielding areas and where land owner preferences are such that they don’t expect compensation for opportunity cost of forgone agricultural production; and cessation of Mallee rolling in targeted areas that represent very low opportunity cost and relatively high carbon yields. Providing landholders in such context information about these opportunities and facilitating low transaction cost ERF application process support may assist private landholders to realise these opportunities.

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