PUBLICATION INFORMATION

This is an author accepted manuscript of an article by Himlal Baral, Rodney J. Keenan, Sunil K. Sharma, Nigel E. Stork, Sabine Kasel. **Economic evaluation of ecosystem goods and services under different landscape management scenarios**. *Land Use Policy*.
DOI: http://dx.doi.org/10.1016/j.landusepol.2014.03.008

Correct citation:
Baral, H., Keenan, R.J., Sharma, S.K., Stork, N.E., Kasel, S., 2014. Economic evaluation of landscape management scenarios in north-central Victoria, Australia. Land Use Policy 39. 54-64
doi:10.1016/j.landusepol.2014.03.008

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Abstract

Human-induced changes in the natural environment are affecting the provision of ecosystem goods and services (EGS). Land use plans rarely include the value of public ecosystem goods such as climate regulation and biodiversity due to difficulties in valuing these services. In this study, we assessed total economic value for five important ecosystem goods and services under five future land-use scenarios using varying levels of costs, prices and discount rates. Results indicated that at higher discount rates normally applied to commercial activities, and assuming the current prices for goods and services, Net Present Value (NPV) was highest for landscape management scenarios aimed at maximising agricultural production. Potential income from services such as carbon and biodiversity does not offset projected income lost from agriculture due to land-use changes. At higher discount rates, NPV was negative for the two scenarios aimed at enhancing the longer term ecological sustainability of the landscape. These results indicate that income from carbon sequestration and biodiversity conservation would need to be considerably higher than current levels in order to justify focusing management of this landscape on ecological outcomes. At lower discount rates (at levels normally associated with public investments), the more ecologically appropriate 'mosaic farming system' had the highest NPV, indicating that this type of system might be attractive for investors interested in longer term return horizons or wider public benefits. Higher income from carbon or biodiversity, or increased return from timber by using higher value tree species, could potentially make more ecologically appropriate systems profitable at higher discount rates.

Keywords: ecosystem goods and services, economic evaluation, land management, land-use scenarios, decision making

1. Introduction

Human life depends on a wide variety of ecosystem goods and services (EGS) provided by healthy ecosystems. As described in the Millennium Ecosystem Assessment (MEA), these include the provisioning of resources such as food, fibre, and raw materials; regulating services such as water filtration, storm buffering, and climate stabilisation; supporting services such as soil formation, photosynthesis, and pollination; and cultural services that are spiritual, aesthetic, and recreational services (MEA, 2005). Many human activities impede ecosystem functions, thereby reducing or increasing flows of these EGS. While the supply of some goods is increasing, the MEA estimates 60% of the ecosystem services have declined globally in the past 50 years (MEA, 2005). However, the critical ways in which ecosystems support and enable human well-being are rarely captured in cost-benefit analysis for policy formulation and land use decision-making (Daily et al., 2009; Laurans et al., 2013; Nelson et al., 2008). Recent studies highlight the need to assess trade-offs among EGS under a variety of future land-use scenarios (Butler et al., 2013; Carpenter et al., 2009; Sanon et al., 2012; Willemen et al., 2012).

Prioritising landscapes for the production or harvest of a single ecosystem commodity, such as food or fibre, can diminish other services such as water quality, erosion prevention or soil formation (Bennett et al., 2010; Bryan and Crossman, 2008; Raudsepp-Hearne et al., 2010; Stoate et al., 2009; Zamit, 2013), as well as undermining overall ecosystem resilience (MEA, 2005). This is certainly the case for south-eastern Australia where such trade-offs have been observed over the past two hundred years (Bryan et al., 2010, 2011; Crossman et al., 2009, 2010; Sandhu et al., 2012). Several authors explore the spatial patterns of provision of multiple EGS in production landscapes, focusing on the win-win opportunities for conservation and production of multiple EGS (Bennett et al., 2009; Egoh et al., 2008; Naidoo et al., 2008; Nelson et al., 2009; Tallis and Polasky, 2009; Zamit, 2013). However only a few deal with the economic valuation of future landscape management scenarios and associated impact on provision of EGS.

Changes in land use and land cover are ongoing due to changes in environmental conditions, patterns of human settlement, modes of production, and demands of society (Lanbin et al., 2001; Verburg et al., 2009). Large areas of native vegetation in Australia have been converted to agricultural production (SOE, 2011) resulting in unforeseen economic impacts such as the costs associated with reduced flood control, the provision of potable water, or increased salinity and soil erosion (i.e., ecosystem services) (SOE, 2011) that are not captured in standard analysis of farming systems. EGS research is relatively new and quantification and valuation of services remain highly uncertain (Hou et al., 2013; Johnson et al., 2012). There are additional uncertainties with the future provision of services due to continuing land-use change and climate change. Therefore, a gross estimate of EGS at a point in time without considering future land-use scenarios will have limited value for decision makers (Fürst et al., 2013; Swetnam et al., 2011).

Identifying such potential changes in land cover, and measuring and managing multiple EGS under future land-use scenarios is a key challenge for policy makers. In the state of Victoria, Australia, efforts are underway to address these challenges. One such initiative is the Future Farming Landscapes (FFL) program, a long-term (~ 30 years) program that aims to reconfigure landscapes to their most sustainable use. Here, we attempt to identify and assess provision of various EGS under a range of plausible landscape configurations, including one FFL-type scenario in this landscape.

Our specific aims were to (i) identify and define plausible land-use scenarios for the study area, (ii) estimate the value of key EGS: carbon sequestration, agricultural production, water, biodiversity and timber production under these land-use scenarios, (iii) show how these key EGS can be included in economic evaluations in order to better support decision making, and (iv) analyse the potential trade-offs and synergies among multiple EGS under these land-use scenarios.

2. Methods

2.1 Study area and policy context

The study area is located in north-central Victoria (Fig. 1), a region spanning over three million hectares and encompassing three bioregions (Murray Fans, Victorian Riverina, Murray Mallee; DSE, 2004). It encompasses approximately 13% of Victoria and is a significant component of the Murray-

Darling Basin. These bioregions support over 2,000 native plant species, including 130 state-wide threatened species with 52 of these considered to be nationally threatened (NCCMA, 2011). They also support more than 400 native vertebrate fauna species including 101 threatened species of which 13 are nationally threatened (NCCMA, 2011). Furthermore the region supports the States most depleted wetland types, high diversity of waterbird species including the waterbirds listed under international agreements (DSE, 2010). The region is particularly important for agriculture producing vast wealth from its irrigated industries in the north and dryland industries in the south. The area has been heavily modified since European settlement, and approximately 70% native vegetation cleared which is higher than state average (65%). Conversion of deep rooted perennial vegetation to annual crops has resulted in a suite of environmental impacts including dryland salinity, habitat and biodiversity loss, and soil degradation (Jones et al., 2007; Pittock et al., 2012). Moreover, this region is situated within the Murray-Darling Basin – the largest river catchment area in Australia, and clearing for crops and over-use of irrigation in this catchment has resulted in extensive environmental impacts (CSIRO, 2012). In recent years, the Australian and state governments, business and landowners have employed a number of strategies, including market-based instruments for conservation, aimed at reversing this decline in environmental condition (Burgin, 2008; Eigenraam et al., 2006; Wheeler et al., 2013).

Climate change is one of the most important challenges in Australia and the study region is no exception. During the last decade (1998 to 2007) average annual temperatures in the region were 0.3˚C warmer than the 30 year (1961 to 1990) average while there has been a substantial decline in the region’s rainfall over the past decade (DSE, 2008). The direct and indirect impacts associated to climate change will have major adverse effects on the environment, society and economy. The Australian Federal government has introduced various initiatives (e.g., Carbon Farming Initiative, Biodiversity Fund) to reduce greenhouse gas emissions, prepare for a changing climate and to build greater environmental resilience across the Australian landscape (CEF, 2011; DCCEE, 2011a). The Australian emissions trading scheme (ETS) legislation (i.e., *The Clean Energy Act (2011)*) passed by the Parliament in 2011,includes carbon pricing mechanism, investing in renewable energy, improving energy effacing and creating opportunities in the land sector. However, proposed new legislation to repeal *The Clean Energy Act (2011)* and direct action to act climate change may reduce some opportunities for the land sector.

2.2. Study site – Reedy Lakes and Winlaton

The study site lies between Kerang and Lake Boga in north-central Victoria, Australia, approximately 320 km north-west of Melbourne (35.972º S, 143.228º E, Fig. 1). The total area is approximately 30,000 ha, bounded by the Little Murray and Lower Loddon Rivers in the North, West and South and the Murray Valley Highway to the West. Within the study area lie the Reedy Lakes and Winlaton Future Farming Landscapes (FFL) projects managed by Kilter Pty Ltd (an asset management group servicing the superannuation sector). The terrain is generally flat and low-lying (70–80 m above sea level). Average annual rainfall is approximately 370 mm (mean, 1962–2012), and mean annual temperature ranges from a minimum of 9 ºC to a maximum of 23 ºC.

 # Fig 1 approximately here#

Reedy Lakes and Winlaton is a typical north-central Victorian landscape that has been subject to extensive vegetation clearing for agriculture and pastoral production and native vegetation is now highly fragmented and often degraded (NCCMA, 2005). Since European settlement in the mid-1800s, an estimated 70% of native vegetation (18,300 ha) has been cleared. This has resulted in widespread declines in biodiversity, increased soil and stream salinity and soil erosion (NCCMA, 2011). Nationally, natural resource management programs have focused on reduction in salinity, improving water quality and environmental flows, and protecting biodiversity (Hajkowicz, 2009). Major land use-land cover types include irrigated farming, dryland cropping, native vegetation, degraded land undergoing rehabilitation, and water bodies (Table 1).

The study area covers less than 0.2 % of Victoria’s land mass. However, it supports a relatively large number of threatened flora species (50 species, 2.5% of threatened plants in Victoria) and fauna species

(81 species, 45% of the threatened Victoria). The high levels of biodiversity, and the pressures on this biodiversity, have resulted in the area being identified as an important site for conservation by the Victorian Government (Wetlands Scientific Committee, 1993). Wetlands within the study area support high richness and abundance of waterfowl species (Lugg et al., 1989) and some sites are of international significance, including the ‘Kerang Wetlands Ramsar Site’ (DSE, 2004).

Land and water use in the study area are in a constant state of flux. Irrigation water entitlements are being bought and sold, there are ongoing changes in where and how farming takes place, and people are moving from rural properties to regional town centres (NCCMA, 2007). More recently, Kilter Pty Ltd targeted land in north-central Victoria for management under the Future Farming Landscapes (FFL), a long-term program that aims to restore landscapes to their most sustainable configurations. Through this program 25% (7552 ha) of the Reedy Lakes and Winlaton study area is currently being reconfigured and managed for both traditional and new income streams including agriculture, forestry, green energy, and water. This potential for future land-use change presented an ideal opportunity to assess the current status of biodiversity and associated ecosystem services provided by each land use-land cover type as a baseline for assessing the implications of future land management options.

 # Table 1 approximately here#

2.3 Plausible future scenarios for landscape configuration and associated land use-land cover

We developed five plausible future land-use scenarios for the study area (Table 2). This was based on a review of recent land use-land cover change patterns in south-eastern Australia and undertaken in consultation with stakeholders.

 # Table 2 approximately here#

2.3.1 Scenario 1: Business-as-usual (BAU)

This scenario assumed continuation of current farming and management systems with no further broad-scale clearing of remnant native vegetation. Gradual loss of remnant vegetation and opportunistic agricultural expansion will potentially occur at the farm scale but this was not included in the scenario. The BAU scenario was considered plausible as the current prices of agricultural commodities, while variable, are likely to be maintained or increased (Ransom, 2011). To this end, farms were likely to continue operating for the foreseeable future. Under this scenario we assumed approximately 0.14% loss of native vegetation per annum which is similar to current native vegetation clearance rate in Victoria (DSE, 2012).

2.3.2 Scenario 2: Mosaic farming systems (MFS)

This scenario assumed that the landscape will be transformed to more ecologically sustainable uses involving changes to farming practices, low rainfall forestry and environmental plantings. This scenario is based on the FFL model and uses a similar land-use reconfiguration, with the goal of developing an estate that includes environmental plantings and extensive grazing (~51%), irrigated farming (horticulture, agriculture ~33%), perennial horticulture (~7%), commercial agroforestry (~4%) and other land uses (~5%) (Kilter Pty Ltd, 2011). The MFS scenario is considered plausible given that Kilter's initiatives were already underway on approximately 25% of the study area (Table 3). Under this scenario we assumed that approximately 50% of dryland farming was primarily converted to environmental planting (60% of converted land) due to the potential demand for carbon credits, and production forestry (30% of converted land). A small proportion (10%) of irrigated farming was assumed to be converted to perennial horticulture.

 # Table 3 approximately here#

2.3.3 Scenario 3: Eco-centric or environmental plantings (ECO)

This scenario assumed that there will be substantial increase in environmental plantings due to growing environmental concerns and growth of new commodities based on environmental values such as carbon and biodiversity credits (Bekessy and Wintle, 2008; Burgin, 2008). The Australian Government and Victorian State Governments have designed economic instruments that provide financial incentives to landowners for undertaking eligible carbon sequestration activity such as revegetation of fragmented landscape via various mechanisms such as Carbon Farming Initiative (DCCEE, 2011a) and the Land and Biodiversity Fund (Caripis et al., 2012; Keenan et al., 2012). Under this scenario it was assumed that all dryland faming would be converted to mixed species environmental planting (70%) due to potentially higher demands for carbon credits, and to a lesser extent commercial tree farming (30%) due to low profitability.

2.3.4 Scenario 4: Agro-centric or production oriented (AGRO)

This scenario assumed that higher demand for food and livestock production due to continued population growth in Australia and globally (Godfray et al., 2010). Global food demand is expected to more than double by 2050 to meet this growing demand (Green et al., 2005). Relatively cheaper land prices, and improved farming and irrigation practices may reduce the production cost and make agricultural production a more profitable venture. The scenario assumed the current areas of agricultural production would increase through clearance of remnant native vegetation and conversion to agricultural production. Under this scenario it was assumed that all available native vegetation on private land (4,502 ha) would be cleared for dryland farming (70% of converted land) and irrigated cropping (30% of converted land).

2.3.5 Scenario 5: Abandoned land use (ALU)

This scenario assumed that higher labour prices and a strong currency may prevent Australian products competing effectively in international markets and reduced water availability due to water trading and climate change, resulting in a decline in agricultural terms of trade, and agricultural land abandonment (Beilin et al., 2014; Garnaut, 2008; Hamblin, 2009; Race et al., 2010). Under this scenario, all irrigated and dryland farming areas would be abandoned and either revert to native vegetation or become weed infested or a combination of both.

2.4 Scenarios and assumptions for costs and associated revenues

Cost of production and associated returns from each EGS were estimated under three commonly used scenarios: (i) base or central cost and revenue assumptions, (ii) optimistic or higher revenue but low production cost, and (iii) conservative or high production cost and lower revenue. Table 4 provides a summary of the various assumptions for each cost-based scenario.

2.4.1 Base or central scenario

This scenario used the actual establishment and management cost provided by Kilter Pty Ltd and a carbon price of \$20 Mg^{-1} CO_2^e. This price was based on the current price under the Australian Government's Carbon Pricing Mechanism (Clean Energy Future, 2012) less the estimated cost for assessment and verification, which was assumed to be approximately 15% of total value. Similarly it assumed moderate stumpage value of timber and average gross revenue from agricultural production.

2.4.2 Optimistic scenario

This scenario used reduced establishment and annual management costs (to 50%) and a higher carbon price \$30 Mg^{-1} CO_2^e. Similarly it assumed higher stumpage value of timber and higher gross revenue from agricultural production.

2.4.3 Conservative scenario

This scenario used a higher planting and annual management cost but a lower carbon price of \$10 Mg^{-1} CO_2^e. This was an average price in the voluntary carbon market used in a number of analyses (Crossman et al., 2011; Polglase et al., 2011). The price of agricultural commodities and livestock would be reduced due to globalisation and increased production capacity through technological advancements. Similarly, this conservative scenario assumed there would be a lower stumpage price of timber and lower gross revenue from agricultural production.

2.5 Ecosystem goods and services

We assessed and valued five important EGS provided by production landscapes in the study area and the region using a mixed approach of quantitative assessment and economic valuation (Bryan et al., 2010;

Butler et al., 2013; Crossman et al., 2009) for the various future land-use scenarios (Table 2). There are other valuable services generated in the Reedy Lakes and Winlaton region such as, salinity mitigation, water regulation, nutrient regulation, and recreation, but these were not considered in the analysis.

EGS values for carbon, timber, water, agricultural production and additional values from biodiversity were estimated as net present value (NPV at base year 2012) per hectare over a time horizon of 30 years (*t* = 30) at three commonly used discount rates (*r*) of social (1.0%), public (5.0%), and commercial (10.0%) consistent with studies elsewhere (e.g. Paul et al., 2013; Polglase et al., 2011). These estimated values were compared with the estimated annual values of agricultural production per hectare available from Kilter Pty Ltd.

2.5.1 Carbon sequestration

Carbon sequestration in environmental plantings was estimated as Mg ha^{-1} using the Carbon Farming Initiative (CFI) reforestation tool (DCCEE, 2011c). Monetary values were obtained firstly by transforming Mg of C (carbon) ha^{-1} into Mg of CO_2 ha^{-1} and secondly by multiplying the resulting Mg by the assumed carbon price. Similar to Crossman et al. (2010), NPV (ha^{-1}) from carbon is estimated by the following formula: $NPV = \sum_{t=0}^{T} \left(\frac{\mathrm{P} * \mathrm{Q_t} - (\mathrm{EC_c} + \mathrm{MC})}{(1+\mathrm{r})^{\mathrm{t}}} \right)$

Where P is the price of carbon, Q_t is the quantity of CO_2^e sequestrated in year *t*, EC_c is the establishment cost, MC is the annual management cost, and *r* is the discount rate.

Different carbon prices were used for base, optimistic and conservative scenarios (Table 4). For the base scenario we used the 2012 carbon price of \$23 Mg^{-1} of CO_2 which was introduced by the Australian Government on 1 July 2012.

2.5.2 Provision of water

Woody vegetation usually uses a large proportion of rainfall compared to other land uses such as agriculture and pasture and can reduce the supply of this resource in streams and rivers (Zhang et al., 1999, 2001). Water yield from different forms of land cover was assessed based on the potential groundwater recharge (in mm yr^{-1}) under given rainfall conditions (Benyon et al., 2007, 2009). Run-off is typically estimated as the balance of water available after rain-based deep drainage and evapotranspiration are subtracted from precipitation (Barratt et al., 2007), that is: $R = P – E – D$. Here, R is run-off, P is precipitation, E is total evapotranspiration, and D is deep drainage/recharge. However, the net change in catchment water storage over a long period of time is zero (Bradford et al., 2001) and hence there is negligible change in deep drainage. To this end we used a simple water balance equation following Chan et al. (2006): $R = P – E$.

The amount of run-off reduction from revegetation was multiplied by the cost of water per ML ha^{-1} to identify the plantation water use cost for environmental planting and timber production. In the case of irrigation, the irrigation requirement for water ML ha^{-1} was multiplied by the prevailing water cost in \$ ML^{-1}.

2.5.3 Biodiversity

Biodiversity can be valued by society for its intrinsic worth or for its contribution to the provision of various EGS in the study area. Both natural and modified ecosystems support certain levels of biodiversity and a number of recent studies have focused on measuring and valuing biodiversity (Atkinson et al., 2012; Butler et al., 2013; Christie et al., 2006; Gracia et al., 2011; Salles, 2011). However, measuring and valuing biodiversity is a challenging issue for a number of reasons: (i) it is complicated by the wide spectrum of spatial scales at which biodiversity operates, ranging from the molecular, to gene, species, ecosystem and landscape levels; (ii) even for a given level of biodiversity, there is no well-established and agreed means for defining, measuring and valuing biodiversity; and (iii) a number of different indicators have been proposed which neither provide consistent nor comparable results on which to base general interpretations (Atkinson et al., 2012; Bene and Doyen, 2008; von Haaren et al., 2012).

Detailed assessment and valuation of biodiversity was not possible in this study. Rather we chose to use an approximate dollar value for biodiversity conservation resulting from market-based approaches used by the Australian and various State governments to conserve native vegetation on private land, such as ‘bush tender’ in Victoria (Stoneham et al., 2003), and ‘biodiversity banking’ in New South Wales (DECCW, 2009). This option was used because there were no comparable studies to transfer appropriate values for the study site. The assumption was that governments would be the primary purchasers of biodiversity conservation services from private landowners in the near future and the recent payments for establishment of mixed species environmental plantings that increase total habitat area and buffer existing remnant vegetation were used in the study (approximately \$450 ha^{-1} over the first 5 years).

2.5.4 Timber production

Commercial timber and wood fibre production is an ecosystem good provided by native vegetation and managed plantations. In contrast to the declining trends for most EGS, timber production capacity is enhanced in many parts of the world (MEA, 2005) due to increasing establishment of managed plantations (FAO, 2010). Although the actual value of timber is realised at the time of maturity, we converted future value in terms of net present value using various discount rates. In this study we used the tree-stand growth model 3-PG (physiological principles predicting growth; Landsberg and Waring, 1997) available from Farm Forestry Toolbox (Private Forest Tasmania, 2011) to estimate timber production. The 3-PG model uses climatic data, site factors, initial tree density, and management practices such as thinning and fertilizer application. We simulated the annual growth of Oil Mallee (*Eucalyptus kochii,* a low rainfall species native to Western Australia and suitable for our study site) as a monoculture plantation. Estimated mean annual increment is then multiplied with the rotation age and various stumpage prices (S. Dawkins, Oil Mallee Australia pers. comm.) and discount rate to calculate the net present value from timber production.

2.5.5 Agricultural production

Dryland cropping (barley, wheat, canola, oats), intensively irrigated cropping (legumes, corn, lucerne), annual horticulture (tomatoes, melons), and perennial horticulture (olives, almonds, stone fruits) are the dominant land use and primary economic activity in the study area (Kilter Pty Ltd, 2011). Agriculture is generally a profitable endeavour generating private returns to landowners. However, agricultural returns are highly variable, and subject to both unpredictable weather patterns and fluctuations in commodity markets (Ransom, 2011). The production value of agricultural land can be quantified by (i) spatially modelling agricultural profitability according to land and water use (Crossman et al., 2010), or (ii) obtaining estimated returns from secondary sources such as data from Australian Bureau of Statistics or landowners and stakeholders from the particular study area. Here we obtained present gross value of agricultural production $\$ha^{-1}\ yr^{-1}$ from Kilter Pty Ltd as this is more accurate rather than extracting other sources or profitability models.

Agricultural production also contributes substantially to Australia's total greenhouse gas emission profile (DCCEE, 2012) but these emissions were not considered in this analysis. However, the emissions from inputs into agricultural enterprises have to be deducted from agricultural profitability. Here we used total estimated greenhouse gas emission values available from Maraseni et al. (2007).

2.6 Analysis

We compared the value of production of EGS under the different land-use scenarios in Australian dollars per hectare (Table 2).

 # Table 4 approximately here#

3. Results

3.1 EGS trade-offs under different land-use scenarios

Two plausible land-use scenarios (mosaic farming systems and eco-centric) realised substantial gains in carbon sequestration, biodiversity conservation and timber production. Conversion of dryland and irrigated farming landscape to perennial vegetation types store more carbon in soils and biomass, which substantially increased carbon sequestration. However, the eco-centric scenario considerably reduced the value of agricultural production due to conversion of agricultural land to biodiversity plantings. Business-as-usual and abandoned land-use scenarios produced mainly negative or neutral outcomes for the assessed EGS (Table 5).

 # Table 5 approximately here#

3.2 Provision of EGS and profitability under different land-use scenarios

Assuming base pricing and a ‘public’ discount rate (5%) and all values priced, mosaic farming systems produced the highest total NPV, followed by the business-as-usual, the agro-centric, the eco-centric and the abandoned land-use scenarios (Table 5). For the business-as-usual and agro-centric scenarios there were no additional gains resulting from timber production, carbon sequestration or reduced emissions due to clearing of native vegetation. The eco-centric scenario resulted in negative NPV due to the low productivity of the study area for timber production.

When using a commercial-level discount rate (10%), relative NPVs for the different scenarios changed considerably. The business-as-usual scenario produced the highest NPV followed by the agro-centric, mosaic farming systems and eco-centric and abandoned land-use scenarios. At the higher discount rate, returns from carbon and timber were negative, which affected the total NPV of the two more ‘environmentally sustainable’ scenarios: the eco-centric and mosaic farming system scenarios. This situation was reversed with a lower ‘social’ discount rate (1%). Overall, the NPVs from each scenario were in the same order, with mosaic farming producing the highest NPV and land abandonment the least. However, the NPV for the eco-centric scenario almost doubled due to increased benefits from timber and carbon. The land abandonment scenario produced the least benefits under all scenarios.

Returns from carbon sequestration produced positive NPV under the most optimistic and base level price assumptions. However, carbon farming resulted in negative benefits under the conservative scenario except at a very low discount rate of 1% (Fig. 2a). With additional payments similar to the BushTender payment mechanism (approximately \$450 ha^{-1} over the first 5 years), the NPV was positive, except when a high discount rate was used (Fig. 2b). However the economic benefits from this source are was considerably below those from agricultural production. Under the base pricing levels with a 5% discount rate and higher carbon price (\$32 Mg^{-1} CO_2^e), the NPV from dryland farming is positive for carbon farming. To compete with the NPV from irrigated farming, the carbon price would need to be considerably higher i.e., \$66 Mg^{-1} CO_2^e.

 # Fig 2 approximately here#

Returns from planting trees for timber production resulted mainly in negative NPV under conservative and base return scenarios (Fig. 3). Positive NPV could only be realised with lower discount rates of 1 and 5% and optimistic price and cost assumptions.

 # Fig 3 approximately here#

4. Discussion

This study set out to identify and assess provision of EGS under a range of plausible future land-use scenarios to satisfy the changing demand of society for EGS. This study supports the concept of addressing conservation from the perspective of investment in EGS (Pagiola et al., 2010) such as payments for carbon sequestration (Crossman et al., 2011), wetland and biodiversity banking (Carroll et al., 2008) or agri-environmental payments (Prager et al., 2012). However, those investing in these services will need to make considerable higher payments to produce a positive NPV at normal commercial discount rates, or accept lower returns.

Results from this study indicated that the economic value from the provision of various EGS varied considerably under each land-use scenario. While the provision of many desired EGS can increase or decrease according to land use and management practices under each land-use scenario, NPV depends on the productivity per unit area, the market value of the commodity or service and discount rate. Under the base scenario of cost and revenue with a 5% discount rate, both the mosaic farming system model, and business-as-usual practices had a positive NPV. However, with a commercial discount rate of 10%, landscape management regimes focused on agricultural production (the business-as-usual and agro-centric scenarios) had the highest NPV, despite management not producing other goods, such as timber, or services such as carbon.

Biodiversity value declined under both agriculturally-focused scenarios but levels of payment assumed in this study were not sufficient to offset the income benefits from farming. This supports the modelling from elsewhere that a focus on agricultural production can impact negatively on other services biodiversity, carbon and water (Crossman et al., 2009; Egoh et al., 2011; MEA, 2005; Prager et al., 2012). Although some studies suggest that the careful design of agricultural production can maintain or increase agricultural income, while also increasing value from other EGS (Batary et al., 2010; Pretty et al., 2006), in the case of biodiversity conservation there is ongoing debate about the relative merits of integrated versus partitioned conservation activity (Phalan et al., 2011; Tscharntke et al., 2012). Continuing profitability of agricultural production is also uncertain due to declining rural populations and labour availability, volatile commodity markets and climate variability (Steffen et al., 2009) and there are potential risk management benefits in maintaining options for multiple income sources.

At a 5% discount rate, the eco-centric scenario produced a lower NPV under the base assumptions for costs and revenues. This indicates that planting trees for carbon or timber alone is not commercially attractive in the study area due to relatively low productivity in these low rainfall conditions. This poses significant challenges to the Australian Government’s Carbon Farming Initiative to increase carbon stocks in rural landscapes. Much of the land that might be used for this Initiative is in lower rainfall zones, with the land becoming available because water rights for irrigation associated with the land have been traded to other locations. Additional payments or incentives being implemented through the Biodiversity Fund or market-based instruments such as BushTender might makes some scenarios attractive but the combination of carbon and biodiversity payments did not come close to current expected returns from agricultural production at higher discount rates.

To compete with returns from dryland farming and irrigated farming, the eco-centric scenario requires either: (i) higher payments through well-designed economic instruments that provide incentives for landowners to sequester carbon and conserve biodiversity (our analysis indicated that the carbon price had to be substantially higher than current levels: \$32 Mg^{-1} CO_2^e and \$66 Mg^{-1} CO_2^erespectively) or (ii) investors need to base their returns on longer terms benefits through applying a low discount rate. The latter situation might apply to non-profit organisations or government funded programs that aim to produce public services.

Separate payment mechanisms for both carbon and biodiversity credits could provide increased incentives for the revegetation of degraded landscapes resulting in positive environmental outcomes (Bekessy and Wintle, 2008; Crossman et al., 2011; Fox and Nino-Murcia, 2005). Because of the long time span between investment to establish plantations and income from timber, NPV from timber was also positive at the low discount rate. Similarly, at a carbon price of \$25 Mg^{-1} CO_2^e, returns from carbon can be as profitable as dryland farming. However, even at a 1% discount rate, the carbon price had to be much higher, i.e., \$54 Mg^{-1} CO_2^e to produce similar returns to irrigated farming.

The carbon price is currently dependent on the carbon pricing mechanism of an individual country, or is determined by the free market mechanism under the voluntary carbon scheme. Carbon pricing is well beyond the control of the land owner or land manager. However a progressive carbon tax (see Dissou and Siddiqui, 2014) and annual carbon price increment as per CPI can provide incentives to the landowner so that they can make an informed decision on land use by evaluating the NPV under different land use scenarios and potential carbon pricing.

The abandoned land-use scenario was neither commercially attractive nor socially or environmentally desirable due to the decline of many EGS that are important for human survival and well-being. However, under certain conditions ‘abandoned’ land could produce better environmental outcomes, if it is managed in a light-handed way to support native vegetation and associated biodiversity (Beilin et al., 2014; Lasanta-Marinez et al., 2005; Luck, 2010). In other cases, abandoned land could be purchased by environmental and conservation organisations such as Australian Wildlife Conservancy and Birds Australia and managed through conservation covenants (Luck, 2010). However, in many cases abandoned land becomes weed and pest infested resulting in ecosystem dis-services (Le Maitre et al., 2014; Dunn, 2010; O'Farrell et al., 2007). In addition, such land may be prone to bushfires and may be difficult to monitor due to limited road access. Similarly, lack of pest management could increase invasive species such as the red fox and feral cat which would have devastating consequences for native fauna (Luck, 2010).

Although planting trees produces many public EGS such as enhanced biodiversity (Brockerhoff et al., 2008; Munro et al., 2009), carbon sequestration (Bottcher and Linder, 2010; Paul et al., 2013), reduced dryland salinity (Crossman et al., 2010), soil protection (de Groot and van der Meer, 2010), and water regulation (Keenan and van Dijk, 2010), planting trees for timber or wood fibre alone in many locations in Australia is not profitable due to low rainfall and low productivity. Two possible alternatives can overcome this situation.

1. Planting high value timber such as Australian sandalwood (*Santalum spicatum*). This species is climatically suited to the study site and can potentially generate significantly higher NPV per ha than other tree species (Brand et al. 2003; Jones, 2002).

2. Enhancing income from plantations through integrating multiple uses involving additional income such as grazing and carbon sequestration (Maraseni et al., 2012). A recent study by Maraseni et al. (2012) demonstrated an approximate 30% additional return potential from integrating grazing and carbon sequestration in timber production systems in medium rainfall study sites in south-east Queensland.

While this study demonstrated that higher economic values can be potentially be achieved through adopting management systems that integrate multiple goods and services, under the current policy there are very few payments or incentive mechanisms for producing a range of EGS (House et al., 2008). For example, timber plantations sequester significant amounts of carbon during their growth and carbon can be stored for long periods of time in a range of timber products but planting trees for timber production did not qualify for carbon credits under current Carbon Farming Initiative guidelines (DCCEE, 2011a). There has been some softening of this position recently and the Australian Government is considering a methodology that allows farmers to claim credits for farm forestry plantings (http://www.climatechange.gov.au/reducing-carbon/carbon-farming-initiative/methodologies/methodology-proposals).

Analysis revealed trade-offs and synergies in the production of goods and services under different land-use scenarios. For example, the eco-centric and mosaic farming systems scenarios involved deriving income from carbon and timber production at the cost of agricultural production. While there was synergy between carbon sequestration and biodiversity, trade-offs were observed between timber production and biodiversity. Similarly, in the business-as-usual and agro-centric scenarios, the focus on production of agricultural goods has an impact on the supply of carbon, timber production and biodiversity benefits. There was potential to reduce these trade-offs at landscape scale without compromising overall profitability (Onaindia et al. 2013) but , in many cases, these trade-offs are inevitable at the site or property scale (MEA, 2005; Rodríguez et al., 2006).

These findings have important implications for forest management internationally. The ‘landscape approach’ has become an increasingly important part of the global forest and land management policy dialogue in recent years (Batáry et al., 2010; Otte et al., 2007; also CIFOR reference). Often this is portrayed in terms of win-win-win outcomes from production systems, conservation and the provision of ecosystem services. However, the trade-offs between the production of goods and services, or in providing different services is not considered. The approach in this paper, using different landscape management scenarios and their associated outcomes, provides a framework for considering and managing these trade-offs. Lessons from this study can be especially useful in areas where agriculture, forestry and other productive land uses compete with goals for conservation or the provision of ecosystem services.

5. Conclusion

Land-use decisions are typically determined by a combination of government policies and the choices of private landowners (Nelson et al., 2008). Information about the effects of different choices on the provision of different types of EGS can provide the basis for more informed policy decisions (House et al., 2008), particularly for regions undergoing considerable change in management due to changing water use demographics and commodity prices. In this study, we assessed total economic value (expressed as Net Present Value, NPV, over a 30 year period) for two types of products (agricultural commodities and timber) and three ecosystem services (carbon, water and biodiversity) under five future land-use scenarios using varying levels of costs, prices and discount rates. Results indicated that at higher discount rates normally applied to commercial activities, and assuming the current prices for goods and services, NPV was highest for landscape management scenarios aimed at maximising agricultural production. Potential income from services such as carbon and biodiversity does not offset projected income from agriculture. At higher discount rates, NPV was negative for the two scenarios aimed at enhancing the longer term ecological sustainability of the landscape. These results indicate that income from carbon sequestration and biodiversity conservation would need to be considerably higher than current levels in order to justify focusing management of this landscape on ecological outcomes. At lower discount rates (at levels normally associated with public investments), the more ecologically appropriate ‘mosaic farming system’ had the highest NPV, indicating that this type of system might be attractive for investors interested in longer term return horizons or wider public benefits. Higher income from carbon or biodiversity, or increased return from timber by using higher value tree species, could potentially make more ecologically appropriate systems profitable at higher discount rates.

The abandoned land-use scenario produced negative NPV under all assumptions. Land abandonment potentially threatens native biodiversity and produces ecosystem dis-services due to potential growth of weeds and pest animals. This study showed that an EGS framework can be used to assess and value different land-use options and demonstrated the potential to manage landscapes to produce a mix of EGS. This can provide a useful input for land use policy and land management decisions elsewhere.

Acknowledgements

Spatial data was provided by the Victorian Department of Sustainability and Environment (DSE) through the University of Melbourne and the North Central Catchment Management Authority. We thank Malory Weston and David Heislers from Kilter Pty Ltd for supplementary data and ongoing support. We thank two anonymous reviewers for comments that helped improve the manuscript.

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Table 1 Distribution of current land use-land cover in the Reedy Lakes and Winlaton study area in north-central Victoria, Australia (see also Fig.1).

Current Land Use	Area (ha)	% of study area
Native vegetation	6,799	22.6
Dryland cropping	7,800	25.9
Irrigated farming	8,516	28.3
Horticulture	157	0.5
Rehabilitated[a]	3,068	10.2
Water	2,868	9.5
Built up	914	3.0
Total	30,122	100.0

[a] Rehabilitated is degraded land undergoing rehabilitation and substantially modified (BRS, 2006).

Table 2 Estimated areas of different land use-land cover under future land-use scenarios.

	Estimated area (ha) under each scenario[a]					
	Current	BAU	MFS	ECO	AGRO	ALU
Native vegetation	6,799	6,519	6,799	6,799	2,297	6,799
Dryland cropping	7,800	8,079	3,900	0	10,951	0
Irrigated farming	8,516	8,516	7,664	8,516	9,866	0
Horticulture	157	157	1,009	157	157	0
Freshwater lakes	2,573	2,573	2,573	2,573	2,573	2,573
Saline lakes and treatment	1,530	1,530	1,530	1,530	1,530	1,530
Channel/aqueduct	293	293	293	293	293	0
Rehabilitation	1,541	1,541	1,541	1,541	1,541	1,541
Built up	914	914	914	914	914	914
Environmental plantings	0	0	2,730	5,460	0	0
Forestry (production)	0	0	1,170	2,340	0	0
Abandoned land	0	0	0	0	0	16,765
Total	30,122	30,122	30,122	30,122	30,122	30,122

[a] Descriptions of scenarios: ‘BAU’ business-as-usual, continuation of current farming and management system; ‘MFS’ mosaic farming systems, landscape reconfiguration to more ecologically sustainable uses that involve changes to farming practices and environmental plantings; ‘ECO’ eco-centric, substantial increase in environmental plantings due to increasing environmental market; ‘AGRO’ agro-centric, increase in agricultural land due to higher demand of food and livestock production in line with the population growth; ‘ALU’ abandoned land use, decline in agriculture and land abandonment due to reduced water availability and depopulation in rural areas. In many cases, ALU may ultimately become some form of native or exotic vegetation in the long run which may support biodiversity. This land type may also be subject to weed and pest infestations which negatively impact native biodiversity.

Table 3 Land currently undergoing change in management under the Future Farming Landscapes program being implemented by Kilter Pty Ltd (Kilter Pty Ltd, 2011).

Land Management Unit	Area (ha)[a]	% of re-configured land	% of study area
Irrigated Cropping	2,789	37	9.3
Biodiversity	1,960	26	6.5
Grazing	1,489	20	4.9
Perennial Horticulture	658	9	2.2
Forestry (production)	342	5	1.1
Rural Living	292	4	1.0
Other	23	0	0.1
Re-configured land total	7,552	100	25.1
Study area total	30,123		

[a] Data for re-configured land is current at December 2011, although this proportion will change over time.

Table 4 Scenarios and associated assumptions for cost and revenue estimation from environmental plantings, production forestry and agricultural production activities.

	Assumption for cost and revenue estimates under each scenario[a]		
Activities	Base	Optimistic	Conservative
Mixed species environmental planting			
Stocking (ha^{-1})	1,000	1,000	1,000
Establishment cost ($ha^{-1})	1,000	800	1,200
Annual management cost ($ha^{-1})	10	8	12
Irrigation requirement (ML ha^{-1})	negligible	negligible	negligible
Carbon price ($Mg^{-1} CO_2^e)	20	30	10
Production forestry			
Stocking (ha^{-1})	1,000	1,000	1,000
Establishment cost ($ha^{-1})	2,000	1,600	2,400
Annual management cost ($ha^{-1})	100	80	120
Irrigation requirement (ML ha^{-1}) first 5 years after planting	2	2	2
Stumpage value ($m^{-3})	50	60	40
Agricultural production (Irrigated farming)			
Total revenue ($ha^{-1} yr^{-1})	1500	1700	1300
Variable cost ($ha^{-1} yr^{-1})	1200	1300	1100
Gross margin ($ha^{-1} yr^{-1})	300	400	200
Irrigation requirement (ML ha^{-1} yr^{-1})	10	10	10
Agricultural production (Dryland farming)			
Total revenue ($ha^{-1} yr^{-1})	120	140	100
Variable cost ($ha^{-1} yr^{-1})	15	20	10
Gross margin ($ha^{-1} yr^{-1})	105	120	90
Other variables used for all analysis			
Water Price (ML^{-1})	20	20	20
Price and cost inflation (% yr^{-1})	3	3	3
Project period (years)	30	30	30
Discount rate (%)	1, 5, 10	1, 5, 10	1, 5, 10

[a] Descriptions of scenarios: ‘base’ current actual establishment and management cost and value; ‘optimistic’ reduced management cost and increased value; ‘conservative’ higher management cost and lower value.

Table 5 Ecosystem goods and services trend under future land-use scenarios at base pricing and discount rate of 1, 5, and 10%.

	Estimated total value of ecosystem goods and services under each scenario (in thousands)					
Future land-use scenarios[a]	Carbon	Agricultural production	Water[b]	Biodiversity	Timber	Total
Base pricing and 1% discount rate						
BAU	$0	$133,901	$0	$16,148	$0	$150,048
MFS	$6,541	$139,810	-$901	$16,841	$1,021	$163,312
ECO	$13,082	$100,269	-$1,802	$16,841	$2,043	$130,433
AGRO	$0	$142,324	$0	$5,690	$0	$148,013
ALU	$0	$0	$0	$16,841	$0	$16,841
Base pricing and 5% discount rate						
BAU	$0	$71,351	$0	$9,746	$0	$81,097
MFS[c]	$2,782	$74,198	-$1,061	$10,165	-$560	$85,524
ECO	$5,564	$52,940	-$2,122	$10,165	-$1,121	$65,426
AGRO	$0	$75,866	$0	$3,434	$0	$79,300
ALU	$0	$0	$0	$10,165	$0	$10,165
Base pricing and 10% discount rate						
BAU	$0	$40,029	$0	$5,893	$0	$45,922
MFS[b]	-$975	$41,632	-$2,059	$6,146	-$2,099	$42,645
ECO	-$1,949	$29,705	-$4,118	$6,146	-$4,198	$25,586
AGRO	$0	$42,566	$0	$2,076	$0	$44,642
ALU	$0	$0	$0	$6,146	$0	$6,146

[a] Descriptions of scenarios: 'BAU' business-as-usual, continuation of current farming and management system; 'MFS' mosaic farming systems, landscape reconfiguration to more ecologically sustainable uses that involve improved farming practices and environmental plantings; 'ECO' eco-centric, substantial increase in environmental plantings due to increasing environmental market; 'AGRO' agro-centric, increase in agriculture land due to higher demand of food and livestock production in line with the population growth; 'ALU' abandoned land use, decline in agriculture and land abandonment due to reduced water availability and depopulation in rural areas.

[b] 'Water' excludes water required for irrigation as this cost is already factored in agricultural or timber production. The negative value of water enhances the value of agriculture or timber production and is therefore treated as an ecosystem service

[c] Under MFS, agricultural production will increase by 20% with improved farming practices and efficient allocation of water.

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