Accounting for private benefits in ecological restoration planning

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Abstract: Opportunity cost constitutes a substantial component of the costs of ecological restoration projects undertaken in agricultural landscapes. Private benefits generated by restored environmental assets are also important in determining the success of restoration projects. In this study, we compare the implications of using different assumptions about private benefits and opportunity cost for the optimal spatial pattern of ecological restoration of a cleared agricultural landscape in north-central Victoria, Australia. We employ a spatially explicit bio-economic model that optimizes ecological restoration through revegetation of a cleared landscape. We compare implications of using different assumptions about opportunity cost: (a) fixed marginal opportunity costs based on property value, and (b) variable marginal opportunity costs that take into account land value and private benefits generated by environmental assets on the property. Using variable marginal opportunity costs that account for private benefits captured by the landowners gives a better biodiversity outcome than using fixed marginal opportunity cost subject to the same budget constraints. Spatial patterns of ecological restoration of these scenarios differ substantially, with ecological restoration pattern shifting towards smaller properties (lifestyle landowners) in the variable-marginal-value scenario. Our results show that in order to avoid providing misleading recommendations to environmental managers about priorities for ecological restoration on private lands, it is important to take into account amenity values to land owners of native vegetation and variable opportunity costs.

Key words: ecological restoration, biodiversity, private benefits, opportunity cost, spatial optimization

Introduction

The decline of biodiversity is of increasing concern in fragmented and degraded landscapes worldwide (Maron and Cockfield 2008). In many agricultural landscapes, where remaining native vegetation is highly fragmented, conservation strategies based on protection of large untransformed landscapes as reserves are difficult to apply. In such circumstances biodiversity loss could be reversed by rebuilding ecologically functioning landscapes (Thomson et al. 2009). When resources are limited, ecological restoration should be prioritized using systematic conservation planning (McBride et al. 2010).

Opportunity cost constitutes a substantial component of the costs of ecological restoration projects undertaken in agricultural landscapes, especially when the majority of land is privately owned. In past studies, opportunity cost in ecological restoration studies has been accounted for using property values (Westphal, Field and Possingham 2007) or capitalized values of agricultural production (Crossman and Bryan 2006). These approaches assume acquisition of land for ecological restoration projects. However, when ecological restoration is conducted on private lands without alienation, the opportunity cost could be different (lower) because the landowner retains ownership of the land and captures part of the benefits generated by the restored ecosystem, such as amenity from native vegetation. Yet, we are not aware of any study that factors private benefits into the optimization of ecological restoration. Furthermore, due to diminishing marginal value of privately captured benefits of ecosystem services, the marginal opportunity costs of landscape reconstruction will be increasing with the size of ecological restoration project. With the exception of Jantke and Schneider (2011) and Butsic, Lewis and Radeloff (2013),who model increase of opportunity cost due to land market feedbacks, no study has attempted to model variable opportunity costs.

In this study, we incorporate opportunity cost and private amenity benefits into an analysis of optimal ecological restoration of a cleared agricultural landscape in north-central Victoria, Australia. The aim of our study is twofold. First, we develop a spatially explicit model of optimal ecological restoration that in addition to ecological values and costs incorporate private amenity benefits of ecological restoration. Second, we test the importance of accounting for private benefits for the outcome of optimal ecological restoration.

Materials and Methods

Study area

Our study area is the Shire of Mount Alexander located in central part of the state of Victoria, Australia (Figure 1). It covers an area of 1,529 km^2 and, at the 2011 Census, had a population of 17,591. Nearly 17% of the Shire is public land, mostly national and state parks as well as state forests. The region has a Mediterranean climate, with hot dry summers, cool wet winters, and most rainfall being received in winter and spring. Average rainfall varies from 500 mm/year in the north-west to 1000 mm/year in the south-east. The elevation ranges between 167 m in the north-west and 744 m in eastern part of the shire. The pattern of native vegetation of the study region has been significantly modified by mining and agriculture since European settlement. Currently, about 36% is covered by native vegetation (Polyakov et al. 2013). The dominant native vegetation types are Box Ironbark Forest, Grassy Woodlands, and Grassy Dry Forest (DSE 2007). The dominant land uses are native pastures, modified pastures, crops, and vineyards, as well as lifestyle farming in close proximity to population centers.

Planning Units

Land use and land cover pattern affects both biodiversity and production outcomes (Polasky et al. 2008; Polasky et al. 2005), therefore landscape representation in the model should suit both modelling biodiversity and modelling economics of ecological restoration. In this study we consider only ecological restoration on private lands, therefore we only included agricultural and rural residential land use. We divide landscape into homogenous irregular planning units, following Polyakov et al. (2011). First, planning region was overlaid by a regular hexagonal grid with the side length of 500 m and area of a hexagon approximately 65 ha. Each hexagonal grid was divided into planning units belonging to a specific property parcel and characterized by land cover (cleared or forested) and group of pre-clearance ecological vegetation classes (EVC) (DSE 2007), all of which are forest and woodlands vegetation classes. The regular hexagonal grid represents the spatial context of the landscape. All spatial units within a hexagon are assumed to have the same relative location in the optimization model. This allows an adequate representation of habitat mix within each hexagon and reduces computational effort.

Conservation Target: Summed Probability of Occurrence

The conservation target is to restore native vegetation on private lands to maximize predicted summed probability of occurrence of 29 species of woodland-dependent birds across the landscape. The species distribution models (Polyakov et al. 2013) were developed based on the data collected by Radford and Bennett (2007). The models predict probability of occurrence of individual species on a habitat patch as a function of characteristics of actual or reconstructed landscape within 2 km of the patch. The explanatory variables in the logistic regression models are characteristics of the landscape such as weighted proportions of the groups of EVCs and densities of the woodlands. Landscape characteristics in the immediate proximity are assumed to have greater effect on suitability of habitat than the landscape characteristics further away; this is represented by applying weights proportional to the inverse of squared distance. Summed probability of occurrence (SPO) is the product of probability of occurrence of a species in the patch of vegetation and patch area summed over a landscape for all species considered for the analysis.

Revegetation Cost, Opportunity Cost, and Private Benefits

We assume that the cost of ecological restoration consist of opportunity cost of converting land from agricultural use to conservation use as well as fencing, revegetation, and management cost. For fencing, revegetation, and management cost we used standard prices used by the North Central Catchment Management Authority (CMA), which is in charge of natural resource management and conservation in study area.

Opportunity cost are modelled using results of the hedonic model of rural property values (Polyakov et al. 2014). The model uses property sales data in the local property market to measure the impact of structural, environmental, and locational characteristics on property prices. These results can be used to predict property values as well as infer households' willingness to pay for marginal changed in structural and environmental attributes. Specifically, Polyakov et al. (2014) focused on estimation of marginal value of native vegetation on rural properties and found that native vegetation has amenity value, but the marginal amenity value diminishes as proportion of native vegetation on a property increases, furthermore, amenity value of native vegetation is smaller for larger properties. These results suggest that, when taking amenity value of native vegetation into account, opportunity cost of converting land in agricultural use to native vegetation (conservation use) on the same property is variable and will increase with the increase of the area of ecological restoration. In some instances there could be no opportunity cost of ecological restoration when loss of agricultural land will be compensated by increased amenity value of native vegetation. The private-public benefit framework of Pannell (2008) suggests that there can be public cost savings from targeting conservation to areas where in addiction to public benefits (such as enhancement of biodiversity) it would create private benefits (such as amenity value to the landowner)

Optimization model

The model optimally allocates ecological restoration across the landscape by maximizing a measure of biodiversity (SPO) subject to a budget constraint. Most studies of optimal ecological restoration have used binary or integer optimization techniques such as integer linear programming (Crossman and Bryan 2006; Polasky et al. 2005) or simulated annealing (Watts et al. 2009; Westphal, Field and Possingham 2007). However, to represent ecological restoration on private lands, it is important to allow for partial ecological restoration within each planning unit. Therefore in this study we implement nonlinear programming model which is solved with GAMS/CONOPT3.

We use two alternative scenarios which has different assumptions about opportunity cost. First scenario assumes fixed opportunity cost. We predict land value for each rural property in the study area (Figure 2) and assume that opportunity cost for each property is equal to its average land value. This is an equivalent of whole property purchased for ecological restoration, or compensation for a fraction of a property converted to conservation use being proportional to a fraction of property value. Furthermore, this scenario ignores amenity value of restored native vegetation. In the second scenario, we use variable opportunity cost that takes into account amenity value of native vegetation. The model of property values is incorporated into an optimization model and estimate opportunity cost as the difference between property value before and after ecological restoration.

Results and Discussion

We maximize aggregate SPO by optimizing ecological restoration in the Shire of Mt Alexander using a range of budgets equal to AU$20, AU $40, AU $80, and AU $160 million. Table 1 presents the biodiversity outcomes and areas of optimal revegetation under a range of budgets and two opportunity cost scenarios. Figure 3 and Figure 4 show spatial pattern of optimal revegetation at AU$20 million and AU$80 million budgets, respectively. The optimal revegetation patterns allocate most of the revegetation in the neighbourhood of existing large patches of remnant vegetation (Figure 3) as reported elsewhere (Thomson et al. 2009; Westphal, Field and Possingham 2007). These patterns persist as the budget increases (Figure 4).

At the lower budgets, there are large differences in area and spatial pattern of revegetation as well as in biodiversity outcome between the fixed opportunity cost and variable opportunity cost scenarios. At the $20 million budget, variable opportunity cost scenario allows revegetating 74% more cleared land and achieve 70% greater biodiversity benefit. This is because the variable opportunity cost scenario assumes that ecological restoration creates private amenity benefits which are captured by the landowners, thus lowering opportunity cost. The optimal revegetation patterns under the three strategies converge as the biodiversity target increases.

Figure 5 A) demonstrates biodiversity outcome in a units of aggregate summed probability of occurrence per AU$1 million of expenditures under different revegetation scenarios and over a range of budgets. Average biodiversity benefit at the fixed opportunity cost scenario slightly increases at $40 million budget and slightly decreases at $80 and $160 million budgets. Average biodiversity is substantially higher at the \$20 million budget, increases at \$40 million budget, and declines almost converging with the fixed opportunity cost scenario at \$160 million budget. This suggests that at smaller budgets, optimal ecological restoration is able to utilize potential for lowering opportunity cost by accounting for private amenity benefits. However, private amenity benefits exhibit diminishing marginal value. For example, Polyakov et al. (2013) found that the proportion on native vegetation that maximizes value of a lifestyle property, which reflects maximum amenity benefits, is 40%. There is a strong ecological reason to locate ecological restoration in proximity to large patches of existing native vegetation. Further increase of the budget leads to allocation of larger amounts of ecological restoration, which do not provide additional amenity value, to the properties in the proximity of existing native vegetation. This causes an increase of opportunity cost. The same relationship is illustrated by Figure 5 B) which shows the cost of an area unit of ecological restoration under alternative scenarios and a range of budgets. Figure 5 C) shows the increase of biodiversity benefit per hectare of ecological restoration under alternative scenarios and budgets. It is slightly lower for the variable opportunity cost scenario, which is understandable because it has substantially lower opportunity cost. Under both scenarios, average biodiversity benefits per hectare of revegetation slightly declines with larger budgets because locations that gets most biodiversity benefits are used up first.

Conclusion

In this study, we compare the implications of using different assumptions about private benefits and opportunity cost on the optimal spatial pattern of ecological restoration of a cleared agricultural landscape in central Victoria, Australia. We find that optimal spatial pattern of ecological restoration as well as environmental outcomes are sensitive to the inclusion of private environmental benefits in economic analysis.

We estimate the marginal values of native vegetation (representing private amenity benefits) and the marginal values of agricultural land (representing opportunity cost) from the property sales data using a spatial hedonic model. We employ a spatially explicit bio-economic model that optimizes ecological restoration through revegetation of a cleared landscape. It incorporates detailed functions of species' responses to spatial pattern and ecological heterogeneity of existing and restored native vegetation. High-resolution spatial data allows identification of existing vegetation, including scattered, roadside and streamside woody vegetation which are small but important elements of habitat in agricultural landscapes in the study region. The model is implemented as a nonlinear programming problem, which allows partial ecological restoration of each represented spatial unit, which is important to represent ecological restoration on private lands.

We compare implications of using different assumptions about opportunity cost: (a) fixed marginal opportunity costs based on property value, and (b) variable marginal opportunity costs that take into account land value and private benefits generated by environmental assets on the property. An assumption of fixed marginal opportunity cost implies that the whole properties are being acquired from landowners as opposed to ecological restoration on a part of private property. When property is acquired from the landowner, the landowner will not capture the private benefits of ecological restoration and therefore should be fully compensated. Because the per hectare value of rural land usually decreases with the increase of property size, this also means that opportunity cost will be very high for smaller properties. An assumption of variable marginal opportunity cost reflects the fact that agricultural land exhibits a diminishing return while natural environmental assets, such as native vegetation, have diminishing marginal amenity value to landowners.

The revegetation priorities are identified as being: sites in the vicinity of existing remnants, riparian areas, and parts of the landscape with diverse vegetation types. Using variable marginal opportunity costs that account for private benefits captured by the landowners gives a better biodiversity outcome than using fixed marginal opportunity cost subject to the same budget constraints. Spatial patterns of ecological restoration of these scenarios differ substantially, with ecological restoration pattern shifted towards smaller properties (lifestyle landowners) in the variable-marginal-value scenario. This outcome is consistent with the findings of Race et al. (2010) that lifestyle landowners and part-time farmers undertake a considerable amount of work to re-vegetate and enhance native vegetation. Our results show that in order to avoid providing misleading recommendations to environmental managers, it is important to take into account amenity values of native vegetation and variable opportunity cost while prioritizing ecological restoration.

The paper will be of interest to conference delegates because it deals with an issue of high policy relevance, it focuses on the private benefits of investments that are meant to generate public benefits, and it demonstrates that the failure of past studies to accurately represent opportunity costs may have led to a loss of environmental benefits.

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Tables

Table 1. Areas and biodiversity outcome of optimal revegetation under different budgets and scenarios

Budget	Fixed opportunity cost		Variable opportunity cost	
	Area, ha	SPO improvement	Area, ha	SPO improvement
$20M	1,552	8,125	2,701	13,853
$40M	3,275	16,957	6,017	29,502
$80M	6,159	30,497	10,613	50,448
$160M	11,816	56,679	12,826	60,273

Figures

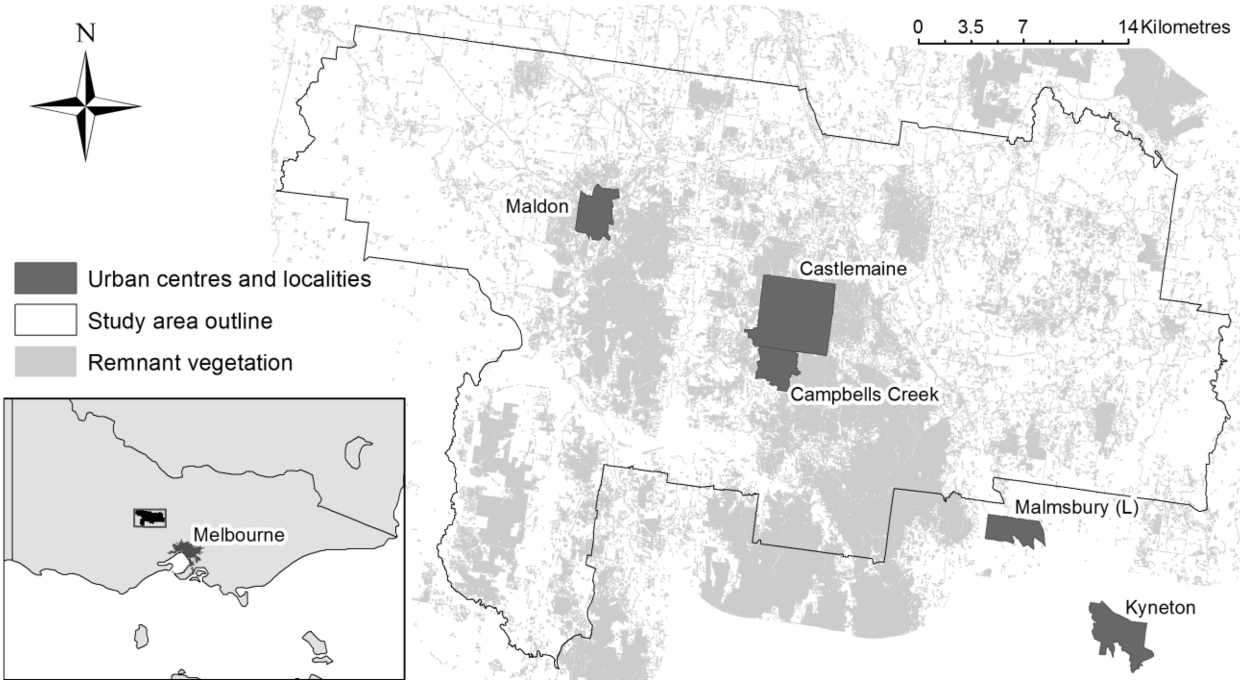

Figure 1. Study area

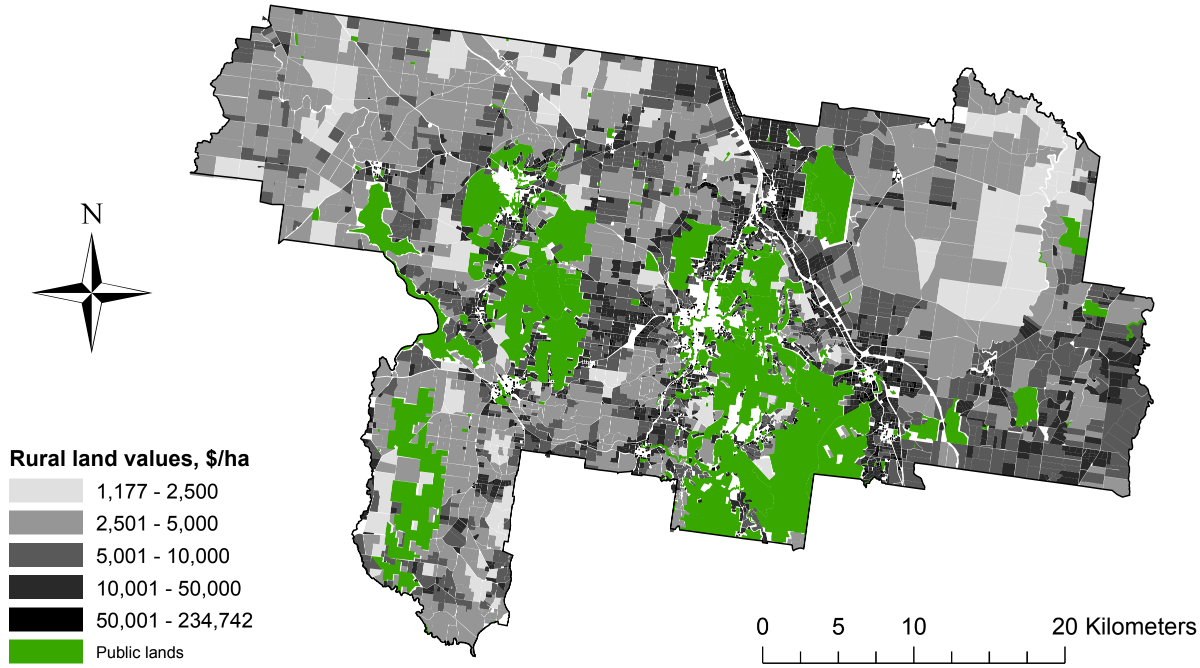

Figure 2. Predicted rural land values in Mt Alexander Shire

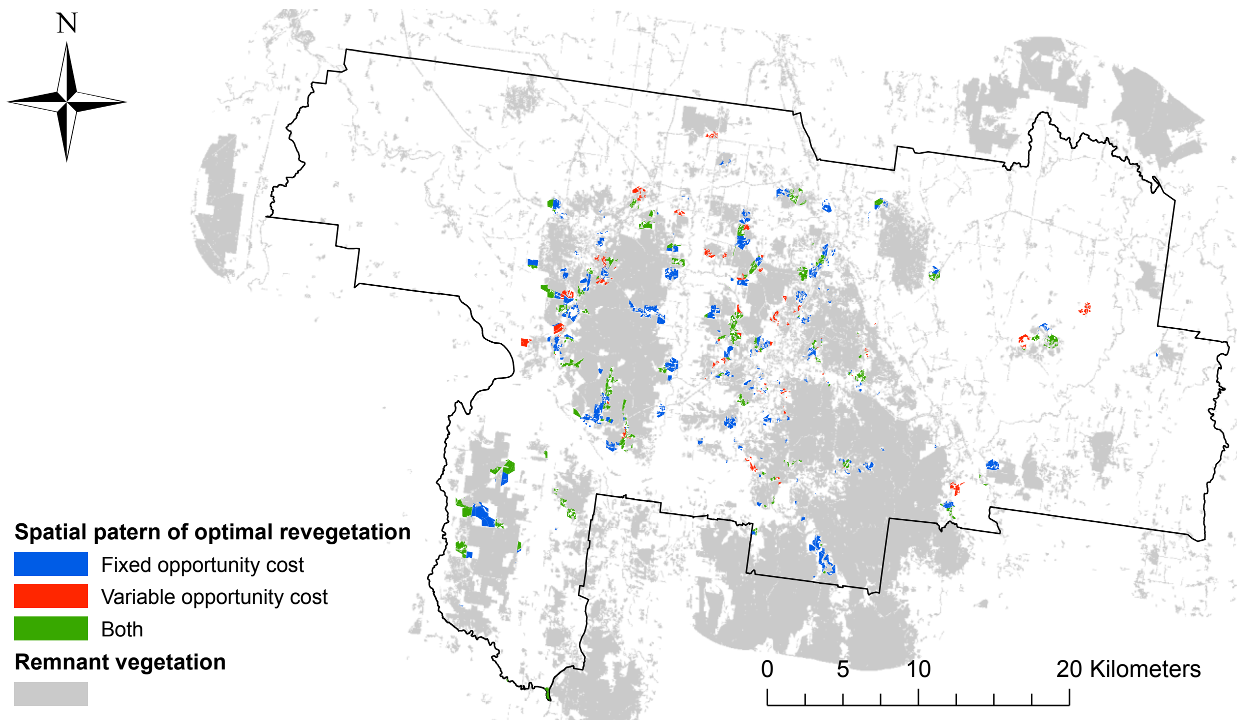

Figure 3. Optimal spatial pattern of revegetation in Mt Alexander Shire to improves aggregate summed probability of occurrence under $20M budget and alternative opportunity cost scenarios

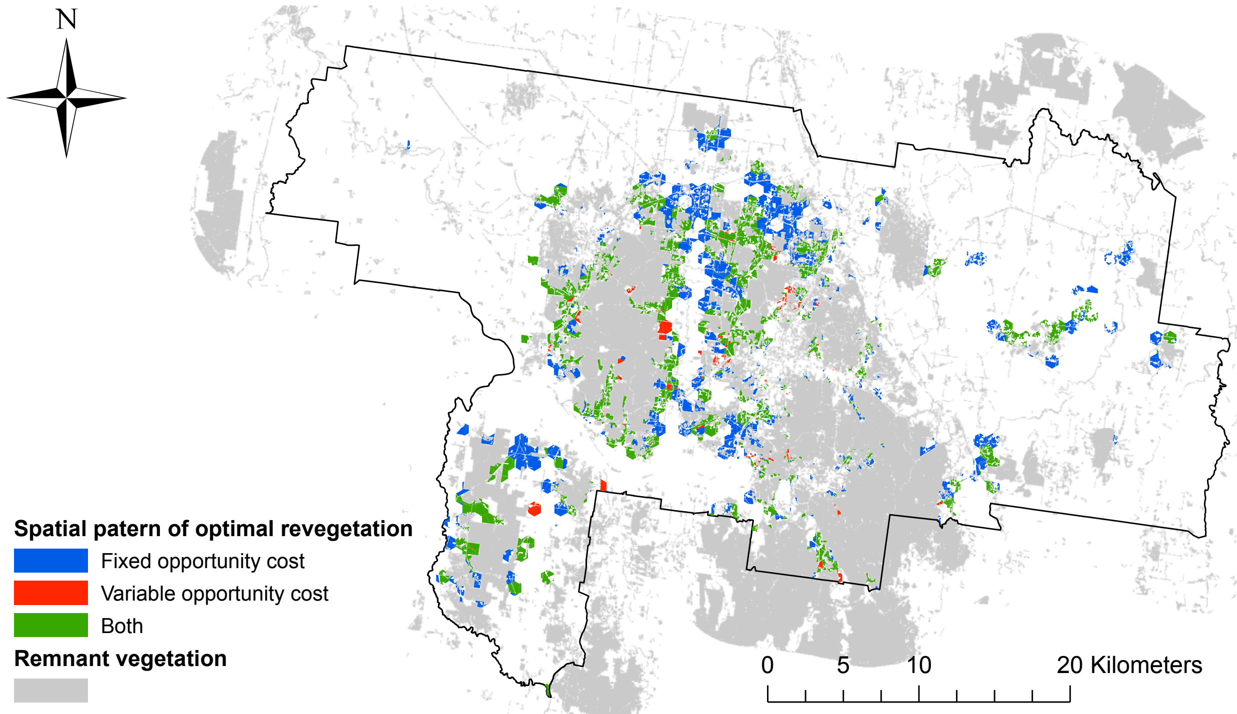

Figure 4. Optimal spatial pattern of revegetation in Mt Alexander Shire to improves aggregate summed probability of occurrence under $80M budget alternative opportunity cost scenarios

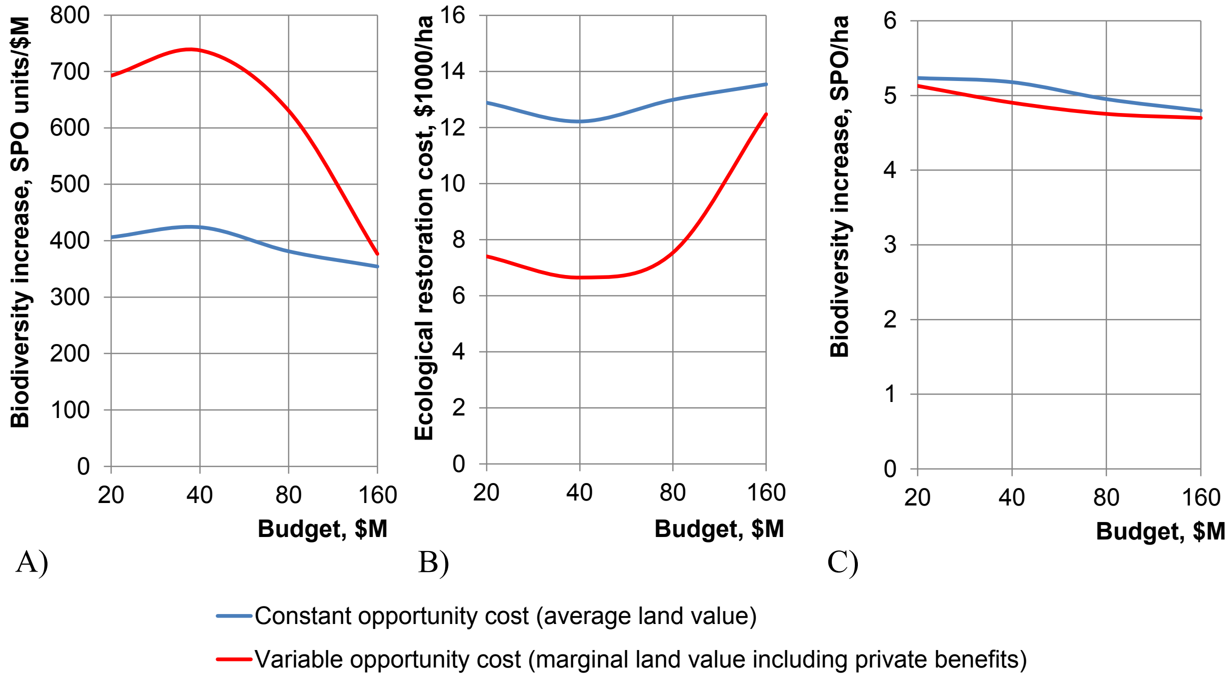

Figure 5. Comparison of ecological restoration under different budgets and two opportunity cost scenarios