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Assessing the benefits and costs of dryland forest restoration in central Chile

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ABSTRACT

Investment in natural capital restoration is increasing as a response to the widespread ecological degradation of dryland forests. However, finding efficient mechanisms to promote restoration among private landowners is a significant challenge for policy makers with limited financial resources. Furthermore, few attempts have been made to evaluate the costs and benefits of restoration interventions even though this information is relevant to orient decision making. Hence, our goal was to estimate the benefits and costs of dryland forest restoration by means of reforestation with native trees in a study area in central Chile. To determine benefits we applied a Contingent Valuation questionnaire that allowed for the calculation of willingness to pay measures. Restoration costs were calculated based on market prices following existing technical recommendations developed for the study area. The results showed that the restoration project had a negative NPV irrespective of the discount rate applied in the analysis. Thus, the NPV varied between −US$71,000 and −US$258,000. The NPV attained positive results only for negative discount rates (US$15,039 for −2%) and only when the national subsidy available for forest restoration was taken into account. This shows that landowners in Colliguay do not have incentives for carrying out restoration interventions due to a classic market failure: that in which ecosystems are mismanaged because many of their benefits are externalities from the perspective of landowners. Overall, these results stress the need for developing new compensation mechanisms and enhancing those in existence, with the aim of making restoration competitive with other land uses.

1. Introduction

Despite their global importance (Miles et al., 2006; Schimel, 2010; UNDP, 2004) dryland ecosystems are currently experiencing high rates of forest loss as a result of overexploitation and conversion of forests to other land uses (Hill et al., 2008; Millennium Ecosystem Assessment, 2005; Reynolds et al., 2007). This situation is especially pervasive in Latin America where socioeconomic problems can be severe, extreme poverty is common, and human emigration rates are often very high (Newton, 2008). For instance, Mediterranean ecosystems in central Chile −a particular type of dryland− have faced a pronounced deforestation in the last three decades: only 58% (113,605 ha) of the forest extent present in 1975 (195,773 ha) remained by 2008, representing a mean annual decline of −1.7%, one of the highest in Latin America (Schulz et al., 2010). As a response to this widespread degradation of drylands in Latin America investment in natural capital restoration has been increasing (Figueroa, 2007).

Ecological restoration is regarded as a generally effective way to increase both biodiversity and the provision of ecosystem services (Lamb and Gilmour, 2003; Rey Benayas et al., 2009). For this reason, it can now be seen as a top priority for society and a good investment in the current state of ecological overshoot (Rey Benayas et al., 2009). In developing countries, nonetheless, where poverty is concentrated and where biodiversity hotspots occur, restoration activities will only find support if they are clearly linked to sound socioeconomic research (Aronson et al., 2006). So far, few attempts have been made to evaluate the effectiveness and efficiency of restoration strategies. In a review of over 2000 restoration case studies, TEEB (2009) reports that less than 5% of them provided meaningful cost information and none assessed economic benefits. More recently, Aronson et al. (2010) reached similar conclusions through a meta-analysis of 1582 peer-reviewed papers. Cost-benefit analysis of restoration projects provides decision

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makers with information by which they can gauge the efficiency of restoration investments (Holmes et al., 2004). This is especially significant for private landowners who must balance conservation goals and economic benefits (Goldstein et al., 2008; Holl and Howarth, 2000).

In the context of landowners' incentives for carrying out restoration interventions, another issue that has been neglected in the development of strategies for restoration stems from environmental economics theory: the existence of externalities results in outcomes that are not socially optimal (Baumol and Oates, 1988; Pearce and Turner, 1990). Forest restoration produces societal benefits which far exceed those perceived by landowners who decide carrying out restoration interventions (Engel et al., 2008; Ferraro and Simpson, 2002). This problem arises because the market does not recognize these positive externalities (e.g. ecosystem services), and the landowner, therefore, has no incentive for taking into account these external benefits when deciding about land uses (Engel et al., 2008). As a result, without economic incentives seeking to internalize what would be an externality, the market failure remains and the private owners will make restoration efforts under the socially optimum level. Given that a great portion of the forest area is privately owned in Latin America, it is essential to assess the incentives that landowners have to restore their properties (Environmental Law Institute, 2003).

While social cost-benefit analysis is important to decide whether a restoration action is socially desirable, most of the time the success of a restoration project depends on a private cost-benefit analysis. Thus, the objective of our study was to estimate the net economic benefits that landowners would obtain from a restoration project aimed at recovering dryland forest ecosystem services in central Chile. Additionally, we considered the economic implications of a national subsidy recently instated which aims to restore degraded forest ecosystems. At present, the economic benefits arising from dryland forest ecosystem services restoration have been scarcely studied in Latin America (e.g. Birch et al., 2011; Rodríguez et al., 2006). In this study, we applied Contingent Valuation (CV) to analyze the economic benefits that landowners would perceive if a restoration project were implemented in Colliguay Valley, a study area that represents one of the main remnants of dryland forests in Chile. Restoration costs were estimated using market prices based on technical recommendations proposed for the study area.

2. Materials and methods

2.1. Description of the study area

The study was conducted in the Colliguay Valley (33°07′–33°14′S and 71°15′–71°00′ W, Fig. 1), which is located in the semiarid portion of the Mediterranean bioclimatic zone of central Chile (Luebert and Pliscoff, 2006; Verbist et al., 2010). Due to its great biodiversity, high degree of endemism, and critical conservation status, this region is one of the world's 34 biodiversity hotspots (Mittermeier et al., 2005), being home to approximately 2400 plant species, 23% of which are endemic (Cowling et al., 1996). Despite the rarity and global importance of Chile's Mediterranean ecosystems, less than 0.8% of them are currently protected (Lara et al., 2010). In fact, despite the fact that the Valley was declared as a protected area by the Chilean Ministry of Agriculture in 1974, and a Priority Site for Biodiversity Conservation in 2002 (CONAMA and PNUD, 2005), at present Colliguay Valley's forests are not under any kind of legal protection.

The Valley is located in the Coastal Range of the Valparaíso administrative region, covering 27,000 ha. According to Luebert and Pliscoff (2006) the Valley is located within the distribution of the sclerophyllous forest formation of the Mediterranean zone in central Chile, which can also be understood as a type of dryland forest (Fig. 1). Owing to the low accessibility to the Valley and the presence of steep slopes, the study area contains an outstanding biodiversity of dryland ecosystems that have been preserved over the last decades (Borde and Gongora, 1956; Zunino et al., 2007).

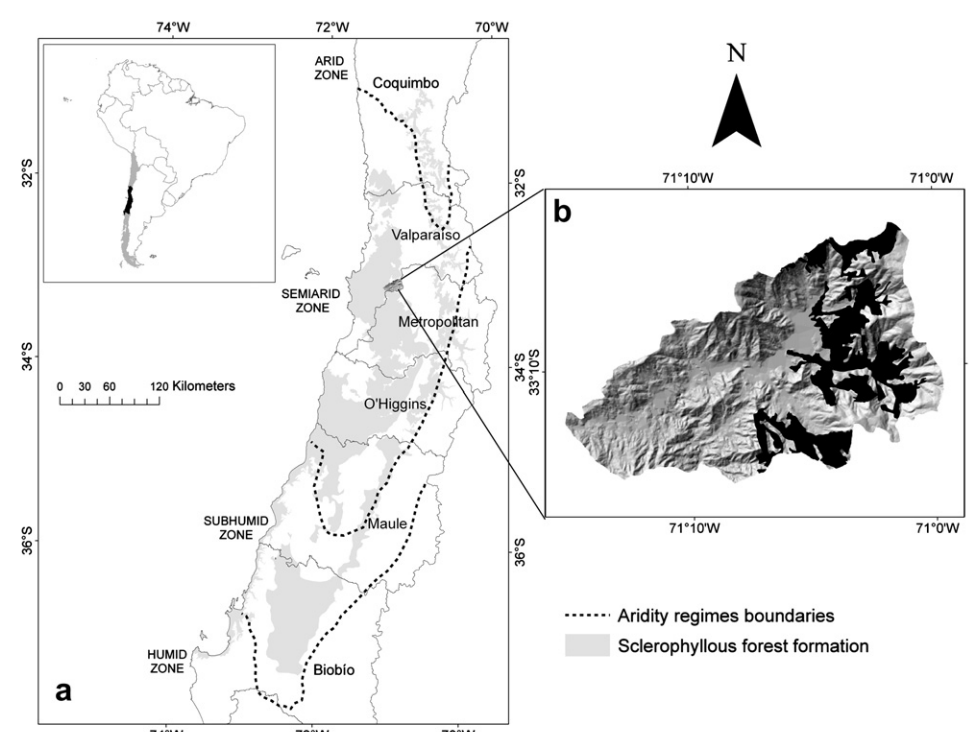

Fig. 1. Index maps. (a) Location of the study area in the Valparaíso administrative region in Central Chile; (b) Map of the Colliguay Valley depicting (in black) the area corresponding to the Priority Site for Biodiversity Conservation.

However, this biodiversity has been affected by human disturbances such as intense forest logging for fuelwood and clearcutting for agricultural expansion (Camus and Hajek, 1998). All this human-induced changes have resulted in a spatially heterogeneous mosaic of vegetation, including some xerophytic plant species. At present, the Valley contains dryland forest at different successional stages. On one hand, remnants of sclerophyllous forests can be found in drainage corridors and on steeper slopes with 75–100% of canopy cover. The forest is mainly composed of species that may reach more than 2 m of height such as *Quillaja saponaria*, *Lithrea caustica*, *Cryptocary alba*, and *Peumus boldus* (Schulz et al., 2010; Zunino et al., 2007). On the other hand, anthropogenic savanna (also known as "espinales") is the predominant vegetation type and covers most of the lower hillsides and plains (Schulz et al., 2010; Zunino et al., 2007). This type of vegetation is mainly formed by the spiny legume tree *Acacia caven*, and is the result of clearing and degradation of the sclerophyllous forest (Ovalle et al., 1996).

2.2. Estimating restoration benefits

2.2.1. Survey design and implementation

We used CV to assess the benefits that landowners would obtain from dryland forest restoration. CV is a survey-based economic technique typically used to value resources for which there is no available market data (Haab and McConnell, 2003). There are other possible methods of measuring the aggregate WTP for such changes, but the use of CV is supported by the fact that restoration interventions affect the provision of a set of ecosystem services, which include use values as well as non-use values (Loomis et al., 2000). Generally, when ecosystem services are highly correlated in their production, CV is a more appropriate approach (Bonnieux and Le Goffe, 1997; Holmes et al., 2004).

Since values elicited via CV are contingent upon the information and market context described in the CV instrument (MacMillan and Duff, 1998; Zhongmin et al., 2003), considerable effort was spent on developing a questionnaire which would allow respondents to formulate a value for the ecological restoration project. In January, 2008 a workshop was held in the Colliguay Valley which congregated over 30 people, including local landowners and public officials. On this occasion a preliminary survey was applied and a panel discussion was conducted regarding dryland forest restoration. After this, the survey was pre-tested to uncover misinterpretation of the questions and ambiguity in response categories. The final household survey was carried out in February, 2008 on a random sample of households, where 58% of the families living in the area (92 completed interviews) were surveyed. The information was gathered through in-depth personal interviews.

The first section of the survey gathered personal information about the interviewee (e.g. age, income). The second section asked about the household's productive characteristics (e.g. land tenure, forest area, farming area). The third section was devoted to forest use practices. Finally, the last section included the CV questions that allowed for the calculation of WTP as a measure of the benefits of restoring dryland forest ecosystem services in the Valley. This part was composed by (i) the portrayal of the problem (i.e. widespread degradation of the Valley's forests) and its possible consequences; (ii) description and characterization of the proposed solution (restoration project); (iii) characterization of the project (based on reforestation with native trees); (iv) expected outcomes; and (v) the question format used to elicit the respondent's true value of the restoration project.

The respondents were handed a list of the key ecosystem services that the forest provides to local people, which were: (i) control of soil erosion and reduction of sediment accumulation in the Valley's streams, (ii) water regulation for better freshwater provisioning during the summer, (iii) nectar from native species for honey production (iv) recreation and tourism opportunities, and (v) provision of non-timber forest products (e.g. medicinal plants). The means by which ecosystem services could be restored from their current status were also described. The payment mechanism proposed in the valuation scenario was a monthly payment made to the local rural water committee. The exact wording of the CV questions was as follows:

i. If a project of forest restoration like the previously described were carried out, would you participate? A) Yes____ B) No____

ii. If your prior answer was negative, what are the reasons for not participating? ______________

iii. If your answer was positive, what is the maximum amount of money that you would be willing to pay monthly for implementing this forest restoration project in your community?

Due to the low number of families in the Valley (159 households), the sample size was small. Therefore, the open-ended format was chosen because it allows for making estimates with small samples. Assuming that the responses are incentive-compatible and unbiased, the principle strength of this CV format lies in the fact that far fewer responses are required in order to achieve a given variance about the mean WTP compared to a dichotomous choice CV (Haab and McConnell, 2003). According to Boyle (2003), responses to open-ended questions result in a continuous distribution of responses in the interval$[0,+\infty)$, and, in terms of estimating central tendency, this elicitation format provides the most efficient estimates compared to other CV formats.

2.2.2. Econometric modeling

Given the censored nature of the distribution of WTP, a Tobit model was used which accounts for a limited-distribution dependent variable (Amemiya, 1984; Cho et al., 2008). The general formulation of the Tobit model is as follows:

$$\begin{aligned} y_i &= x_i'\beta + \varepsilon_i \ \text{ where} \\ y_i^* &= 0 \ \text{ if } \ y_i \le 0, \ \text{ and} \\ y_i^* &= y_i \ \ \text{if} \ \ y_i > 0, \end{aligned} \tag{1}$$

where y_i is WTP to carry out the project by household i, x is a vector of endogenous explanatory variables relevant to WTP, β is a vector of unknown parameters to be estimated and ε_i is a residual error assumed to normally be distributed with zero mean and constant variance σ^2. The final specification of the Tobit model was the following:

$$\text{WTP} = \beta_0 + \beta_1\text{INCOME} + \beta_2\text{VISION} + \beta_3\text{LAND} + \beta_4\text{JOB}, \tag{2}$$

where INCOME is the average monthly household income, VISION is a binary variable that equals one if the respondent thinks forests can be sustainably exploited, LAND is the total farm area of each respondent, and JOB equals one if the respondent has an off-farm salary and zero if not (Table 1). Tobit model parameters do not directly correspond to changes in the dependent variable brought about by changes in the covariates. Hence, marginal effects were computed.

2.3. Estimation of restoration costs

2.3.1. Prioritization of restoration areas

One fundamental issue of forest restoration is the identification of priority areas for intervention (Orsi and Geneletti, 2010). The prioritization issue is a primary topic considering the shortage of

Table 1
Variable description and sample statistics.

Variable	Description	Mean	Standard Deviation
WTP[a]	Monthly willingness to pay for the restoration project (US$)	5.14	8.48
INCOME[a]	Monthly household income (US$)	355.88	223.89
VISION	Binary variable, equal to 1 if the respondent thinks forests can be sustainably exploited and 0 otherwise	0.19	0.40
LAND	Total farm area	6.69	13.92
JOB	Binary variable equal to 1 if the respondent has an off-farm salary and 0 otherwise	0.31	0.47

[a] Chilean pesos were converted to US dollars using the 2008 exchange rate equal to $522; sample size for estimation was 83.

economic resources (Myers et al., 2000). Existing studies on forest restoration priorities (e.g. Orsi and Geneletti, 2010) suggest that ecological restoration priority is a function of (i) the need for restoration (where should forest be restored to increase the provision of ecosystem services?), and (ii) the feasibility of the restoration process (where is the recovery process likely to succeed?).

The majority of the respondents (69.6%) declared water scarcity as their main concern for the near future followed by forest overexploitation (12%). Indeed, dramatic reductions in annual precipitation have been detected in precipitation records of central Chile over the last century (Le Quesne et al., 2006). Owing to this, we designed a restoration scenario aimed at improving water regulation to ensure freshwater provision during the summer in the study area (Bennett, 2003; Ward and Trimble, 2004). The restoration scenario included the following interventions based on reforestation with native trees (see Table 2):

(i) Recovery of an 80 m wide strip of riparian vegetation along the primary water courses in the Valley. This buffer zone, covering 211 ha, excluded croplands and dense native forests; the proposed management focused only on restoring barelands and anthropogenic savannas.
(ii) Human and livestock exclusion from the buffer strip area by fencing the restoration areas, which improves the natural regeneration of native species and stabilizes the stream banks.
(iii) Reestablishment of native vegetation by multi-species planting, in which the species selected to be planted are those that showed the best results (i.e. highest survival and biomass development) in restoration field trials presented in Echeverría et al. (2010).
(iv) Three site conditions were considered for the design of the plantings in the buffer strip area: north-savanna site, south-savanna site and open site. These types of site conditions were identified using a 2008 land cover and land use map (Schulz et al. (2010). To estimate the area of each site condition ArcGIS 9.2 was used (ESRI, 2006).
(v) Finally, in each type of site plantings were designed with the multiple aim of providing not only stream protection, but also the other ecosystem services stated in the survey. Hence, the tree species selected for the restoration scenario are multipurpose.

The feasibility of the proposed interventions was based on technical recommendations generated from several restoration trials conducted in the study area (Echeverría et al., 2010).

2.3.2. Assessment of restoration costs

Unlike benefits, costs are mostly “marketed”. In this study, we focused mainly on implementation and operating costs. Since croplands were excluded from the design of the buffer strip area, we assumed zero opportunity cost for forest restoration. It could be argued that restoration would limit the opportunity for raising cattle, but during the drought season the farm households take their livestock to the Andean foothills, and during the winter the animals feed in the Valley’s hillsides. Restoration does not affect tourism activities either, because it considers maintaining the access points to the natural pools located in the Valley. Additionally, the estimated costs do not take into account property tax payments, because the land is exempt from them due to its “preferably forest aptitude” and the occurrence of native forest (Lara et al., 2010). The costs were calculated on a per hectare basis and then extrapolated to the 211 ha of the buffer strip zone. The expenses included (i) establishment costs and (ii) follow-up operational costs calculated on a per-person-per-day basis of US$15.3 (the wage rate in central Chile). Establishment costs represent the financial resources needed for the first two years of the project, while the follow-up costs are thought to be bore over the remaining 23 year period.

2.4. Cost-benefit analysis

A Cost-benefit analysis (CBA) was performed to examine whether the benefits arising from the increment in ecosystem services provision (estimated applying CV) outweigh the costs of implementing the restoration scenario in Colliguay Valley. The analysis was carried out over a policy-relevant time horizon of 25 years. The Net Present Value (NPV) of the project was estimated at a range of discount rates to explore the sensitivity of the results and discuss different implications in choosing a particular discount rate.

Table 2
Description of the three site conditions identified for a restoration scenario in Colliguay Valley.

Site conditions	Area (ha)	Features	Recommendation	Native species to be planted	Planting density (seedlings/ha)
North-Savanna site	61.5	North facing sites dominated by *Acacia caven*	To plant intermediate-shade tolerant species underneath *Acacia caven* to take advantage of its beneficial action as a nursery species (Echeverría et al., 2010; Ovalle et al., 1999)	*Quillaja saponaria*, *Schinus latifolius*	250
South-Savanna site	81.0	South facing sites dominated by *Acacia caven* and shrub species	To plant shade tolerant species underneath *Acacia caven* (Ovalle et al., 1999; Echeverría et al., 2010)	*Beilschmiedia miersii*, *Peumus boldus*, *Cryptocaria alba*	200
Open site	68.5	Sites corresponding to barelands	To create restoration nucleus by planting pioneer species (Lamb and Gilmour, 2003; Rey Benayas et al., 2008)	*Acacia Caven*, *Baccharis linearis*	300

The analysis included the economic implications for landowners of the subsidy stated in the Recovery of Native Forest and Forestry Promotion Law (RNF) passed in 2008. This recently enacted law introduces economic incentives for native forest restoration, funding activities that favor its regeneration, recovery or protection, such as the cost of planting, seeding, and fencing. The RNF establishes a bonus of up to 5 UTM (Monthly Tax Units)[1] per hectare plus an additional 15% coverage if restoration actions are undertaken on smallholding farms.

2.5. Sample description: characteristics of the interviewees

About 68% of the people interviewed were more than 46 years old and a similar percentage (65.2%) had lived all their lives in Colliguay Valley. Only about 2% of the respondents were less than 25 years old. Half of the respondents declared to have only completed elementary education (up to 8 years of formal education in Chile) whereas 8% had no kind of formal studies. Monthly income of the surveyed households fluctuated between US$239 to US$431 and came mainly from off-farm activities (38.9%), and subsidies and pensions (29.4%). Agrosilvipastoral activities with the highest contribution to family income were cattle raising (10%) and selling of forest products (6.7%). According to the Family Budget Survey (INE, 2008), the majority of the Valley's families lie within the first and second quintiles of the income distribution (i.e. the poorest ranges). The average farm size was 9.5 ha, ranging from 0.05 to 200 ha; 76% of the surveyed households had land parcels smaller than 5 ha, with the most frequent farm size being 1 ha. Household land tenure is fragmented and holdings undergo constant division because of demographic pressure and inheritance practices.

3. Results

3.1. Econometric model analysis, benefit estimation and restoration costs

Results revealed that several household-level variables were not significant in explaining landowners' WTP and therefore a limited number of variables were selected for their inclusion in the final statistical model (see equation (1) and Table 3). The variables VISION and LAND were positive and significant at the 1% level, whereas household INCOME and JOB were also positive but significant at the 5% level, indicating that WTP increases with all the observed variables (Table 3). The marginal effect coefficient of INCOME suggests that increasing annual income by US$100 would increase WTP for restoration by US$0.9, while having an off-farm salary (JOB) positively affected WTP with a marginal effect of US$3.4. The fact that respondents with larger incomes are willing to pay more supports the notion that ecosystem services are normal goods (Cho et al., 2008). Regarding the variable LAND, respondents that held larger properties were likely to pay more as they feel they have a higher chance of receiving the restoration project's benefits.

At the sample mean of the explanatory variables the conditional expected value of monthly household WTP was US$5.5. This implies that each household would pay an average of US$66 per year for the restoration project. Multiplying the mean annual WTP by the Valley's population, the annual aggregate benefits of restoring forest ecosystem services in Colliguay was US$10,534. Although the annual WTP per household reflects a high value for restoration, the aggregate value is modest due to the low number of families in the Valley.

[1] The average UTM for the year 2008 equals $35,770 Chilean pesos, which in turn equals $68.8 US dollars.

Table 3
Estimation results of the Tobit regression model.

Variable	Regression coefficient	Marginal effect	T −Statistic
Constant	−4.0546	−2.8488	−2.34**
INCOME	0.0094	0.0066	2.33**
VISION	7.4171	5.2113	3.25*
LAND	0.2749	0.1931	4.16*
JOB	4.7862	3.3629	2.46**
σ	7.6575	–	11.47*

*Statistically significant at 1% level, **statistically significant at 5% level. Log likelihood function: −246.168.

On the other hand, the restoration scenario involved a range of costs such as planting, nurturing, and fencing. In the first year of the project, the main expenditure corresponded to the purchase of materials, which represent around one third of the total costs. The other two thirds of the costs are distributed among the expenditures in seedlings and labor, respectively. The average establishment costs during the first year of the project reached US$1442 per hectare for the three site conditions distributed in labor expenses (US$398), materials (US$571), and seedling acquisition (US$473). The establishment costs in each site differed due to the different planting densities (see Table 2) and prices of the native species seedlings used. The costs for the second year were mainly related to the replacement of dead plants, and were estimated according to the survival rates obtained from previous restoration field trials (Echeverría et al., 2010). The total value of establishment costs (first two years of the project) is US$368,389 for the 211 ha. Follow-up operating costs (for the other 23 years of the project) only explain a small fraction of the total costs of the project, with a mean amount of US$1414 per hectare. This cost distribution is consistent with other published cost estimates (Currie et al., 2009; Goldstein et al., 2008).

3.2. Net present value of the restoration project

Fig. 2 shows the flow of benefits and costs under different discount rates with and without subsidy. Irrespective of the discount rate considered in the CBA performed without the subsidy, the restoration project does not show a positive result. The NPV varied between approximately −US$71,000 and −US$271,000, using −2 and 10% discount rates, respectively. Under these conditions, the restoration project does not meet the economic efficiency criteria.

For the scenario that takes into account the available subsidy, the results differ slightly. Financial assistance provided through the

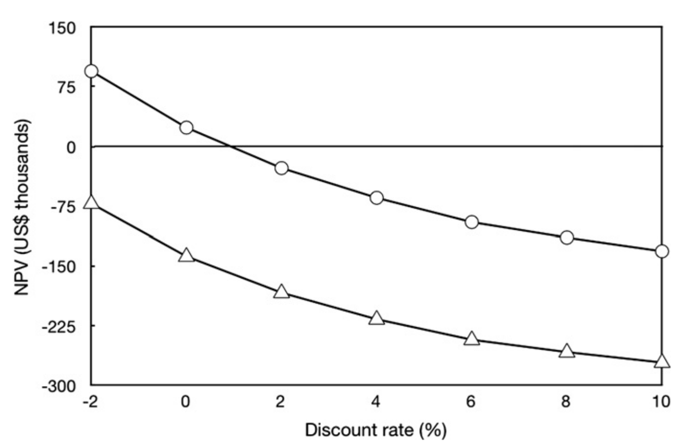

Fig. 2. NPV of the dryland forest restoration in Colliguay Valley, Central Chile, using discount rates from −2% to 10%. The scenarios were NPV estimated without subsidy (open triangles), and NPV with subsidy (open circles).

RNF would cover mainly establishment costs, raising to some extent the benefits perceived by the landowners. In the case of the north-savanna site, the subsidy funding reaches US$24,325, and for the south-savanna and open sites, the funding reaches US$32,038 and US$27,099, respectively. Thus, in this scenario the NPV attained was only positive for negative discount rates (US$15,039 for −2%), while the result remains negative for the other applied rates. This variation in the result raises the question about the selection of a discount rate when making decisions about private and public investments.

4. Discussion

4.1. Incentives for forest restoration in central Chile

Not surprisingly, the scenario without subsidy showed that landowners in Colliguay do not have incentives for carrying out restoration interventions, since the economic benefits that they perceive from the proposed project do not outweigh the restoration costs. In fact, the negative NPV of the restoration project empirically shows one of the classical results of environmental economics: when externalities are not internalized by the economic agent (i.e. landowner), the socially optimum level of services provision does not coincide with the private optimum (Baumol and Oates, 1988; Pearce and Turner, 1990). In this case, the economic value estimated through WTP reflects only the landowners' benefits arising from forest restoration. However, it is well documented that forest restoration produces benefits for society as a whole, which far exceed the benefits perceived by landowners (Engel et al., 2008; Ferraro and Simpson, 2002). For instance, restoration can generate benefits for downstream populations who would receive the benefits of improved water quality, and also for the global community because of an increase in carbon storage. Additionally, the Valley's numerous visitors would benefit from the landscape's increased aesthetic value. Therefore, the social benefits arising from ecosystem service restoration are far greater than private benefits, but, when making decisions, landowners do not consider the benefits which they are unable perceive.

Thus, if the market is left to itself, the landowner, whose activity positively affects other's utility levels, will not receive compensation for this activity, and, consequently, will not carry out restoration interventions at the socially desirable level (Baumol and Oates, 1988). In fact, this market failure determines to some extent the current situation in the Valley (and in most of central Chile): while native forests have been reduced by 1907 ha from 1976 to 2008, barelands and anthropogenic savannas have increased by 1418 and 1517 ha, respectively, during the same period (Schulz et al., 2010). In synthesis, the Valley's forest ecosystem is being depleted, and landowners clearly do not have incentives for its conservation and even less for its restoration. They receive more benefits from overgrazing, firewood collection and charcoal production, than alternative land uses such as forest restoration.

Recognizing that forest ecosystems' depletion is much greater than socially optimal, the Chilean State established RNF subsidy to encourage restoration interventions (Lara et al., 2010). This subsidy seeks to internalize that which would otherwise be an externality, helping to make ecological restoration a more attractive option for landowners. Considering this subsidy, landowners would have incentives for carrying out forest restoration, but only at negative discount rates (−2%). In spite of there are worthy justifications for applying negative discount rates from a public point of view (see Blignaut and Aronson, 2008; Rees et al., 2007), it is important to knowledge that rural communities often have high discount rates well over 10% and up to 30% or 40%, reflecting their urgent need to address subsistence today rather than in the future (Poulos and Whittington, 2000). Therefore, as it is currently defined, the subsidy is not enough to make restoration competitive with alternative land uses that show greater rates of returns (e.g. firewood extraction).

Overall, these results stress the need for developing new compensation mechanisms, with the aim of encouraging landowners to engage in forest restoration practices. In this context, the main issue that must be considered is when it is worth it for a landowner to restore as opposed to other alternative land uses. That is, it is necessary to consider landowner's opportunity costs (i.e. the best alternative forgone) when designing restoration incentives. Therefore, there is a major challenge in designing policies for restoration since these initiatives have to compete with alternative land uses that show much greater return rates; clearly, the landowner will not decide to invest in a project which is profitable only at a rate of −2%. In other words, it will only be possible to induce a land use change (e.g. from overgrazing to ecological restoration) when expected returns are greater than or equal to the best alternative discarded.

However, it is important to recall that landowners' decisions about restoration depend not purely on economic variables, but also on their attitudes and beliefs. Therefore, it is possible that landowners who highly value the environment could be willing to restore it while sacrificing greater return rates. We do not know how much more (in terms of return rates) a landowner who highly values the environment would be willing to pay as an additional cost for the environmental benefits he would perceive. But, considering that with the current subsidy the NPV was positive only with negative discount rates, it is very unlikely that the landowner would be willing to sacrifice much higher return rates. Again, this consideration stresses the need to improve the subsidy stated in the RNF.

4.2. Challenges and policy recommendations for forest ecosystem restoration in central Chile

In the case at hand, the combination of (i) lack of effective economic incentives for landowners to carry out restoration (as we discussed above), (ii) high cost of forest restoration, and (iii) the fact that most goods and services derived from ecological functions do not provide direct revenues to forest owners because they are currently non-market services, negatively affects dryland forest restoration (Merlo and Croitoru, 2005).

In relation to (i), making restoration economically attractive remains an important goal in order to expand restoration projects, particularly on private lands (Goldstein et al., 2008; Milton et al., 2003). In this context, it is illustrative to compare the establishment costs of the restoration scenario with the funds given to landowners who implement restoration interventions. In the case of north-savanna, south-savanna and open sites, the subsidy established in the RNF only offsets 24%, 25% and 19% of these establishment costs. These proportions contrast with the incentives stated in the *facto* policy that has been applied since 1974 with the establishment of Decree Law 701 (DL 701), which provides subsidies for forestation, creating a rapid expansion of exotic plantations (Lara and Veblen, 1993). The DL 701 funds 75% of establishment expenses while landowners only have to provide the other 25%. While the subsidies given under DL 701 permit plantations of native species, it can be estimated that less than 5% of these subsidies have been used for this purpose due to a market and industry dominated by exotic species (Lara et al., 2010). From the prior comparisons it becomes even more apparent that the financial funding established in the RNF will not be enough to promote forest restoration on a broad scale. Moreover, the low subsidy level stated in RNF could lead to wasting public funds on restoration interventions on lands of lower profitability (i.e. with low opportunity cost) that would have been conserved anyway, as has occurred in other experiences (Sánchez-Azofeifa et al., 2007).

Regarding (ii), it is generally recognized that the costs involved in ecological restoration are extremely high, imposing further restrictions on carrying out restoration interventions (Currie et al., 2009; Holl and Howarth, 2000; Lamb and Gilmour, 2003). Particularly, this study shows that restoration costs are of significant magnitude even at limited spatial scales (i.e. watershed). These results are consistent with Birch et al. (2011) and Currie et al. (2009), which found that restoration interventions considering reforestation and more comprehensive approaches were not cost-effective. These findings bring about the need to carefully consider restoration actions. Although reforesting with native trees may be more desirable because it is more likely to promote the increase of ecosystem services in a shorter period of time than other restoration methods (i.e. natural regeneration), it may not be economically feasible.

In this sense, we recommend the application of a mixed strategy combining reforestation with native trees and assisted natural regeneration (i.e. fenced degraded areas). As long as the latter relies more on the forest's capacity to naturally recover, this approach assumes the use of less input for its implementation, which, in turn, means lower costs than other approaches (Chazdon, 2008; Lamb and Gilmour, 2003). For instance, according to our data, assisted natural regeneration for the Colliguay Valley would cost less than half the cost of reforesting with native trees. Natural regeneration, therefore, could be more useful to meet the economic efficiency criteria in certain situations and scales of interventions. Promising results on the natural regeneration capacity of Mediterranean forests have been reported for central Chile (Gutiérrez et al., 2007). Therefore, restoration strategies such as reforesting with native trees should focus on more degraded areas where the natural regeneration can be slow even after the removal of further disturbances (Lamb and Gilmour, 2003; Ovalle et al., 1996).

Regarding (iii), there is a need to identify financial pathways by combining multiple, compatible income sources in order to create a "menu" of options that can meet landowners' diverse land management and financial goals (Goldstein et al., 2006, 2008; Milton et al., 2003). One promising business strategy for dryland forest restoration in central Chile is the development of sustainable productive systems based on *Quillaja saponaria* (Quillay). Besides the positive results that it has shown in field trials, Quillay shows a great commercial potential based on the production of *saponinas*, a substance used for many purposes, such as its ability to activate the immunological response of vaccines (Echeverría et al., 2010; Lara et al., 2010). Central Chile is the sole world supplier of this valuable substance. One important advantage of Quillay is the relatively short period of time (10 years) that it needs to reach merchantable size in comparison to some alternatives (30–50 years in the case of *Acacia koa*) discussed in the literature (see Goldstein et al., 2006, 2008). Thus, in synergy with the economic incentives stated in the RNF, the economic benefits of tree-planting schemes based on Quillay could be substantial for protecting forests by increasing the return rates of restoration projects.

In the previous context, one step forward is the creation of new markets for natural capital restoration (Pejchar et al., 2007). Payments for Environmental Services (PES) have precisely attracted increasing interest as a mechanism that can translate external, non-market values of the environment into real financial incentives for landowners to provide such services (Engel et al., 2008). Future policy efforts in Chile should focus on developing PES programs on a large scale; to date, no PES have been implemented in Chile. However, this mechanism could be favorable due to predominately well-defined (private) property rights. Finally, another potential mechanism is the implementation of REDD-Plus programs, which could be used to provide incentives for forest restoration (Sasaki and Yoshimoto, 2010). Recent studies have shown the global importance of dryland forests in terms of carbon sequestration (Rotenberg and Yakir, 2010). Yet, to implement these alternatives properly, it is crucial to extend the application of existing valuation methods in order to obtain comprehensive measures of both market and non-marketed values, and conduct biophysical studies for the quantification of ecosystem services provided by dryland forest ecosystems in central Chile.

5. Conclusions

This work represents one of the first attempts to value ecological restoration of dryland forest ecosystem services in Latin America. Our main objective, estimating the net benefits that local people obtain from dryland forest restoration, was accomplished. The results showed that landowners in the study area do not have incentives for carrying out forest ecosystem services restoration, even when considering the available subsidy for restoration interventions. Thus, the subsidy stated in the RNF is simply not enough to make a change in the economic behavior of landowners. These results stress the need for developing new compensation mechanisms, enhancing those in existence, and creating new markets for natural capital that encourage landowners to engage in forest restoration practices.

If we want to implement effective incentives for dryland forest ecosystem restoration, it is necessary to radically change the current system of economic incentives, which includes environmentally harmful subsidies such as Decree Law 701. The development of public policies regarding forest restoration has to consider increasing the profitability of the restoration interventions. Therefore, future research should focus on identifying: (i) ecological restoration approaches based on species of economic value that will generate the greatest financial revenues; (ii) the subsidy level that will make restoration competitive with other land uses; and (iii) how much value landowners assign to their environmental preferences; in other words, how much are they willing to sacrifice in terms of return rates for carrying out a restoration project.

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