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Patterns of ecosystem services supply across farm properties: Implications for ecosystem services-based policy incentives

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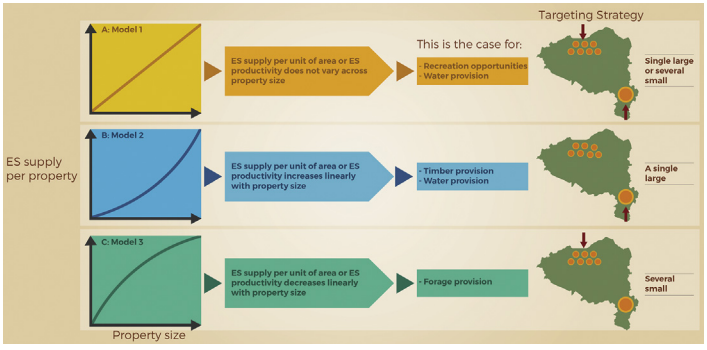
HIGHLIGHTS

- We tested three models of ecosystem service supply-farm area relationships.
- Farm size influenced forage and timber supply more clearly than recreation and water.
- Larger farms were more effective in providing timber.
- Small farms were more effective in providing forage.
- Large and small farms were equality effective in providing recreation opportunities.

GRAPHICAL ABSTRACT



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ABSTRACT

In developing countries, the protection of biodiversity and ecosystem services (ES) rests on the hands of millions of small landowners that coexist with large properties, in a reality of highly unequal land distribution. Guiding the effective allocation of ES-based incentives in such contexts requires researchers and practitioners to tackle a largely overlooked question: for a given targeted area, will single large farms or several small ones provide the most ES supply? The answer to this question has important implications for conservation planning and rural development alike, which transcend efficiency to involve equity issues. We address this question by proposing and testing ES supply-area relations (ESSARs) around three basic hypothesized models, characterized by constant (model 1), increasing (model 2), and decreasing increments (model 3) of ES supply per unit of area or ES "productivity". Data to explore ESSARs came from 3384 private landholdings located in southern Chile ranging from 0.5 ha to over 30,000 ha and indicators of four ES (forage, timber, recreation opportunities, and water supply). Forage provision best fit model 3, which suggests that targeting several small farms to provide this ES should be a preferred choice, as compared to a single large farm. Timber provision best fit model 2, suggesting that in this case targeting a single large farm would be a more effective choice. Recreation opportunities best fit model 1, which indicates that several small or a single large farm of a comparable size would be equally effective

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in delivering this ES. Water provision fit model 1 or model 2 depending on the study site. The results corroborate that ES provision is not independent from property area and therefore understanding ESSARs is a necessary condition for setting conservation incentives that are both efficient (deliver the highest conservation outcome at the least cost) and fair for landowners.

1. Introduction

Around the world, there is increasing recognition that ecosystems in working landscapes deliver ecosystem services (ES henceforth) of enormous value (Kubiszewski et al., 2017). The challenge is to turn this recognition into incentives and institutions that guaranty their protection (Costanza et al., 2017; Daily and Matson, 2008). Institutions (i.e. property rights) along with the features of ES, frame the policy context for the design and implementation of policy incentives for the private and public provision of ES (Guerry et al., 2015). For example, cautiously designed policies, such as payments for ecosystem services (PES), can motivate potential ES suppliers to maintain and enhance ES provision. However, in the context of private lands, guiding the allocation of such payments requires ES researchers and practitioners to address a largely ignored question: for a given targeted area will a single large farm or several small ones provide the most ES supply? The answer to this question has significant connotations for incentive design and allocation, which involve both efficiency and distributional issues.

The allocation ES-based incentives on private lands including agri-environmental schemes has trusted scarcely on the knowledge of ES supply across properties (De Lima et al., 2017; Ferraro et al., 2015; Stoeckli et al., 2017). In absence of this knowledge, the measurement of the efficiency of payments has had to rely on imperfect proxies of ES provision such as avoided deforestation (Ferraro et al., 2015), which impairs the possibility of evaluating the true environmental benefits of payment mechanisms (De Lima et al., 2017). Furthermore, in view of the lack of this information, an increasing number of PES contracts have started to target medium to large properties (Alix-Garcia and Wolff, 2014; Arriagada et al., 2012), which has led to significant critiques on equity and environmental justice grounds (He and Sikor, 2015; Sikor, 2013).

The discussion is particularly relevant in developing countries, keepers of the most threatened biodiversity (Butchart et al., 2015; Montesino Pouzols et al., 2014) and ES worldwide (Turner et al., 2007) and where ES protection rests largely on individual landowners, outside public protected areas or community owned lands and forests (Villamagna et al., 2015). Moreover, most landscapes have been modified by agricultural activities and most natural, unmanaged ecosystems sit in a matrix of agricultural land uses (Power, 2010).

Private lands in these working landscapes comprise millions of individual small landowners that coexist with large operations, in a reality of highly unequal asset distribution that perpetuates and exacerbates inequity and poverty (De Ferranti et al., 2004; OXFAM, 2016; Rodríguez-Pose and Hardy, 2015).

Particularly, Latin America is the world's most unequal region in terms of land distribution. The Gini coefficient for land—an indicator of between 0 and 1, where 1 represents the maximum inequality—is 0.79 for the region as a whole, 0.85 in South America and 0.75 in Central America. These figures indicate much higher levels of land concentration than in Europe (0.57), Africa (0.56) or Asia (0.55). Within Latin America, Chile occupies the second place (after Paraguay) with a Gini coefficient for land of 0.91 (OXFAM, 2016).

In such contexts, land use, biodiversity and ES provision are expected to be highly dependent on property size for several reasons (Coomes et al., 2016; Richards and VanWey, 2015). Small landowners may differ from large owners in their access to credits for replacing native forests by cash crops, or their need for firewood and forage, their interest on and capacity for sustaining non-agricultural land uses (e.g., eco-tourism) (Plieninger et al., 2012), and their access to markets and resource stocks (Miteva et al., 2017). Therefore, different variation patterns of ES supply per unit of area or "ES productivity" can be expected according to ES types and property sizes.

Undeniably, the lack of complete, high-resolution, updated spatial information to obtain ES indicators is a primary restriction to the development of conservation planning assessments in developing countries, including the design of ES-based incentive mechanisms (De Lima et al., 2017). Furthermore, the monitoring of ES at the farm level is not without challenges, ones that are much larger than observing forest cover across time (Cord et al., 2017; Maes et al., 2016).

We address the question of ES supply distribution across farms by proposing and exploring ES supply-area relationships (ESSARs hereafter) around three basic hypothesized models, characterized by constant (model 1), increasing (model 2), and decreasing increments (model 3) of ES supply per unit of area (or ES "productivity"). Model 1 supports the equal effectiveness of targeting a single large or several small properties of the same area in order to ensure an ES supply goal. Model 2 advocates for the greater effectiveness of a single large property instead of several small ones. Model 3 supports the selection of several small properties over a large one. We assert that understanding ESSARs is a necessary condition for setting conservation payments that are both efficient (deliver the highest conservation outcome at the least cost) and fair for landowners.

We are not aware of any research that has set to explore such relations and hence our results provide novel insights into the challenges of mainstreaming ES in decision making in working landscapes with asymmetrical distribution of property sizes.

2. Methods

2.1. Study sites

The two study areas chosen for this inquiry exemplify the distinctive unequal distribution of land that has positioned Latin America as the most unequal region of the world (ECLAC et al., 2015). Ancud municipality, Inner Sea of Chiloé Island (41°50′–42°15′S and 73°15′–74°15′W), is located in the province of Chiloé in Los Lagos Region, southern Chile (Appendix S1). It covers a territory of 1724 km^2 of which <1% is classified as urban. According to the last census of 2002, of the total population (39,946 people) 31.7% is rural (INE, 2003).

Forest degradation has been reported to be a drastic process in Ancud, having as its main immediate cause the unsustainable timber extraction to supply the firewood demand of nearby municipalities (Carmona et al., 2010). Small properties (conventionally those with <60 ha) represent 83.8% of total, whereas medium (60–999 ha) and large properties (>1000 ha) account for 15.7% and 0.5% respectively.

Panguipulli municipality (38°30′–40°5′S and 71°35′–72°35′W) is located in the Andes Range of Los Ríos Region, southern Chile (Appendix S1). It has an area of 3292 km^2 of which <0.5% is classified as urban. The municipality has a total population of 33,273 people, of which 52.2% is considered rural and 25.3% belongs to an indigenous group (Nahuelhual et al., 2016). Forest degradation and exotic tree plantation expansion on previously forested land or pastures, are reported as the main land use changes (Reyes et al., 2016). Small properties represent