



Simulating land use changes under alternative policy scenarios for conservation of native forests in south-central Chile



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ABSTRACT

In this study, we combined policy analysis with landscape change modeling to simulate outcomes of alternative forest conservation instruments proposed by opposing policy coalitions. In 1992, concern over rapid land conversion to timber plantations (*Pinus radiata* and *Eucalyptus* spp.) in Chile gave rise to a protracted policy process resulting in the 2008 Native Forest Law (NFL), which subsidizes reforestation and management with native forest. To date, however, NFL has had little impact on native forest conservation. To understand how the policy process that created the NFL shaped its outcomes, we employed the Dyna-CLUE modeling approach to simulate land use changes in south-central Chile from 1993 to 2007, based on 3 scenarios: (1) enactment of NFL in 1993 when the law was originally debated, and the different configurations of subsidies and regulations proposed in the NFL policy debate by (2) the industrial forestry coalition and (3) the forest conservation coalition. We observed no major difference in native forest loss between simulated outcomes of the industry-advocated policy and the actual NFL legislation. The conservation coalition's policy scenario increased native forest area, primarily in shrub steppe areas, but also via conversion of pine plantations if incentive payments were large enough. However, NFL payments are inadequate to make native forest management a viable economic land use alternative to industrial pine plantations, which are also subsidized in Chile. Gains in native forest cover occurred mostly on lands under ancestral indigenous claims (unrelated to the discussion of the NFL). We conclude that the NFL, even if enacted in 1993, would have been ineffective in preventing native forest loss, because tree plantations are more profitable and NFL regulations were weakened by the industrial coalition that opposed—and strongly shaped—the final legislation. Effective incentives for protecting early-successional forests and shrublands are needed to mitigate further losses and foster recovery of Chile's native forests.

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1. Introduction

Efforts to conserve global forest cover seek to sustain the ecosystem benefits of forests that support human well-being at local, regional and global scales (Bonan, 2008; Foley et al., 2005). Land use change, specifically the large scale conversion of forest lands to agricultural, pastoral and industrial uses, remains an ongoing challenge for global conservation efforts. Countries such as Brazil and Indonesia that have the most extensive, productive and diverse forests also have rapidly growing exports of commodities such as wood pulp, soy, beef, biofuels and palm oil (FAO, 2014). For non-industrialized open economies, the potential profits of commodity

production create a high opportunity cost for landowners in forest protection programs, which poses a fundamental challenge for large-scale forest conservation efforts (Verburg et al., 2014).

According to marginal economic theory if a good provides social benefits that are not captured in market transactions, incentive-based mechanisms can be used to realign the collective and individual well-being (Horne, 2006; Keipi, 1997; Kremen et al., 2000). Therefore if society needs more forest, then it should provide incentives to landowners to conserve and manage existing forests and to establish new forests (Perman et al., 1996). However, in most cases the effectiveness of those incentives will depend on the opportunity cost that the landowner faces, i.e., if alternatives to forest conservation include land use(s) that generate large profits or other direct benefits. Policy instruments must compensate this opportunity cost to influence the decision of the land owner, and at a larger scale, reduce or reverse trends in forest land conversion (Horne, 2006; Kremen et al., 2000). Nevertheless, not all

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land owners will seek to minimize opportunity costs, but rather will prioritize the generation of stable income from their land, as is often the case with small private land owners (Catalán et al., 2006). In that case, the incentive to promote and conserve native forest should be at least enough to cover the cost of sustainable management practices as means to prevent forest degradation.

Chile is a leading country in forest exports, in large part because plantations of *Pinus radiata* (Monterey pine) can provide one of the highest return on investments worldwide (Cubbage et al., 2007; Sedjo, 1983). The Chilean government has subsidized timber plantations since 1974 to foster economic growth and address severe erosion resulting from land degradation due to agriculture and overgrazing. Despite the fact that the highest rates of deforestation happened in past century (Lara et al., 2012), several studies have shown that in Chile deforestation, forest degradation and native forest replacement by timber plantations remains an ongoing trend (Aguayo et al., 2009; Altamirano and Lara, 2010; Echeverria et al., 2006; Miranda et al., 2015; Nahuelhual et al., 2012; Schulz et al., 2010; Zamorano-Elgueta et al., 2015). For example, a literature review for 9 case studies in south and central Chile conducted by Miranda et al. (personal communication), found that the annual deforestation rate between 1970 and 1990 was 2.9%, which decreased to 1.6% between 1990 and 2000, but then increased to 2.4% between 2000 and 2010. Miranda et al. (personal communication) found that most of the forest loss involves conversion to shrub/scrub vegetation. However, since 1990, exotic tree plantations have become the second most common land use replacing native forest, displacing agriculture as the second most prevalent cause of forest loss. The ongoing trend of forest loss and change resulting from the expansion of timber plantations is considered the foremost threat to biodiversity in Chile (Echeverria et al., 2006; Rojas et al., 2013). Although intensively managed stands of the exotic *Pinus* and *Eucalyptus* are highly profitable, they are less biologically diverse (Braun, 2015) and do not provide the same ecosystem benefits that native forest can provide (Lara et al., 2009; Little et al., 2009).

Out of concern over rapid land conversion to plantations and loss of native forest, in the 1980s conservation advocates and scholars proposed a new policy to conserve and manage the Chilean native forest. The established trade associations, or *gremios*, which included the forestry industry as well as agriculture associations, opposed this legislation from the outset and were successful in delaying its progress for 16 years (Arnold, 2003; Biblioteca del Congreso Nacional de Chile, 2008; Manuschevich, 2014). Throughout this period, the policy debate covered a variety of configurations of subsidies and land use change regulations to promote native reforestation and prevent native forest loss. According to the Advocacy Coalition Framework (Sabatier and Weible, 2007), policy is developed through a process in which stakeholders form coalitions and advocate for desired outcomes, but this process is constrained by the functioning of the political system and its constitution. For example, according to the Chilean constitution, any land use regulation or legislative measure that is considered to affect property rights requires a supermajority to pass (i.e., two thirds of the legislature), which can greatly limit the policy options for conservation.

Despite the importance of the political process in shaping policy outcomes, scenario-based land use modeling has rarely taken into account the political dynamics of the system under study. Instead, policies are typically taken as given—e.g., climate change adaptation, trade liberalization (see Metzger and Schröter, 2006; Renwick et al., 2013; Sieber et al., 2013)—without consideration of their origination via a political process. Studies on the human dimensions of conservation policy and practice point out the need to understand belief systems and politics underlying the political support or opposition for conservation principles (Alcorn, 1993; Hajer, 1993; Jacobson and Duff, 1998). Conservation policy proposals, which

Table 1

Land use transition matrix for the study area in hectares between 1993 and 2007. Data from CONAF et al. (2009).

1993 Land use	2007 Land use				
	Agriculture	POS	TF	NFDS	Totals
Agriculture	63,404	803	28,865	3341	96,414
POS	648	11,640	9,986	2,453	24,726
TF	3,302	2,498	68,007	5373	79,179
NFDS	1,597	2,751	6,809	48,570	59,727
Totals	68,951	17,692	113,667	59,737	

can inspire vigorous and polarizing political debates over core and near-core beliefs (e.g., Cawley, 1993), tend to require difficult compromises before becoming law that may detract significantly from their desired outcomes (Beier, 2008; Meffe, 1997; Primm and Clark, 1996; Rasker and Hackman, 1996).

In this study we simulated the land use implications of different policy proposals that emerged in the debate of Chile's Native Forest Law, as a means to understand possible impacts of the legislation in achieving its stated objectives, which were “to protect, recover and improve the native forests, in order to ensure forest sustainability and environmental policy”. For the purpose of this study we will focus on the possible impacts of the NFL by investigating whether any of the policy proposals, as advocated during the NFL discussion, would have had an impact on land use change in the region of Araucanía.

More broadly, we sought to explicitly integrate political processes into land use and land cover change (LULCC) modeling. By combining a policy analysis with a land use change model (Conversion of Land Use and its Effects, or Dyna-CLUE) (Verburg and Overmars, 2009), we simulated the land use outcomes of the final NFL legislation and the contrasting policy proposals of opposing industrial and conservation coalitions. Dyna-CLUE can simulate multiple transitions among several land uses and can account for ‘top-down’ social processes (e.g., demand for timber) as well as ‘bottom-up’ natural processes (e.g., forest succession from abandoned farms) influencing land use change (Verburg and Overmars, 2009). We investigated the land use outcomes of political compromises on Chile's Native Forest Law and sought broader insights on the efficacy of a system of competitive subsidies when alternative land uses provide a large profit.

2. Methods

2.1. Overview

Using the advocacy coalition framework (Sabatier and Weible, 2007), we conducted a policy analysis of Chile's 2008 Native Forest Law to identify the configuration of subsidies and regulations proposed by opposing coalitions (industrial forestry versus native forest conservation). Next we used the Dyna-CLUE modeling framework to translate the policy proposals into land use change scenarios (Swart et al., 2004; Verburg and Overmars, 2009). As inputs to the modeling process (Table 2), Dyna-CLUE requires spatial predictor variables, policy restrictions, and land demand (area assigned to each land cover type within the study landscape). Spatial predictors are identified and parameterized using statistical models and policy restrictions on land use changes are implemented as transition rules. To estimate land demand, which Dyna-CLUE requires for simulation of land use change, we estimated the net present value of different land cover types and incorporated the relevant subsidies for both timber plantations and native forests. Using this approach, we evaluated a group of scenarios (Table 3) in Dyna-CLUE to validate the basic model and simulate land cover change from 1993 to 2007 under different con-

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