

Path dependent policyscapes: an agent-based modeling approach to the evaluation of polymixes for biodiversity conservation

David N. Barton¹, Christian Klassert², W.L. (Vic) Adamowicz³,

¹Norwegian Institute for Nature Research (NINA), Norway. david.barton@nina.no

² Helmholtz Centre for Environmental Research (UFZ), Germany. christian.klassert@ufz.de

³ University of Alberta, Edmonton, Canada. vic.adamowicz@ualberta.ca

Teaser: Spatial locations of mixes of conservation instruments such as protected areas and PES have emerged over time as a result of heterogeneous landscape characteristics, policy targeting, and random shocks to land use demand. The paper explores the potential of agent-based models (ABM) to simulate the emergent and path-dependent characteristics of the resulting policyscape over time.

Abstract:

A policyscape can be defined as the spatial configuration of a policy mix (Barton *et al.*, 2013). Spatial locations of mixes of conservation instruments such as protected areas and PES have emerged over time as a result of heterogeneous landscape characteristics, policy targeting, and random shocks to land use demand (Barton and Adamowicz, 2013). The paper explores the potential of agent-based models (ABMs) to simulate the emergent and path-dependent characteristics of the resulting policyscape over time. Modeling spatially explicit emergent properties quickly becomes intractable in analytical optimization models. In contrast, ABMs have a comparative advantage in modeling local spatial interactions (Epstein, 2006). ABMs are models where individuals or agents are described as unique and autonomous entities that interact with each other and their environment locally (Railsback and Grimm, 2012).

In this paper we implement a simple ABM of the spatial allocation of two negative deforestation incentives (Figure 2) absolute protected areas (PA) and payments for protection of forest (PES). The paper explores the potential of the ABM to describe emergent and path-dependent spatial allocations of PA and PES locations. A number of modeling features are discussed using a simple ABM:

- extending a simple von Thunen land-rents model, where rents decline with distance to market (Randall and Castle, 1985), to also include rents' dependence on land use suitability (site index).
- implementing Pannell's (2008) public-private benefits framework for instrument allocation (Figure 2), as behavioural rules for a public agent allocating PAs, and a private agent adopting PES based on the ratio of public to private net benefits
- evaluating the targeting of policy instrument location to a random allocation of biodiversity and ecosystem services characteristics of forests (Figure 1), versus a landscape where land productivity (site index) is correlated with the presence of endemic species (biodiversity).
- using forest and cleared-land benefit functions to explore the effects of export demand shocks on forest clearing and demand contractions on forest regeneration.
- evaluating the spatial allocation of land-rents - with and without international import/export markets for timber and agriculture - by making the slope of forest and cleared-land benefit functions conditional on the total supply of forest cover and cleared land (Figure 3).

We conclude with a research agenda for 'agent-based policyscape analysis'.

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Private net benefit of forest clearing land use change

Player net benefit of forest clearing land use change	Positive incentives (forest clearing subsidies)	Technology change (no action)	$TD/0$ $+D$	Development extension or flexible positive incentives (development permit) (TDR buyer) ED/D
	No action	0	$-D/0$ $-D$	No action or flexible negative incentives (development cap) (TDR seller)
Player net benefit of re- and afforestation land use change	Negative incentives (Protected areas, Environmental liability, enforcement/ compliance subsidies, Protection (PES), forestry subsidy removal)	No action (or extension or negative incentives)	0	$-R/0$ $-R$
	No action	0	$TR/0$ $+R$	Conservation extension or flexible positive incentives (rehabilitation, BDO seller)

Private net benefit of re- and afforestation land use change

Player net benefit of re- and afforestation land use change	Positive incentives (agronomy, fertilization, Pesticide and Repellent) (PES)	Technology change (no action)	$TR/0$ $+R$	Conservation extension or flexible positive incentives (rehabilitation, BDO seller) ER/R
	No action	0	$-R/0$ $-R$	No action or flexible negative incentives (Environmental liability) (BDO buyer)
Player net benefit of forest clearing land use change	Negative incentives (None, agribusiness subsidies)	No action (or extension or negative incentives)	0	$-R/0$ $-R$
	No action	0	$TR/0$ $+R$	Conservation extension or flexible positive incentives (rehabilitation, BDO seller)

Figure 1: A graph showing the relationship between forest cover and the benefits of forest and non-forest land. The x-axis represents forest cover from 0% to 100%. The y-axis represents benefits. Three lines are plotted: a red line for private benefits of non-forest land (R_{priv}), a green line for private benefits of forest land (NR_{priv}), and a blue line for public benefits of forest land (NR_{pub}). The red line is upward sloping, while the green and blue lines are downward sloping. The green line starts at a positive value at 0% forest cover and ends at zero at 100% forest cover. The blue line starts at zero at 0% forest cover and ends at a positive value at 100% forest cover. The red line starts at zero at 0% forest cover and ends at a positive value at 100% forest cover. The graph is divided into three regions by vertical dashed lines: 0% forest cover, a middle region, and 100% forest cover. In the middle region, the green line is above the blue line, and the red line is above the green line. The equations for the lines are: $R_{priv} = R_{priv} \cdot x$, $NR_{priv} = NR_{priv} \cdot (1-x)$, and $NR_{pub} = NR_{pub} \cdot (1-x)$.

Source: Barton and Adamowicz (2013)