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Smallholder policy adoption and land cover change in the southeastern Peruvian Amazon: A twenty-year perspective

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A B S T R A C T

The Peruvian Amazon has undergone extensive changes in land-use and land-cover changes in the last decades related to policy implementation at local to national scales. Understanding the complexity of such changes is one of the more important challenges at present and requires research approaches capable of spanning temporal and spatial scales and academic disciplines. Here, we investigate the impacts of agriculture incentives and infrastructure development in the Southeastern Peruvian Amazon using such an approach. We integrate Landsat satellite derived land-cover maps spanning the years 1986 and 2006 to understand the land-use/land-cover changes, including forest, crops and pasture, and secondary vegetation, and their implications stemming from voluntary policy adoption along the Iñapari-Iberia portion of the Inter-Oceanic highway. This road portion is one component of the broader Initiative for the Integration of Regional Infrastructure expansion, which is resulting in rapid and extensive socio-economic and biophysical changes in the region. Results from this research highlight that changes in land-cover are associated with the farmers' voluntary adoption of agricultural policies, and that policies associated with cattle expansion and credit incentives, among others, have greatly influenced forest conversion. Although land-use/land-cover change causes are manifold and linked to more than policy events, the method used in this study improves the understanding of the effects of complex policy processes in this biodiversity and culturally rich region of the Amazon.

Introduction

Rapid deforestation throughout the tropics has global implications, including for biodiversity conservation, sustainable development, and global climate change (Angelsen & Kaimowitz, 1999; Fearnside, 2000; Geist & Lambin, 2002; Malhi & Grace, 2000; Wood & Porro, 2002). Understanding the complex drivers of land-use and land-cover changes (LULCC) continues to be a major challenge for global change research and the land change science community (Geist & Lambin, 2002; Gutman et al., 2004; Lambin & Geist, 2006). Comprehensive discussions of tropical deforestation have pointed to a number of underlying drivers that include state policies as they affect incentives for landholders to clear forests (Lambin & Geist, 2006; Turner, Geoghagen, & Foster, 2004).

This is of essential significance for frontier regions, which in Latin America often preserve tropical forest cover while at the same time promote frontier expansion (Schmink & Wood, 1992; Walker et al., 2009). A suite of LULCC studies have contributed to a better understanding of the specific impacts on rates of deforestation based on various socio-economic explanatory factors (Aldrich, Walker, Arima, & Caldas, 2006; Caldas et al., 2007; Fox, Rindfuss, Walsh & Mishra, 2003; Hecht, 2005; Moran & Ostrom, 2005; Turner et al., 2004; Walsh & Crews-Meyer, 2002; Wood & Porro, 2002). However, despite the important contributions by various disciplines, much work remains to be done to comprehend the implication of socio-economic processes and their relationship with deforestation. Further, policy analyses of LULCC are still scarce

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and often limited to what-ifs scenarios (Andersen, Granger, Reis, Weinhold & Wonder, 2002; Fox et al., 2003; Rudel, 2005). A thorough understanding of the specific impacts of diverse policies on rates of deforestation remains limited (Lambin & Geist, 2003; Mather, 2006; Oliveira et al., 2007). Given this gap, there is a pressing need for empirical detailed policy analysis of LULCC outcomes.

In this study, we seek to address this gap through a detailed assessment of LULCC following implementation and adoption of agricultural policies at the local and regional scale for a study area located in the southeastern Peruvian Amazon. Specifically, we ask how LULCC has been affected by the adoption of agricultural policies between the years 1986 and 2006, which allows for comparing LULCC across periods with distinctive policy regimes and therefore the identification of direct causal linkages. Given that under even ideal conditions, indirect effects may constrain LULCC dynamics and landholders do not always participate in the studied policies, we compare LULCC dynamics within, and between policy periods and among voluntary adopters and non-adopters. We hypothesize that the main factor driving land conversion from forest to non-forest is the voluntary adoption of agricultural policies such as cattle insemination, agricultural mechanization and credits during specific presidential administrations (Chávez, 2013). For example, the voluntary adoption of seed improvement and/or *copoasu* plantation policies would be linked to land conversion from forest to non-forest. Likewise, the non-adoption of non-forest induced policies would affect the transformation to forest cover areas. While this approach does not control for all possible effects, it offers an advance over pure multi-temporal analysis and the information from this study provides baseline information useful for assessing the direct causal effects of policy incentives at the landholding level.

Methodology

Study design

This study constructs a LULCC history of the Inter-Oceanic-Highway corridor from Iñapari to Iberia in the southwestern Peruvian Amazon from the mid-1980s to 2006, focusing on policies related to agricultural expansion in three specific time periods (Fig. 1). Two main comparisons are important in this study: (a) The comparison of LULCC dynamics among policy periods; and (b) the comparison within each period of LULCC dynamics of policy adopters and non-adopters, with voluntary policy adoption taking place during different policy periods. Multi-date Landsat satellite data is used to provide estimates of land-cover change between 1986 and 2006 along the road connecting the towns of Iñapari and Iberia, Madre de Dios, Peru, where our study households are located.

Study area

Our study area lies within the region of Madre de Dios and corresponds politically to the districts of Iñapari and Iberia in the province of Tahuamanu in Southeastern Peru (Fig. 2). The province of Tahuamanu covers an area of 21,197 km^2, out of which 2040 km^2 are considered in our study area. The focus of this study is the path of the 2006-paved Inter-Oceanic Highway, which links the Brazilian southern state of Acre with Peru and covers a road extension of 1580 km from the Brazilian border to the Peruvian ports in the Pacific Ocean. Specifically, this study is focused on the road connecting Iñapari to Iberia, which has a length of approximately 70 km.

The climate is hot and tropical, seasonally humid, with abundant rains from October to March with a short dry season from June to September (Chávez, 2009). The vegetation is composed of lowland rainforests located both along low terraces bordering major rivers on higher grounds than the alluvial terrains and water bodies and distinguished by diverse forest types on solid ground (i.e., *Terra firme*). Although the tree species diversity of Amazonian moist forests is generally among the highest of any forest type in the world (Gentry, 1988), mono-dominant stands of bamboo (*Gadua* spp.) or palm (*Mauritia flexuosa* or *Jessenia bataua*) develop in some areas (IIAP-CTAR, 2001). The province of Tahuamanu is known for preserving big-leaf mahogany, one of the most critically endangered forests species (ITTO, 2005), and for extensive stands of Brazil Nut trees (*Bertholletia excelsa*).

The Tahuamanu Province had an estimated human population of 10,742 in 2007 (INEI, 2007). Land tenure comprises a mixture of indigenous reserves, small and middle-sized private holdings (mainly agriculture and ranching), state land, timber concessions, and unclaimed land (IIAP-CTAR, 2001). Land-use patterns are associated with major productive activities and consist of slash and burn-based subsistence agriculture (mainly rice, beans, and maize), forest extraction, and to a lesser extent cattle ranching (INADE-OEA, 1998). Although areas with agricultural potential represent 28% of the total area, only 0.6% is devoted to agricultural activities, an indication of the poor returns to farmers from cultivation and the lack of market access (INRENA, 1999; Mora, 1993). Despite the low population density, the region of Madre de Dios has experienced the highest migration and population growth rates in Peru (annual population growth rate of 6%), generally concentrated around transportation routes (Tahuamanu, 2001). Historically, the Madre de Dios Region has experienced LULCC through national policies based on rubber, Brazil nut ("*castaña*"), gold, and timber boom-bust economic cycles (Chávez, 2013; Chávez &Perz, 2012). Economic prosperity has been slow, since rural and urban areas have required adequate communication and transportation infrastructures, and most government incentives have lacked the focus on competitive market opportunities, trading mechanisms, and price stability (Chávez, 2009). This area is therefore ideal for the analysis of the interaction between policy shifts, policy adopters, and LULCC.

Policy periods and participation

Figure one illustrates the three specific policy periods (I–III) corresponding to expected land transformation outcomes as measured from remote sensing. Landholder households may choose to either participate or not in the offered incentive of each studied policy influencing the outcome of LULCC differences (Chávez &Perz, 2012). In general, policy adoption by households increases the probability of land conversion (Perz, 2003). For this reason, we compared land conversion rates for between these two groups within each policy period. In order to account for time lags between policy participation and altered LULCC we analyzed forest clearing or reforestation occurring within a time span of approximately five years following initiation of the policy period (Chávez, 2013). Land conversion rates are measured using field data and satellite images chosen to correspond to each policy period.

Specifically, the policy periods are: (I) Policies that favored the establishment of annual crops and pasture from the year 1985 through 1990. This period is tied to the first presidency of Alan Garcia and represents the time when credit for annual crops and incentives for cattle were available. During this time, the government facilitated expenditure opportunities among farmers through the Agrarian Bank, which provided financial support and guaranteed the purchase of farmer's crops at preset retail values (Escobal D'Angelo, 1992); (II) Policies that favored reforestation from the