Biological Conservation 171 (2014) 247–258

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Assessing the influence of land-cover change and conflicting land-use authorizations on ecosystem conversion on the forest frontier of Madre de Dios, Peru

Jason J. Scullion [a,*], Kristiina A. Vogt [a], Alison Sienkiewicz [a], Stephan J. Gmur [a], Cristina Trujillo [b]

[a] School of Environmental and Forest Sciences, University of Washington, Box 352100, Seattle, WA 98195-2100, USA
[b] Association for the Conservation of the Amazon River (ACCA), Jiron Dos De Mayo 237, Barranco, Lima, Peru

ARTICLE INFO

Article history:
Received 11 October 2013
Received in revised form 19 January 2014
Accepted 26 January 2014

Keywords:
Ecosystem conservation
Land conflict
Conservation additionality
Matching
Remote sensing
Frontier

ABSTRACT

Despite the many benefits natural forests provide, they are being lost worldwide at unsustainable rates as development frontiers expand. One approach to improving the efficacy of natural forest conservation efforts is to refine local forest conservation policies based on insights from the place-based study of conservation policies and land-use and land-cover change (LULC) dynamics. To demonstrate the strength of this approach, this research explores the dynamics of LULC and conservation policies on the forest frontier of Madre de Dios, Peru. The main objectives of this research are to evaluate the efficacy of designated conservation lands in a rapidly expanding frontier landscape and to assess the effect on ecosystem conversion of granting conflicting land-use designations, such as mining concessions, inside conservation areas. Using statistical matching and a GIS-based analysis of LULC, this research shows that for the period 2006–2011, designated conservation lands on the forest frontier of Madre de Dios significantly reduced ecosystem losses compared to non-conservation lands, but the effect was highly variable across conservation designations. Also, when present, conflicting land-use authorizations inside conservation areas, specifically overlapping mining and agricultural titles, eliminated the policy additionality of designating lands for conservation. This finding demonstrates that authorizing conflicting land-use rights inside conservation areas should be avoided to ensure intended land conservation outcomes. This case study also provides examples of how local forest conservation policies can be improved through detailed and frequent analyses of LULC and conservation policies, particularly in dynamic frontier landscapes where LULC and socio-economic conditions are rapidly changing.

1. Introduction

Globally, forest ecosystems provide a myriad of human benefits at multiple spatial scales, including the provision of ecosystem goods, such as timber and clean water, and the delivery of ecosystem services, such as carbon cycling (MEA, 2005). However, the widespread continued loss and degradation of forests around the world, particularly tropical rain forests, has led to calls for the adoption of additional forest conservation measures (e.g., Shearman et al., 2012; Laurance et al., 2012). Frequently, actions taken to advance forest conservation include implementing new conservation policies, including: new protected areas, international treaties, and payment for ecosystem service programs. Unfortunately, for most conservation policies, scientists and policy-makers still do not have a full understanding of their likely socio-environmental impacts and the optimum conditions for their application (Pullin and Knight, 2001; Parrish et al., 2003; Pattanayak et al., 2010; Miteva et al., 2012).

Over the last decade, in response to increasing awareness that conservation efforts could be improved with more empirical evaluation, a variety of studies evaluating the efficacy of conservation policies have been undertaken (e.g., Pattanayak et al., 2010; Miteva et al., 2012; Blackman, 2013). Frequently these studies have focused on assessing the effect of designating lands for conservation, including the global protected areas network (e.g., Joppa and Pfaff, 2010) and regional protected areas networks (e.g., Vuohelainen et al., 2012). Studies designed to assess the impact of designating lands for conservation suggest designated protected areas often have lower levels of land conversion than unprotected areas. Collectively, this body of research suggests that land

Abbreviations: LULC, land-use and land-cover change; ETM+, enhanced thematic mapper plus; TM, thematic mapper; RMS, root mean square error; GIS, geographic information system.

* Corresponding author. Tel.: +1 425 351 9025.
E-mail address: scullion@uw.edu (J.J. Scullion).

http://dx.doi.org/10.1016/j.biocon.2014.01.036
0006-3207/

designation can be an important factor influencing land conservation outcomes, but also that designation is only one factor among many that determine the efficacy of conservation policies (e.g., Scullion et al., 2011; Vuohelainen et al., 2012).

Since land designation is simply a title conferring a "bundle of rights" that legally determine who benefits from the land and how that land can be used (Robinson et al., 2011), targeted analyses of the systemic factors that determine the environmental outcomes of land designations are likely to yield insights that can inform comparable conservation activities. An important factor likely to influence the efficacy of designated conservation lands occurs when government agencies grant land-use rights to different parties that conflict, such as granting mining concessions inside authorized ecotourism concessions. Given that conflicting land-use authorizations are common in many parts of the world (e.g., Finer et al., 2008), it is surprising that the role of overlapping land designations on the efficacy of conservation outcomes has been poorly researched (but see Holland et al., 2013).

The great potential for unintended environmental outcomes resulting from authorizing overlapping and conflicting land-use rights within conservation areas suggests that conservation outcomes should be sensitive to the influence of conflicting land-use authorizations. In the Amazon region alone, many large-scale and conflicting land-use authorizations have already been implemented on designated conservation lands. Examples in Amazonia include: the Ecuadorian government's recent zoning of 65% of its Amazon territory, e.g., Ecuador's famous Yasuni National Park (Bass et al., 2010), for oil extraction; and the government of Peru granting oil leases on 72% of its Amazonian territory that includes designated conservation areas (Finer et al., 2008).

Because of the high potential for negative impacts from overlapping and conflicting land-use designations on the conservation and management of forests globally, this research examines this issue locally in Madre de Dios, Peru. In Madre de Dios, various affected land users have already identified overlapping land designations as problematic. For example, local Brazil nut gathers are facing logging threats from authorized forest concessionaires who have rights to harvest timber on approximately 1.3 million hectares of Brazil nut concessions, as well as from gold miners because mining concessions have been granted on top of 47,000 ha of Brazil nut concessions (Fraser, 2013).

To better understand how conservation designations and overlapping land conflicts influence conservation policies in Madre de Dios, this study used a mixed-methods approach to answer the following questions: (1) What is the efficacy, or policy additionality, of designated conservation lands on the rapidly expanding frontier of Madre de Dios for the period 2006–2011?, (2) What are the main factors influencing the efficacy of designated conservation areas?, and (3) How does granting conflicting land-use rights inside conservation areas, particularly mining concessions and agricultural titles, affect ecosystem conservation outcomes in areas designated for conservation?

2. Methods

2.1. Study area

Located in Peru's southeast Amazonian province of Madre de Dios, the 2,060,000 ha study area includes the majority of the province's contemporary LULC dynamics (Fig. 1). Madre de Dios is Peru's designated "Capital of Biodiversity" and part of the Tropical Andes Biodiversity Hotspot (Myers, 2001) (Federal Law 26311). Madre de Dios is also recognized worldwide as a conservation priority due to its relatively intact forests, exceptionally high levels of biodiversity, strategic location in connecting large wilderness parks in Peru, Bolivia, and Brazil, and projected resilience to climate change (Malhi et al., 2008; Killeen et al., 2008; Rosenthal et al., 2012). In addition to the high biological value of Madre de Dios and the western Amazon in general, the region is also home to a rich mosaic of cultural diversity that includes some of the last uncontacted indigenous groups living in voluntary isolation (Wessendorf, 2008; Shepard et al., 2010).

Prior to mid-1960, Madre de Dios had few inhabitants and little development. This changed after the construction of a road leading into the province. Since then, human population and land-cover conversion have increased substantially, and the region has experienced comparatively high levels of forest disturbance and deforestation within Peru (Oliveira et al., 2007). During the 1980s and 1990s, the loss of natural forests in Madre de Dios was primarily caused by government subsidized agricultural expansion (Alvarez and Naughton-Treves, 2003; Chavez and Perz, 2012). In the 2000s, gold mining became an important driver of regional LULC following the discovery of gold deposits and an increase in the international price of gold (Swenson et al., 2011; Asner et al., 2013). Since the discovery of gold, an estimated 30,000 artisanal miners have migrated to Madre de Dios (Webster, 2012). It is thought that ~95% of gold mining operations in the region are illegal because the miners either lack the proper permits to run their operations or because they are working outside authorized mining concessions (Keane, 2009a,b).

In addition to the expansion of gold mining, the recent completion of the Interoceanic Highway is also an important contributing factor to regional LULC due to its central role in facilitating local trade and resource extraction (Southworth et al., 2011). In 2011, approximately 68% of the study area was under one of six land designations that defined ecosystem conservation as a primary land-use objective (Table 1). At the same time, 94% of the study area was covered by natural ecosystems, including mature lowland rainforests, which comprised 69% of existing natural ecosystems, followed by montane forests, which were the second most abundant ecosystem (23.3%). The other existing natural ecosystems covered less than 3% of the total study area and included: palm swamps (2.9%), secondary lowland rainforests (2%), bamboo groves (1.6%), and riparian forests (0.9%).

In recent years, efforts by the government to regulate mining activities in Madre de Dios have led to intense social and political conflict. Much of this conflict is because the mining industry has created tens of thousands of local jobs, generates an estimated $369 million (USD) in annual revenue, and accounts for greater than 50% of all regional economic activity (Mosquera et al., 2009; GOREMAD, 2009). Due to the jobs and revenues generated, the local mining industry has become the region's dominant socio-political force, surpassing the economic importance of other local industries, including ecotourism, which still brings an estimated 50,000 tourists to the region each year (Kirkby et al., 2010). In addition to continued conflict over where gold mining should occur in the study area (e.g., in rivers and protected areas), a major socio-political issue facing the region is how several government agencies have authorized conflicting land-use rights to different parties for the same land. A recent example illustrating the local challenges presented by conflicting land-use authorizations is the ongoing dispute over forest management between Brazil nut harvesters who depend on specific large standing trees inside closed canopy forests and gold miners whose land-use activities generally require removing forest cover (Fraser, 2013).

2.2. Image classification and analysis

To analyze changes in land-cover over the study period, images acquired by NASA's Landsat sensors were classified for the years 2001 (ETM+ & TM), 2006 (TM), and 2011 (TM) (Path/row 2/69, 3/