Land Use Policy 63 (2017) 440–449

Contents lists available at ScienceDirect

Land Use Policy

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

Comparison of land use change in payments for environmental services and National Biological Corridor Programs

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ARTICLE INFO

Article history:
Received 29 April 2016
Received in revised form 3 February 2017
Accepted 6 February 2017
Available online 20 April 2017

Keywords:
Buffer zones
Deforestation
Environmental policy
Protected areas
Remote sensing

ABSTRACT

Costa Rica established the National Biological Corridor Program in 2006. Under the National Biological Corridor Program, the long-running Payment for Environmental Services Program was newly prioritized into biological corridors throughout the country. The National Biological Corridor Program caused a nationwide spatial shift in placement of payments for environmental services throughout Costa Rica. We classified ASTER 15-m resolution imagery in a central Costa Rica corridor connecting the eastern and western protected areas networks to analyze the change in forests during the National Biological Corridor Program with its targeted payments for environmental services effort. We used object-based classification methods, and compared land cover changes over an initial four-year period of corridor policy enactment. We calculated the changes within PES properties and outside of PES regions, and we also calculated forest patch metrics during the same time period. Results indicate a decline in forest cover over the study period, along with an increase in urban and pasture land covers, with higher change and loss of forest centered inside of the biological corridor, near the construction area for the new San Carlos highway, and within eastern pasture areas. We also saw a higher percentage of forest loss inside of the biological corridor area as compared to areas outside of the biological corridor. Forest loss was drastically less within current and historic PES properties, as compared to the overall study region. Across the entire study region, patch metrics show a decrease in the number of patches and a slight decrease in average patch size. These results suggest that current and past designation of PES prevents forest loss within PES properties while the current designation of priority conservation status via the National Biological Corridor Program is not increasing connectivity and forest conservation. This is shown by increased land use change and a decrease in forest associated with biological corridor designation. These results are antithetical to the goals of the National Biological Corridor Program.

1. Introduction

Land conversion and deforestation are closely linked to agriculture throughout much of the world, and within Latin America these drivers have resulted in increased isolation of protected areas (DeFries et al., 2005). Deforestation and land conversion are tied to losses in environmental services, and these services have been shown to benefit human and wildlife populations through mitigation of climate change, stabilization of water resources, and preservation of biodiversity (Foley et al., 2007). Governments and other entities attempt to thwart deforestation and the loss

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http://dx.doi.org/10.1016/j.landusepol.2017.02.005
0264-8377/

of environmental services through conservation policies, such as neoliberal modeled Payments for Environmental Services (PES) policies (Pagiola, 2008; Wunder and Albán, 2008). PES is a system where outside benefiters of environmental services pay local communities or landholders to manage their properties to provide those environmental services, either through restoration or protection (Wunder, 2005). While many countries in Latin America have experienced forest loss, Costa Rica has seen an increase in forested areas, starting in the 1980s, with 2010 forest coverage totaling ~52% (Aide et al., 2013; FONAFIFO, 2012).

Costa Rica is proactive in developing environmental policies to preserve and conserve natural resources. In 1996, Costa Rica established the national PES program, under Costa Rica Forestry Law No. 7575. The goal is to promote watershed stability, biodiversity protection, scenic beauty, and carbon sequestration. This voluntary program solicits applications from landholders with properties that promote conservation, including protection of primary forests, reforestation, or agroforestry; and in return, these registered lands provide environmental services. Well defined land tenure and transparent actors make this system function within the PES framework (Sunderlin et al., 2009). Many entities, including beneficiaries of the environmental services as well as polluters, pay into the program, including national hydroelectric interests and the World Bank (Pagiola, 2008). Primary forest payments are eligible for renewal every five years, and agroforestry and reforestation are allowed one contract for five years, with no renewal. Most reforestation contract holders have plans to sell the wood for timber after 15–20 years, while a few contract holders are using the payments to reforest the land permanently. Contract holders plant both native and non-native tree species. Some tree species include Teak (*Tectona grandis*), American mahogany (*Swietenia humilis)*, Rainbow eucalyptus (*Eucalyptus deglupta*), Melina (*Gmelina arborea*), and Almendro (*Dipteryx panamensis*). Timber products in Costa Rica include wood for pallets or furniture, among others (Floors, 1997).

Jointly aligned with the PES program, the National Biological Corridor Program (NBCP) of Costa Rica was established in 2006 through Executive Order 33106 by the office of the Ministry of Environment, Energy and Telecommunications (MINAE) (National System of Conservation Areas SINAC, 2009; Villate et al., 2009). The stated goals of the NBCP are to achieve connectivity among neighboring protected areas and to increase biodiversity through sustainable use (SINAC, 2008). The NBCP aims to strengthen existing protected areas, using spatially targeted PES as a tool inside of biological corridors to increase forest cover and connectivity, as well as by supporting cooperatives and local groups to enhance stakeholder alliances and sustainable development in the biological corridor network (National System of Conservation Areas SINAC, 2009; Vargas, 2014). Along with biological corridors, other priority areas for targeted PES include the Huetar Norte Forest Program region, areas designated for protection of water resources, areas with a Social Development Index of less than 40%, and lastly, areas with expiring PES contracts (Wunscher et al., 2006).

Costa Rica ranks in the top 20 most biodiverse countries in the world, with 0.03% of the earth's land surface holding 4% of the world's species (INBio, 2015). Biological corridors and connectivity are integral components to the overall protection of biodiversity, reducing extinction rates from restricted gene flow due to fragmentation and decreasing the impact of stochastic disturbances acting on isolated populations (DeClerck et al., 2010; Hodgson et al., 2011). The Costa Rican biological corridors are embedded within the multinational Mesoamerican biological corridor, which was created in 1998 and runs through eight countries from Mexico to Panama (Miller et al., 2001). Costa Rica has 47 proposed biological corridors, covering 35% of the country, and in 2010 had 24 active biological corridors, each facing unique conservation challenges (DeClerck et al., 2010). Many of the Costa Rica biological corridors are composed of agricultural matrices, encompassing all forms of land use from private farms to government hydroelectric projects. Extensive human habitation, with its variety of land uses, causes heterogeneous patterns of human pressures within these corridor matrices.

The Paso de las Nubes Biological Corridor (CBPN) is a critical connection point for the eastern and western transects of the greater Mesoamerican corridor within Costa Rica, and is important for national protected area connectivity (Fig. 1). Located northwest of the capital of San José, this corridor serves as the northern-most corridor connection for protected areas on either side of the continental divide, and is the main corridor linking the northwestern dry forests to the eastern slopes. The CBPN encompasses a large altitudinal gradient, ranging from 300 to 2100 m above sea level, making the CBPN well-suited for the protection and persistence of biodiversity in the face of a changing climate (Becker et al., 2007; Loarie et al., 2009). Lastly, this biological corridor and neighboring protected areas serve as the headwaters for more than five major rivers that provide drinking water for cities throughout northern and central Costa Rica. The Juan Castro Blanco National Park on the eastern border is even named "The Park of Water", because of the wealth of rivers originating within its bounds.

The NBCP utilizes the conservation strategy of land sharing to foster connectivity. Land-sharing studies have shown the importance of remnant forests contained in a permeable agricultural matrix (Daily et al., 2003; Horner-Devine et al., 2003; Perfecto and Vandermeer, 2010). This matrix is composed of agricultural production areas, human settlements, agroforestry, and remnant forests, and these matrices can function as habitat or as a corridor system linking distant protected areas (Baum et al., 2004; Nagendra et al., 2013; Perfecto and Vandermeer, 2002). The existence of Costa Rican protected areas has been shown to decrease deforestation in areas directly outside of protected area boundaries, further aiding in connectivity and enriching the agricultural matrix (Andam et al., 2008). Along with connectivity, the agricultural matrix can provide environmental services to local human populations, and these services are rewarded through the PES program (Jauker et al., 2009). The maintenance of biological corridors within the agricultural matrix is essential for effective management of protected areas, biodiversity, and environmental services.

Within the matrix, some wildlife species are able to persist and travel, but many forest dependent species cannot cross large stretches of open lands between protected areas (Daily et al., 2003; Tabarelli et al., 2010). Within Costa Rica, the majority of large-bodied forest dependent mammal species are nationally endangered due to loss of habitat and hunting (Elizondo and Humberto, 1999). Within the Mesoamerican multi-national corridor, Costa Rica has one of the highest percentage of land held within protected areas at 26% (World Bank., 2015), but even with large areas under protection, connectivity is key for the utility of protected areas for wildlife species. The CBPN is essential for the movement of species requiring large home ranges or long dispersal distances. Male jaguars (*Panthera onca*) have a home range between 40 and 83 km^2, while male puma (*Puma concolor*) require a home range of 200–800 km^2, and male ranges rarely overlap (Rabinowitz and Nottingham, 1986; Reid, 1998; Soisalo and Cavalcanti, 2006). Even small carnivores such as the jaguarundi (*Puma yaguarondi*) require home ranges of up to 20 km^2 (Michalski et al., 2006). Neighboring protected areas do not have sufficient area to cover the home range of one individual male puma. Thus, the CBPN acts as a buffer zone to the extensive adjacent protected areas of Juan Castro Blanco National Park (145 km^2), Alberto Manuel Brenes Biological Reserve (78 km^2) and Monteverde Cloud Forest Reserve (260 km^2), further extending essential habitat for wildlife species (Fig. 1).

The value of natural experiments is indispensible in understanding the utility of conservation programs. Conservation policies must