Journal of Environmental Management 230 (2019) 392–404

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Evaluating and supporting conservation action in agricultural landscapes of the Usumacinta River Basin

Raúl A. Vaca[a,*], Rocío Rodiles-Hernández[a], Susana Ochoa-Gaona[b], Nathaline E. Taylor-Aquino[c], Rafael Obregón-Viloria[d], Daniela A. Díaz-García[c], Darío A. Navarrete-Gutiérrez[e]

[a] Departamento de Conservación de la Biodiversidad, El Colegio de la Frontera Sur, Carretera Panamericana y Periférico Sur s/n, 29290 San Cristóbal de Las Casas, Chiapas, Mexico
[b] Departamento de Ciencias de la Sustentabilidad, Adaptación Humana y Manejo de Recursos Naturales en Ecosistemas Tropicales, El Colegio de la Frontera Sur, Av. Rancho Polígono 2[a], Ciudad Industrial, Lerma 24500, Campeche, Campeche, Mexico
[c] Corredor Biológico, Calz de Pipila 65, Barrio de Fátima, 29264, San Cristóbal de Las Casas, Chiapas, Mexico
[d] Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Liga Periférico Insurgentes Sur 4903, Parques del Pedregal, Tlalpan 14010, DF, Mexico
[e] Laboratorio de Análisis de Información Geográfica y Estadística, El Colegio de la Frontera Sur, Carretera Panamericana y Periférico Sur s/n, 29290 San Cristóbal de Las Casas, Chiapas, Mexico

ARTICLE INFO

Keywords:
Agricultural landscape
Biological corridor
Farming systems
Land tenure structure
Landscape-scale conservation
Sustainable resource management

ABSTRACT

There is increasing recognition that ecosystems and their services need to be managed at landscape scale and greater. The development of landscape-scale conservation strategies need to incorporate information from multiple sources. In this study, we combine various research tools to link landscape patterns with production units and systems in the Usumacinta River Basin, and inform the discussion of key questions around decision-making related to conservation action and policy in Southern Mexico. A typology based on policy-relevant farmer characteristics (land tenure, farm size, source of income, farming system) differentiated between farmers (traditional vs. cattle ranching) with different motivations that determine how management affects landscape configuration. Five main types of traditional farming systems were identified that combine different forms of land use and vary in their degree of land intensification. Major fragmentation and decrease in connectivity coincided spatially with floodplains dominated by large-scale commercial farms that specialize in livestock production. Traditional practices within large units with low-sloped high quality land were also seen to be intensive; however the presence of trees was notable throughout these units. Policies that promote livestock farming are among the principle causes motivating deforestation. Land intensification by traditional farmers decreased as the landscape became increasingly rugged. Traditional farmers are the focus of initiatives developed by the Biological Corridor project which seeks to increase forest cover and landscape connectivity. These initiatives have shown high levels of rural participation (10,010 farmers benefited from 27,778 projects involving 95,374 ha of land) and acceptance (producers carried out more than one project and several types of projects during the first eight years of work). Strong action is still required to take on the segment of large-scale ranchers. Changes in the structure of land tenure over the past decade are highlighted that could have a profound impact on conservation policies and programs.

1. Introduction

In tropical regions, landscapes are increasingly dominated by human land use (Dudgeon et al., 2006; Laurance et al., 2014; Lewis et al., 2015). Extensive and continuous areas of native vegetation have been replaced by a matrix of conventional agriculture, cattle production systems, and secondary vegetation; as a result, undisturbed forests are now restricted to a few protected areas or inaccessible areas (Challenger, 1998; Strassburg et al., 2014). The current pace of deforestation and chronic fragmentation underscore the urgent need for interventions to restore and protect biodiversity, among other targeted goals including the maintenance of ecological function and the supply

* Corresponding author.
E-mail addresses: rgenuit@ecosur.mx (R.A. Vaca), rrodiles@ecosur.mx (R. Rodiles-Hernández), sochoa@ecosur.mx (S. Ochoa-Gaona), nationat@hotmail.com (N.E. Taylor-Aquino), rafael.obregon@conabio.gob.mx (R. Obregón-Viloria), ddiaz@conabio.gob.mx (D.A. Díaz-García), dnavarre@ecosur.mx (D.A. Navarrete-Gutiérrez).

https://doi.org/10.1016/j.jenvman.2018.09.055
Received 17 July 2018; Received in revised form 6 September 2018; Accepted 15 September 2018

of goods and ecological services (García-Oliva et al., 1995; Maass et al., 1988, 2005; Murphy and Lugo, 1995).

Creating protected areas is the primary biodiversity conservation strategy used across geographic scales to avert biodiversity loss (González-Maya et al., 2015; Margules and Pressey, 2000). However, in areas subjected to intense human use, biodiversity conservation strongly depends on the maintenance of key ecological processes, which determine the composition and structure of biological communities (Lindenmayer et al., 2008). It is known that changes in area, shape, and connectivity of the patches cause changes in species richness, distribution, and persistence of populations, and increase the probability of disturbance affecting community structure and function (Debinski and Holt, 2000; Fahrig, 2003; Laurance and Cochrane, 2001; Saunders et al., 1991; Wiegand et al., 2005).

In order to ensure the long-term survival of biodiversity while simultaneously maintaining peoples' livelihoods and continued productivity, tropical forests should be managed as sustainable ecosystems (Ceballos and Garcia, 1995; Harvey et al., 2008). The explicit purpose is to achieve an effective combination of conservation policy and sustainable resource management programs (Bennett et al., 2009). This issue has drawn increasing attention, most notably concerning planning for processes associated with large-scale connectivity (e.g. Klein et al., 2009; Soulé et al., 2004).

The Usumacinta River Basin in southern Mexico is one of many regions in Mesoamerica where nature conservation strategies have mostly consisted of the establishment of federal reserves to protect threatened species and communities. The reserve system includes some of the most important protected areas of Mexico and encompasses 20% of the basin area. Biodiversity conservation in this region is of great concern due to the basin's high biodiversity value (Tapia-Silva et al., 2015). This region has been identified as a hotspot of tropical biodiversity (Hudson et al., 2005), and is one of the most productive regions of the country in terms of ecosystem services (Tapia-Silva et al., 2015). Protected areas, however, are embedded within agricultural landscapes in which cattle grazing and agricultural activities have continued their expansion (Vaca et al., 2012). In these agricultural landscapes, conservation practices and, consequently, agricultural landscape patterns, are influenced by government policy and farmers' decisions about how they manage their land. In this context, biological corridors have emerged as a new complementary conservation approach for integrated landscape management, in which conservation and production units within the agricultural matrix are managed jointly for long-term sustainability (Eccardi, 2003). Three (i.e. Corredor Biológico Selva Maya-Zoque, Corredor Biológico Pantanos de Centla-Cañón del Usumacinta y Corredor Biológico Sierra de Tabasco) out of five biological corridors in southern Mexico extend toward the Usumacinta River Basin, encompassing 44.8% of the basin area.

Explicit conservation strategies within biological corridors need to incorporate knowledge of the underlying farmer characteristics that may influence the adoption of conservation practices (Daloglu et al., 2014), and ultimately affect landscape context, including how the surrounding agricultural matrix is configured (i.e. how different types of land use are distributed spatially and temporally) and managed (i.e. how production is carried out) (McNeely and Scherr, 2003; Perfecto and Vandermeer, 1997; Vandermeer et al., 2007; Wallace et al., 2005).

In this study, we combine the analysis of biodiversity and landscape configuration with farmer typology in the Usumacinta River Basin, in order to link agricultural landscape patterns with production systems, spatial units, and agents, and provide a description of the heterogeneity of landscapes relevant to conservation policy. This study was designed to evaluate existing initiatives for landscape-scale conservation within biological corridors in the region, and support the development and implementation of policies relating to the conservation, restoration, and sustainable use of natural resources. We define and map floristic communities in relation to environmental predictors, and we compare these data to remotely mapped attributes of vegetation cover to evaluate the impacts of anthropogenic activities on biological diversity and key ecological processes in the Usumacinta River Basin. While the study does examine the coverage and effectiveness of protected area networks, the main focus is on areas that are not protected but are being actively used either to support the livelihoods of rural communities or economic development. We emphasize the spatial configuration and connectivity attributes at the landscape level. We also use data compiled by the Biological Corridor project to define a farmer typology based on types of land use and management characteristics.

We considered seven complementary objectives when designing our analytical framework: (1) to define baselines of plant species richness; (2) to evaluate relative exposure to deforestation and anthropogenic fragmentation and assess potential threats to plant species by using remote sensing data on a stratified community-based map; (3) to measure the permeability of the landscape to the movement of groups of organisms with different habitat requirements and identify barriers to movement; (4) to define a farmer typology based on combinations of types of land use and management characteristics; (5) to link biodiversity and agricultural landscape patterns with production systems, relevant agents, and production units; (6) to describe the Biological Corridor project initiative in the region with respect to the conservation, restoration and sustainable use of natural resources; and (7) to evaluate the adoption of conservation practices by farmers and present preliminary results for the first eight years of the Biological Corridor project's progress in the region.

2. Study area

The study area consists of the complete area of the Usumacinta River Basin located in Mexican territory (Fig. 1). Its surface area totals 41,180 km^2 and ranges in altitude from zero to 2600 m.a.s.l. The part of the basin that lies within Mexican territory can be divided into three different parts based on physiography and hydrography: the upper region (150–2600 m.a.s.l.), floodplain (50–150 m.a.s.l.) and coastal plain (0–50 m.a.s.l.). Rainfall in the region is the highest in the country and one of the highest in the world, averaging 2143 mm per year. The annual mean temperature is 24 °C (Hudson et al., 2005).

Most of the study area was probably originally covered with tropical forests, and hydrophytic vegetation likely dominated the coastal plain (Challenger, 1998). The current pattern of usage in most of the Usumacinta River Basin has origins in a deliberate policy of settlement in the region (Sánchez-Munguía, 2005). Historical clearance of native vegetation has been driven mainly by cattle grazing and agriculture expansion. Urbanization has also contributed to permanent clearance of native vegetation and intensification of land use throughout the region (Sánchez-Munguía, 2005).

3. Material and methods

3.1. Data sources

3.1.1. Biodiversity data

We collected vegetative and reproductive samples of tree and hydrophytic plant species in remnants of mature vegetation, protected areas, and wetlands. Individuals were identified to species by expert technicians from the herbaria at El Colegio de La Frontera Sur (ECOSUR) and the Universidad Juárez Autónoma de Tabasco (UJAT). Samples were compared with herbarium specimens in order to corroborate species identification. We also compiled data for the study region from the herbaria of the Universidad de Campeche (UAC), the Escuela Nacional de Ciencias Biológicas (ENCB), the Universidad Juárez Autónoma de Campeche (UJAT), El Colegio de la Frontera Sur (ECOSUR-SCLC) and the National Herbarium (MEXU) of the Instituto de Biología, UNAM, as well as from the floristic database at the Sistema Nacional de Información Sobre Biodiversidad de la Comisión Nacional Para el Conocimiento y Uso de la Biodiversidad (SNIB-CONABIO).