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Planning restoration in human-modified landscapes: New insights linking different scales

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ABSTRACT

The transformation of tropical ecosystems by humans have resulted in forest loss, which, in turn, have caused negative impacts on biodiversity and the provisioning of ecosystem services. There is an urgent need to plan the restoration of these human-modified landscapes, using methodological approaches that consider key processes occurring at different spatial scales while engage local community participation, offering them the best possibilities of tangible benefits. In this study, was evaluated the landscape spatial pattern and local conservation status of existing forest remnants, showing an analysis of possible restoration scenarios for a human-modified landscape in La Montaña, an indigenous region in south-western Mexico. Therefore, landscape and local scale approaches were linked to identify specific landscape elements where efforts to improve connectivity must be concentrated. Also, this approach allowed finding a set of species from reference sites that showed the best socioecological characteristics to be used in different restoration strategies. As expected, La Montaña region showed a spatial pattern typical of highly human-modified landscapes, i.e., several small (<21 ha) and irregular forest remnants with strong forest edge effects. Furthermore, these small and irregular forest fragments displayed forest structure, diversity and composition characteristics similar to those communities disturbed by selective harvesting or in an early successional phase. However, about 100 of woody species were found inside the fragments, some with important potential to provide ecosystem services. The landscape connectivity was very low, and an analysis of possible restoration scenarios showed that is equally important to restore the productive areas as well as open forest, to recover up to 47% of landscape connectivity. In this sense, it was proposed a productive restoration strategy to enrich open forests and create biodiversity-friendly habitat in agricultural areas, using species with high socioecological potential. We believe that the same approach could be applied to other highly human-modified tropical landscapes with similar socioecological problems.

1. Introduction

Forest loss is a global concern, particularly in countries with a high abundance of natural forest resources (FAO, 2010, pp. 9–23). Between 2000 and 2012, it was estimated that 2.3 million km^2 of forests worldwide were lost by human disturbances (Hansen et al., 2013), causing negative impacts to biodiversity and provisioning of ecosystem services (Cardinale et al., 2012). Human activities, such as agriculture, deforestation and mining, are considered to be the main drivers of forest loss (Foley et al., 2011; Houghton, 2012). Furthermore, poverty and ecosystem fragility frequently contribute to forest loss and land degradation, creating a negative cycle or "poverty traps" (Sachs & McArthur, 2005).

Forest loss can also cause forest landscape fragmentation and a negative impact on biodiversity when isolation and edge effects entail habitat loss (Haddad et al., 2015; Heather & Fahrig, 2013). Forest fragmentation reduces genetic diversity and species

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population growth rates within fragments, altering the interactions among species and promoting local extinctions (Haddad et al., 2015; Ponce-Reyes, Nicholson, Baxter, Fuller, & Possingham, 2013; Sork & Waits, 2010). The social consequences of forest fragmentation involve the loss of ecosystem services provision and thereby quality of life, especially for those people most dependent of forest resources (Chao, 2012; FAO, 2010, pp. 9–23).

The management and restoration of human-modified landscape to ameliorate countless negative effects from fragmentation is a crucial global issue (Chazdon et al., 2015; Damschen, Haddad, Orrock, Tewksbury, & Levey, 2006; Holl, 2017; Mitchell, Bennett, & Gonzalez, 2013; Ng, Xie, & Yu, 2013). However, identifying an effective methodological approach to guide landscape restoration planning poses several challenges because all ecological systems are unique and their composition and ecological processes are in function of their location, spatial context, history and current status as well as type of land use (Lindenmayer et al., 2008). Instead of providing specific recommendations for on-the-ground management and because specific applications will be always context-dependent, some authors have proposed a set of general considerations to guide a better landscape conservation and restoration planning. These considerations embrace and identify not only the landscape dynamics but also consider both the amount and configuration of habitats and particular land cover types, identify important species, ecological processes as well as landscape restoration strategies (Bennett & Mac Nally, 2004; Lindenmayer et al., 2008; Maginnis, Rietbergen-McCracken, & Sarre, 2012; Rudnick et al., 2012; Turner, Donato, & Romme, 2013).

Landscape restoration strategies could focus on several issues such as forest remnant conservation and increase in forest area and connectivity among forest remnants, through wildlife corridors or improvement of the matrix permeability (Haddad et al., 2015; Metzger & Brancalion, 2013; Perfecto & Vandermeer, 2010). These strategies should also take into account the predominant type of disturbance in the landscape (acute vs. chronic; Arroyo-Rodríguez et al., 2015; Ribeiro, Arroyo-Rodríguez, Santos, Tabarelli, & Leal, 2015), processes that occur on different scales of space and more importantly, the participation of local communities (Ceccon, 2013, pp. 139–149; Flores-Ramírez & Ceccon, 2014; Metzger & Brancalion, 2013; Perfecto & Vandermeer, 2010). In a landscape that has suffered strong chronic human disturbances, succession can be slow or arrested with direct effects on ecosystem functions (Arroyo-Rodríguez et al., 2015). Under these circumstances, it is imperative to assess the role of secondary forest remnants to serve as biodiversity repositories and provide ecosystem services. Therefore, an appropriate remnant management would potentiate their functions according to specific conservation and social goals at a landscape scale (Arroyo-Rodríguez et al., 2015).

Mexico is a megadiverse country; however, it presents high rates of net deforestation at national and regional scale (García-Barrios et al., 2009; Hansen et al., 2013; Mas & Cuevas, 2015). La Montaña region, in the south of Guerrero state, has one of the highest levels of land degradation and social vulnerability in Mexico (Bollo Manent, Hernández Santana, & Méndez Linares, 2014; Landa, Meave, & Carabias, 1997). In an evaluation about the state of environmental integrity in the country using 15 indicators associated with anthropic modification and socioeconomic status, Bollo Manent et al. (2014) found that La Montaña region had an unstable state, i.e., high vegetation degradation and social vulnerability in terms of health, education and quality of life.

Most landscapes in this region are subject of chronic disturbance (Arroyo-Rodríguez et al., 2015), predominantly by harvesting of timber and fuelwood (Locally, 100% of population use firewood to cook; Salgado, 2015), extraction of non-timber forest products, subsistence agriculture, hunting and livestock. This region is also one of the poorest in the country (CDI, 2005, pp. 10–47; PNUD, 2012), some of the municipalities in the area show a Human Development Index similar to some sub-Saharan African countries (Taniguchi, 2011), with strong isolation and social marginalization (Landa & Carabias, 2009). The dependency on natural resources has been evident in some of the recent studies carried out in the region. For example, Miramontes, DeSouza, Hernández, and Ceccon (2012), found a deterministic searching pattern of firewood in this region, which is typical of degraded landscapes with scarcity of resources. Likewise, Salgado (2015) found that species with the highest firewood potential are rarely used due to a low abundance in their natural habitats.

At present, in the La Montaña region, there are numerous governmental and non-governmental initiatives; such as Xuajin Me Phaa, A.C., a non-governmental organization dedicated to reversing the negative effects of forest fragmentation and land degradation in two municipalities of the region. However, these objectives can only be reached by developing programs that include restoration and protection of forest remnants, and activities incentivized by the organization that also offer tangible benefits for 990 families who belong to the indigenous group Me'Phaa.

A long partnership between the research group and Xuajin Me'Phaa A.C., in the region has resulted in some important studies that give us valuable lessons about the communities' dependency on natural resources, traditional knowledge, lifestyles, and their urgent socioeconomic needs (Borda-Niño, Carranza, Hernández-Muciño, & Muciño-Muciño, 2016; Ceccon, 2016; Galicia-Gallardo & Ceccon, 2016; Hernández-Muciño, Sosa-Montes, & Ceccon, 2015; Hernández-Muciño, Borda-Niño, & Ceccon, 2016; Miramontes et al., 2012; Salgado, 2015).

In a human-modified landscape such as La Montaña region and considering the socioecological complexity of ecological restoration in the country (Ceccon, Barrera-Cataño, Aronson, & Martínez-Garza, 2015), a suitable methodological approach to landscape restoration planning must link local and landscape scales and should include, at least, the following five components: i) assessment of the landscape spatial pattern and connectivity, ii) knowledge of the conservation status of existing forest remnants, iii) recognition of specific landscape elements where efforts to improve connectivity should be concentrated, iv) identify species in reference sites with the best socioecological characteristics (species with high potential as ecosystem services providers), to establish different restoration strategies, and v) establish possible restoration scenarios to improve landscape connectivity, according to a set of general considerations for restoration planning (Bennett & Mac Nally, 2004; Lindenmayer et al., 2008; Maginnis et al., 2012; Turner et al., 2013). This study aimed to assess these components in order to generate information which can provide the scientific foundations for designing future landscape restoration strategies in the La Montaña region, and in any other human-modified tropical landscapes with similar socioecological conditions. This research approach included collaboration with communities and the non-governmental organization; Xuanjin Me'Phaa A.C., and represent an innovative action-participation model that is applicable and achievable to have a positive impact on people's welfare.

2. Material and methods

2.1. Study site

This study was carried out in a human-modified landscape of the La Montaña region, located in the municipality of Acatepec, in eastern Guerrero state, Mexico (UTM coordinates; 498209-493082X a 1908985-1890946Y). The study site was located in a transition zone of mixed pine-oak forests and tropical deciduous