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Lands at risk: Land use/land cover change in two contrasting tropical dry regions of Mexico

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1. Introduction

Land use and land cover change (LULCC) processes have been widely acknowledged as one of the main global transformations, given their pace and profound ecological consequences, including habitat and biodiversity loss, climate change, and land degradation, affecting also ecosystem structural and functional integrity (Foley et al., 2005; Rockström et al., 2009; Turner et al., 2007). LULCC has accelerated dramatically in the last four decades (Metzger, Rounsevell, Acosta-Michlik, Leemans, & Schröter, 2006), turning large landscapes into heterogeneous mosaics of different land uses and vegetation cover types (Chomitz & Gray, 1996; Naveh, 1995).

Agricultural expansion is recognized as the most relevant LULCC process worldwide, as by 2000, 45% of the planet's ice-free land surface was covered by agriculture (Lambin & Meyfroidt, 2011; Ramankutty, Evan, Monfreda, & Foley, 2008). However, establishing the main underlying drivers of LULCC with precision has been elusive because, as any other socio-environmental process, it behaves as a complex nonlinear system; therefore, LULCC drivers depend upon the spatio-temporal scale of analysis and vary among different socioeconomic, political and environmental contexts (Carr, Suter, & Barbieri, 2005; Lambin & Meyfroidt, 2011).

Regardless of its complexity, a meta-analysis conducted by Geist and Lambin (2002) established the existence of general proximate and underlying factors of LULCC. For example, infrastructure expansion and the growth of primary economic activities are broadly deemed as direct drivers, whereas economic, demographic, technological, political, institutional and cultural factors are regarded as indirect forces, shaping the action of proximate factors. Moreover, environmental conditions and processes, such as climate, physiography, soil and vegetation properties influence the pace, magnitude and ecological consequences of LULCC (Gasparri & Grau, 2009; Tucker, Randolph, & Castellanos, 2007; Velthuizen, 2007).

LULCC studies have paid much attention to tropical forest ecosystems, given their importance regarding extent, biodiversity, relevance for global ecological processes, and rates of change (Balvanera, 2012; Lambin, Geist, & Lepers, 2003; Ramankutty et al., 2008). Particularly, tropical dry forests (TDF) are fragile systems, subjected to high transformation pressures, but also less investigated and protected by conservation initiatives (Espírito-Santo et al., 2009; Stoner & Sánchez-Azofeifa, 2009). TDFs are comprised by a group of community types that occur in intertropical lowlands, characterized by a well-defined dry season ranging from four to six months, total annual precipitation ranging from 500 to 1800 mm, and mean annual temperature from 18 to 26 °C (Trejo, 1996, 1998).

Vegetation types present in the seasonally dry tropical regions of Mexico include tropical dry forest, sub-tropical scrub, thorn woodland, xerophytic scrub, medium-statured tropical dry forest, gallery forest, savanna, palm grove, tropical oak grove, and tropical pine grove (Pérez-García, Meave, & Cevallos-Ferriz, 2012). Tropical forests account for nearly 5.5 % of the country's total surface, but more than half of this area is covered by TDF, representing 3.4 % of total land area (INEGI 2014). TDFs are widely distributed in the country, in areas of dry to sub-humid climates (annual rainfall 400–1,300 mm; temperature, 22–26 °C), with strong seasonality (6–8 months nearly rainless), and in the 0–2,000 m elevation range (Trejo & Dirzo, 2000). Its geographic range spans from *ca.* 28° N, down to the Guatemala border. On the Pacific watershed, it occurs almost continuously with major areas in western Jalisco, and in the Balsas and Santiago river basins, whereas on the Gulf of Mexico's coast, its distribution is more discontinuous (Miranda & Hernández-X. 2014; Trejo & Dirzo, 2000).

Overall, Mexican regions characterized by the presence of TDF are remarkable due to their high plant species richness, which partly responds to these systems' high beta diversity, and their high level of endemism (Gallardo-Cruz, Meave, Pérez-García, & Hernández-Stefanoni, 2010; Rzedowski, 1991). These forests provide a wide array of life-support functions, such as flood control, climate regulation, agricultural and pastoral goods, fresh water and diverse resource provisioning, soil fertility maintenance, and pollination, among others (Maass et al., 2005).

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The vulnerability of TDF derives partly from their slow successional rate after LULCC, which depends on the existence of primary vegetation remnants, water and soil nutrient availability, and their history of disturbance; also, certain attributes recover faster than others, and thus overall resilience may be low (Lebrija-Trejos, Bongers, Pérez-García, & Meave, 2008; Mora et al., 2015; Quesada et al., 2009; Álvarez-Yépiz, Martínez-Yrízar, Búrquez, & Lindquist, 2008). Vulnerability is also related to disturbance regimes. Regions dominated by TDF have been historical scenarios of human activities, particularly agriculture and cattle-raising (Challenger, 1998; Trejo & Dirzo, 2000).

Given the high loss rates of Mexican TDF (Trejo & Dirzo, 2000), it is crucial to understand the dynamics and patterns of LULCC in the regions where they occur. Comparative analyses may be particularly enlightening, considering the high ecological, socio-economic, political, and cultural heterogeneity present in Mexico and other tropical countries. This study analyses comparatively LULCC processes and dynamics in two TDF-dominated regions located in contrasting geographical settings, for a period comprising 30 years.

2. Material and methods

2.1. Study sites

We conducted LULCC analyses for three *municipios* (administrative units of lower hierarchical level than state) in the southern portion of the Isthmus of Tehuantepec, Oaxaca State, and in one *municipio* in the central region of the Mexican Volcanic Belt, in Morelos State (Fig. 1). The combined area of the *municipios* in Oaxaca (Ciudad Ixtepec, Asunción Ixtaltepec, and Barrio de la Soledad) spans 120,941.5 ha, whereas the *municipio* in Morelos (Tepoztlán) has a smaller extent (24,226.6 ha). Though these regions share the predominance of tropical dry forests, the Oaxacan site also encompasses savannas, pine and oak woodlands, and semi-evergreen and evergreen seasonal forests, while in Tepoztlán temperate forests, scrub and grasslands also occur.

Socio-historical development differs considerably between the two regions. In the Oaxacan *municipios* population belongs mostly to the Zapotec ethnic group; agriculture and cattle-raising have been historically important economic activities, but also the Isthmus of Tehuantepec has been subjected to large-scale development investment as a geostrategic zone, since the late 19th century, with the construction of the Trans-Isthmic Railroad (Coronado Malagón, 2009). Today, more recent large-scale development projects, financed by public and private national and multinational sectors, shape this geostrategic region as a commerce and commodity hub, and as a petrochemical and wind energy producer, transforming the socio-economic dynamics of the region, creating job and income opportunities, but also local socio-environmental conflicts (Alonso Serna, 2017; Prévôt-Schapira, 2009). This region is also characterized by strong and long-standing social movements, associated with peasants' territorial rights and political democracy (Campbell & Tappan, 1989). In the three *municipios*, local forest conservation initiatives have resulted in voluntary conservation areas, which are small-size, scattered areas with a high potential for biodiversity conservation, officially registered by the Mexican Commission of Natural Protected Areas (CONANP), but managed and preserved by local communities (Martin et al., 2011; Meave, Romero-Romero, Salas-Morales, Pérez-García, & Gallardo-Cruz, 2012).

Unlike the Oaxacan localities, population in Tepoztlán (Morelos) is dominated by the Nahua ethnic group; agriculture and cattle-raising have lost importance there due to the strong development of tourism, driven both by public policies and its vicinity to the large urban areas of Mexico City and Cuernavaca (Paz, 2005). Consequently, immigration and urbanisation have grown substantially in recent decades. Most of Tepoztlán's territory is included in two federal protected areas (PA): El Tepozteco National Park and Chichinautzin Biological Corridor, with the latter spanning through the central part of the Mexican Volcanic Belt (CONANP 2001, 2008). Tepoztlán has also a long-standing history of social movements, mostly focused on the defence of territorial and environmental rights (García & Alberto, 2008).

2.2. Remote sensing

We assessed LULCC dynamics through the thematic classification of mid-resolution imagery (Landsat) for each decade between 1985 and 2005, and for five-year periods between 2005 and 2015. Table 1

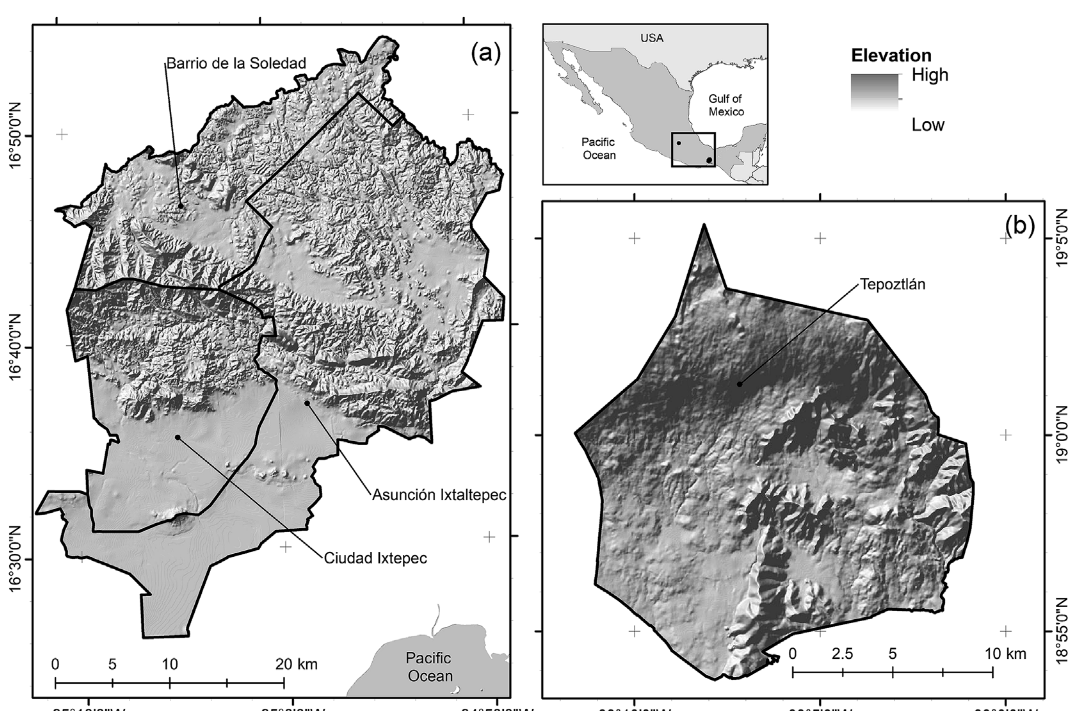

Fig. 1. Geographical location of study sites. *Municipios* included in Oaxaca State (a; southeastern Mexico) and Morelos State (b; Central Mexico).