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Can wildlife management units reduce land use/land cover change and climate change vulnerability? Conditions to encourage this capacity in Mexican municipalities

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ABSTRACT

Climate change and land use/land cover change (LULCC) are associated with local vulnerability, defined as the intrinsic tendency of a system to be negatively affected by an event or phenomenon, but this can be ameliorated by ecosystem conservation. In Mexico, extensive Wildlife Management Units (eWMUs) are environmental policy instruments designed to promote ecosystem conservation and rural development via the sustainable use of wildlife by local populations. However, evidence of the successful reduction of LULCC by eWMUs is contradictory, and there has been no investigation into their potential as an action to promote climate change adaptation. In this study, we focused on the overall patterns of LULCC associated with eWMU throughout the country and examined strengths and weaknesses of eWMUs as policy instruments to address climate change. In particular, we analyzed how differences in areas with eWMUs influence LULCC and assessed how eWMUs could contribute to reducing vulnerability, particularly in double exposure municipalities. We calculated the percentage of eWMUs per municipality from official information and estimated LULCC from *vegetation* changes between 2002 and 2011. We then used the Kruskal-Wallis test to find statistically significant differences in *vegetation* changes based on the percentage of eWMUs and performed between-group comparisons using a *post hoc* Dunn test. Although Mexico has 2456 municipalities, only 37% have eWMUs. Furthermore, 64% of Mexico's municipalities have lost *vegetation* cover, whereas only 36% have either gained *vegetation* or remained stable. In municipalities that recorded changes to the *vegetation*, those changes were, overall, minimal and involved less than 10% of the total area of those municipalities. In general, municipalities with less than 10% of their total area dedicated to eWMUs experienced higher *vegetation* losses than those with more than 10% of their total area dedicated to eWMUs. We detected twelve double exposure municipalities, *i.e.* they are vulnerable to climate change and lost more than 10% of their *vegetation*. Double exposure municipalities dedicated less than 2% of their total area to eWMUs as well. Our results suggest that incremental increases in the area dedicated to eWMUs may reduce LULCC and protect *vegetation*, particularly in double exposure municipalities. Based on the literature, some ecological, economic and socio-cultural factors may determine the success of eWMUs and strongly impact LULCC. Therefore, additional efforts must be made to enhance our understanding of ecological and

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climatic processes; habitats must be monitored using a standardized methodology; biological, cultural, economic and institutional diversity must be incorporated into the planning, implementation and monitoring of eWMUs; and agreements must be established to strengthen social organization and human capital. Taking all this into account, we suggest that reducing vulnerability and improving double exposure areas by increasing the number and interconnectedness of eWMUs could represent an effective strategic approach at the municipal level to address LULCC and climate change.

1. Introduction

The vulnerability of terrestrial ecosystems to global change and actions to reduce such vulnerability are current scientific and policy priorities. Vulnerability is defined as the inherent tendency of systems to be negatively affected by particular events or phenomena (Shitangsu 2013). Two main drivers of vulnerability have been identified: climate change and land use/land cover change (LULCC). Climate variability, extreme climatic events, and LULCC adversely affect habitat size and human settlements, whereas long-term climate change could negatively impact habitat quality, food security and human health. Researchers have warned of the irreversibility of current anthropogenic climate changes (Oreskes, 2004) and their harmful effects on species, such as shifts in distributions, disruptions to ecological interactions (Blois et al., 2013; Warren et al., 2013; Cramer et al., 2014; Oppenheimer et al., 2014), constraints on adaptive capacity in fragmented environments (Nuñez et al., 2013), and known species extinction rates ranging from 18% to 35% (Thomas et al., 2004). Indeed, these effects will have significant consequences for ecosystem function, many of which will critically impact humans.

Mantyka-Pringle et al. (2015) used models incorporating the interactions between LULCC and climate change and found more intense impacts from LULCC on certain biological groups compared to models that only include climate change, and Myers et al. (2013) demonstrated that human health and wellbeing are more heavily impacted when these two phenomena interact locally. It follows that there are positive feedbacks between LULCC and climate change (Laurance and Williamson 2001; Laurance 2007), and synergisms between the impacts of these two processes are defined as double exposure (*sensu* O'Brien and Leichenko, 2000). Thus, reducing vulnerability in double exposure sites by implementing effective policies and management practices is a priority (Alley et al., 2003; O'Brien et al., 2004; Shitangsu 2013).

In contrast to climate change, LULCC can be constrained or even eliminated when the public is committed to change. Therefore, appropriate management mechanisms must be ascertained and implemented, and degraded land must be improved via ecological restoration and conservation. The implementation of these strategies could significantly reduce the negative impacts of climate change by mitigating greenhouse gases (GHG), promoting carbon sequestration (IPCC, 2014), regulating local and regional climates by conserving vegetation (Mahmood et al., 2014) and promoting adaptation through ecosystem conservation (ecosystem based adaptation approach, EbA). In this context, the benefits of ecosystem functions that provide the "life support systems" that are essential for people to adapt to climate change impacts by protecting livelihoods, alleviating poverty, and improving resiliency are recognized worldwide. Hence, biodiversity conservation, LULCC reduction, and the ecological restoration of degraded lands are highly recommended as climate change adaptation (Munang et al., 2013) and sustainable development strategies.

In the last decade, Latin America has experienced an overall loss of vegetation (Aide et al., 2012), but also it has increased in certain municipalities due to forest recovery, reforestation and woody encroachment (Clark et al., 2012). Similarly, estimates of annual deforestation rates in Mexico varied from 1% to 10.4% for the period from 1976 to 2002 and depended on the methods used as well as the vegetation types and location (Velázquez et al., 2002). Nevertheless, Rosete-Vergés et al. (2014) noted that the overall rate of deforestation in the country was reduced because of contemporary environmental policy instruments. The establishment of protected areas is currently the most widespread conservation mechanism to minimize the negative impacts of LULCC and climate change. Evidence of the positive impact of protected areas was provided by Leverington et al. (2010), who demonstrated the contribution of protected areas to biodiversity maintenance and human wellbeing, but other mechanisms and instruments have also been proposed. One such plan is the establishment of Wildlife Management Units (WMUs), which has been underway in Mexico since 1997.

Mexico is located between 32°43′06″ and 14°32′27″ north latitude and 118°27′24′ and 86°42′36″ west longitude, and it borders the United States of America to the north and Guatemala and Belize to the south. Mexico is located between the Nearctic and the Neotropical biogeographical regions, and it is one of the more megadiverse countries in the world, both biologically and culturally. One of the main conservation concerns for the country is to have a spatially explicit system to document biodiversity and population processes, and the National Institute of Statistics and Geography of Mexico (Spanish acronym, INEGI) generates official cartographic information in the form of thematic maps as well as the administrative boundaries. INEGI provides sequences of "Land Use and Vegetation" maps scaled at 1:250,000, specifically Series I (1985), Series II (1993), Series III (2002), Series IV (2007), and Series V (2011), all of which are vectorial databases that show, *inter alia*, eleven types of natural vegetation cover around the country: four types of tropical forest, tree types of temperate forest, xerophyte shrub, grassland, hydrophyte vegetation and other types of vegetation.

INEGI also generated a Geostatistical Municipal Framework (GMF), a vector database that includes 2456 polygons that delimit the municipalities of Mexico (INEGI, 2010). Municipalities are the smallest geographical and administrative units that can plan, manage, and make decisions regarding the participation and well-being of their inhabitants (Ladrón de Guevara and García-González, 2007). Bonilla-Moheno et al. (2013) classified the Mexican municipalities according with the dominant land tenure regime as private property (where there is only one owner) and social property (where the community owns the land and the resources are managed by the entire community). The municipalities in Mexico are classified according to an index of marginalization based on economic and population indicators. This index classifies the municipalities in five categories of poverty ranging from very low to very high (SEGOB, 2010).

Mexico is party to the United Nations Framework Convention on Climate Change as well as the Convention on Biological Diversity (CBD), and it has developed some legal instruments to achieve national and international compromises. The Special Climate Change Program identified 319 municipalities as being the most vulnerable to climate change (MMVs) in the country, based