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Estimation of human induced disturbance of the environment associated with 2002, 2008 and 2013 land use/cover patterns in Mexico

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ABSTRACT

Land use/cover types have an associated level of human induced disturbance of the environment. Previous studies in Mexico document the extent of land use/cover types and their changes over time. This information is important but not sufficient to support land use planning and environmental conservation decisions. This article explores the informational value of generating a numerical quantification of the level of human induced disturbance of the environment associated with land use/cover classes and their patterns at the national and state levels in Mexico. Estimates for land use/cover patterns existing in 2002, 2008 and 2013 are created. A disturbance scale created in a previous study was adapted and calibrated for 14 broad land use/cover types through domain expert opinions. The results indicate that the disturbance of the environment is increasing at the national level, but at a significantly slower rate between 2002 and 2008 (1.9%) and 2008–2013 (0.8%). Six states report a decrease in total environmental disturbance. A land use/cover transition analysis conducted for these states indicates a large proportion of transitions from anthropogenic land use/covers to natural ones.

1. Introduction

Human activities have touched nearly every location, component, and process in the biosphere (Goudie, 2013). World wide and in Mexico, the need to provide food, fiber, water, and shelter to a growing population with higher demands on the environment has driven changes to forests, agricultural lands, waterways, and air (Newbold et al., 2014; Smith et al., 2010; Tu, 2011). Croplands, pastures, plantations, and urban areas have expanded in recent decades, accompanied by large increases in energy, water, and fertilizer consumption, as well as considerable losses of biodiversity (Foley et al., 2005; Newbold et al., 2014; Smith et al. 2010; UN, 2011; Velazquez et al., 2010). These changes are potentially undermining the capacity of the environment to support ecosystem components, functions, and the provision of diverse goods and services in the long run (Foley et al., 2005; Matthews, Payne, Rohweder, & Murray, 2000). There is an urgent need for information that would allow us to better understand and manage the short-term and long-term environmental effects of land use/cover patterns and their transitions over time.

Past studies in Mexico have focused on estimating disturbance levels on specific ecosystems (Calderón-Aguilera et al. 2012), generating statistics documenting the disappearance of forests and natural areas (FAO, 2012; Merlin-Uribe et al., 2013; Peralta-Rivero, Contreras-Servin, Galindo-Mendoza, Caussel, & Algara-Siller, 2014; Velázquez et al., 2010), or estimating the level of anthropogenic pressures on those areas (Moreno-Sanchez et al., 2012). Others have attempted to find some of the drivers of land use/cover changes (Bray, Ellis, Armijo-Canto, & Beck, 2004; Currit & Easterling, 2009; Gómez-Mendoza, Vega-Peña, Ramírez, Palacio-Prieto, & Galicia, 2006; Jaimes, Sendra, Delgado, & Plata, 2010; López, Bocco, Mendoza, Velazquez, & Aguirre-Rivera, 2006; Mas et al.,

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2004; Velazquez et al., 2010), or quantify the impacts of these changes on hydrological systems at the watershed level (Mendoza, Bocco, López, & Bravo, 2010, 2011).

While these data and studies successfully identified land use/cover patterns and their changes, or provide valuable information for specific areas and ecosystem functions, they don't inform us about the degree to which human activities may be affecting the environment as a whole at the national level. The purpose of this study is to generate a first approximation to the numerical quantification of the level of human induced disturbance of the environment associated with land use/cover classes and their patterns at the national and state levels in Mexico. We generate these disturbance estimates for the land use/cover patterns existing in 2002, 2008 and 2013. These dates correspond to the national land use/cover information contained in the Series III, IV and V data sets published by the National Institute of Statistics and Geography (INEGI http://www.inegi.org.mx/) in Mexico. National geographical data sets such as this identify the extent and location of different land use/cover classes (Niño and Victoria, 2013).

The methodology used in this study is based on the work of Brown and Vivas (2005). These authors developed a Landscape Development Intensity Index (LDI) that quantifies the impact of human activities on the environment based on land use/cover type. This technique translates land use/cover types into numeric values representing the level of human induced disturbance of biological, chemical and physical processes of surrounding lands or waters. Disturbances come in the form of air- and water-born pollutants, physical damage, changes in the environmental natural conditions, or a combination of all of them (Brown & Vivas, 2005). The more developed a landscape, the greater the intensity of impacts. In our study, the LDI scale created by these authors was modified and adjusted for 14 broad land use/covers in Mexico. The results presented demonstrate the importance and informational value of a numerical picture of the level of human induced disturbance of the environment associated with land use/cover patterns.

The information generated can be beneficial in a number of ways. First, it provides a quantitative representation of human induced disturbance of the environment that conveys useful information beyond the number of hectares gained or lost by specific land uses/covers. Second, a scale quantifying the level of disturbance associated with each land use/cover can be used as a monitoring tool to assess the implications and impacts of current land use/cover patterns and their changes over time. Third, once fully calibrated and fined tuned, the disturbance scale can be used to assess impacts at different geographical and temporal scales. Integration of this multi-scale information will better support environmental management, land use planning and conservation decisions in Mexico.

2. Methods

The conditions of landscapes and the ecological communities within them are strongly related to levels of human activity. Land use/cover patterns and change are driven by the interaction between sociocultural, economic and environmental systems. Conversely, land use/cover patterns and changes have a potentially large impact on the physical and social environment (Veldkamp & Verburg, 2004; Verburg, Neumann, & Nol, 2011). Several studies have attempted to assess the level of impact on the environment produced by different land use/covers at different scales and in different processes and contexts (Estoque & Murayama, 2012; Koellner & Scholz, 2007; Nuissi, Haase, Lanzendorf, & Wittmer, 2009; Mendoza et al. 2010; Pualeit, Ennos, & Golding, 2005; Tang, Engel, Pijanowski, & Lim, 2005). Yet, there are few studies that have quantitatively evaluated the levels of human disturbance on the environment (Brown & Vivas, 2005; Theobald, 2013).

The methodology used in this study is based on the work of Brown and Vivas (2005). According to these authors, land use/cover can be used to quantify the degree of human induced disturbance of the environment. The degree of human disturbance is estimated using the amount of non-renewable energy (i.e. electricity, fuels, fertilizers, pesticides, irrigation, public water, etc.), measured in solar energy joules, required to sustain a particular land use/cover. The higher the level of human activities, the greater the disturbance and impact on natural ecological systems and processes (imagine a city); conversely, a natural landscape (e.g. a natural forest) would have low levels of human activity and hence less human disturbance to ecological systems and processes. In between these two extremes, there is a gradient of possible levels of human induced disturbance of the environment applicable to various land use/cover types (Brown & Vivas, 2005). Brown and Vivas (2005) applied this approach to define a Landscape Development Intensity Index (LDI) that uses a 1 to 10 scale to assign values to potential human disturbance (see Appendix 1).

The following sections present the details of the basic steps used in this study. Briefly they involve: 1) Grouping the original INEGI land use/cover classes into broader land use/cover classes that are suitable for the purpose of this study; 2) adding the location of major roads and population centers to the broad land use/cover classes to better account for human presence and activities; 3) assigning a value of human disturbance of the environment to each of the broader land use/cover classes, roads and population centers identified; and 4) calculating statistics of the values of human disturbance of the environment at the national and state levels.

2.1. Data sets

The data sets used in this study were the Series III (2002), Series IV (2008) and Series V (2013) land use/cover data sets produced by the National Institute of Geography and Informatics (INEGI) in Mexico. Each of these data sets is at a scale of 1:250,000 and is provided in the Lambert Conical Conformal projection. INEGI has homogenized the land use/cover classes in these layers, hence temporal changes can be evaluated.

After identifying the broader land use/cover classes as described in the next section, a land use/cover layer ready for analysis was created for each date (2002, 2008, 2013) by combining the land use/cover layer with a layer of roads for 2013 and the point location of population centers (approximately 200,000 of them) reported in the 2010 INEGI national census. The latter two layers were incorporated into the analysis to improve the representation of human activities and impact on the landscape (e.g. Coffin, 2007). The roads information was obtained from the Mexican National Institute for Transportation (IMT – http://www.imt.mx/), it is the most comprehensive and up-to-date information available and only includes major paved roads; no information is available for dirt roads at the national level. The 2013 road network was incorporated into the 2002 and 2008 land use/cover layers given that, few major paved roads have been built since those dates across the country. Furthermore, the density of these roads is low across all dates and hence has little impact on the calculations of total and average disturbance values at the state and national levels. The point location of the population centers enhances the information contained in the INEGI Series, which only contains polygons representing sizeable urban areas. This layer was included to help account for the presence and impact of humans in areas that might otherwise appear as pristine natural land covers (e.g. forests). The point layer was obtained from the National Commission for Biodiversity (CONABIO) (http://www.conabio.gob.mx/informacion/gis/) because they have processed the original INEGI census data to