Applied Geography 94 (2018) 58–70

Contents lists available at ScienceDirect

Applied Geography

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

Emerging trends of tropical dry forests loss in North & Central America during 2001–2013: The role of contextual and underlying drivers

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ARTICLE INFO

Keywords:
Deforestation
Tropical dry forests
Mexico
Central America
GIS

ABSTRACT

Historical anthropogenic pressures on tropical dry forests (TDF) have led to the loss of more than 50% of its potential coverage worldwide. However, information on the temporal and spatial dynamics of TDF deforestation or disturbance is scarce. In this study, we present a national and sub-national level assessment of TDF loss patterns in Mexico and Central America at high spatial and temporal resolution using remote sensing and GIS technologies. We used the Global Forest Change (GFC) dataset published by Hansen et al. (2013) which shows detected forest loss at 30-m pixel resolution at interannual rates from 2000 through 2013. We analyzed TDF loss within a peer reviewed moderate resolution map of TDF extent based on 2004 satellite imagery, eliminated potential sources of errors and enforced all polygons to correspond to forest loss only within TDF dominated cover. We analyzed trends in the magnitude of deforestation (total forest loss area) and TDF loss patch size as well as density of forest loss across the region. We also investigated the spatial pattern of increasing or decreasing temporal trends of forest loss by applying a space-time hotspot analysis. For the 2001–2013 period, we identified five areas where TDF loss was high and had the tendency to increase; while widespread low TDF loss with the tendency to decrease was found across most Central America countries and most of the Pacific coast of Mexico. Contextual and underlying causative factors vary, conforming to cultural and socioeconomic differences across the region, with rural migration, small-scale agricultural expansion, agricultural intensification, oil palm expansion and cattle ranching amongst the main causes of TDF conversion.

1. Introduction

Tropical forests have undergone an unprecedented rate of loss in the last century driven by human demographic, social and economic pressures (Achard et al., 2002). And while most tropical forests are under threat, it is the tropical dry forest (TDF) ecosystem the one that has lost most of its historical coverage becoming the most endangered tropical ecosystem (Janzen, 1988; Miles et al., 2006). It is estimated that TDF expand for approximately 1,1 million km^2 across the world's tropical region, with more than half of its extent located in the Americas (Miles et al., 2006). According to Portillo-Quintero and Sanchez Azofeifa (2010), the potential extent of TDFs in North and Central America, South America, and the Caribbean islands is approximately 1,520,659 km^2 while the current extent is actually 519,597 km^2. Such finding indicates that the TDF has suffered the loss of 66% of its historical potential cover in the region. Human territorial planning for development in the neotropics have historically undermine the potential of this ecosystem to sustain an important diversity of plant and animal species, to function as a source of pollinators for crops and to provide watershed stability, soil conservation, and other ecosystem services.

Drivers of deforestation in TDFs can be very different between countries and within countries, but the main general driver of deforestation is unequivocally intensive anthropogenic disturbance. According to Fajardo et al. (2005), the tendency for TDFs to have relatively flat terrain, fertile soils, a seasonality in rainfall that allows for short-cycle crop agriculture, a more suitable climate for livestock, low suitability for mosquitoes that spread diseases, and lower overall biomass that facilitates clearing are all the primary reasons that human populations have an affinity for TDFs. Many resources that are useful to human populations, not only in rural areas, but urban as well, are found in TDFs: plants used for food, beverages, condiments, construction materials, firewood, medicinal/herbal remedies; animals for hunting; and shade and fresh air for locals to enjoy (Anaya et al., 2006; Balvanera et al., 2011; Bye, 1995; Castillo et al., 2005; Portillo-Quintero et al., 2014).

Tropical dry forests remnants currently located in North and Central America are especially endangered. There are seven countries in the N

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https://doi.org/10.1016/j.apgeog.2018.03.011
Received 27 January 2017; Received in revised form 14 October 2017; Accepted 15 March 2018
0143-6228/

& C America region sharing twelve different TDF ecoregions with the majority of these located within Mexico. With the exception of Yucatan dry forests which extend for more 27,000 km^2 representing 5% of the TDF in the Americas, most of TDF remnants in the region are embedded in highly fragmented landscapes with significant pressure from agricultural, tourism and urban development and low degrees of protection (Miles et al., 2006; Portillo-Quintero & Sanchez Azofeifa, 2010). Nicaragua, Honduras, Guatemala and Panama in particular, have roughly 16,000 km^2 of TDF from a potential coverage of approximately 75,000 km^2 (approximately 25% of the potential extent) with none of these remnants being currently under strict protection (Portillo-Quintero & Sanchez Azofeifa, 2010). Furthermore, Mexico holds about 180,000 km^2 of TDF, but only around 0.2% of its extent is protected. El Salvador only protects 0.3% and Costa Rica, which has been a champion for biodiversity conservation for decades, protects around 15% of its TDF extent.

Protecting the TDF remnants of N&C America and implementing policies to promote the conservation of intact and secondary dry forests will pose a significant challenge in the years to come. Baseline information on the ecosystem conservation status such as extent, geographical distribution, level of fragmentation and level of protection has been achieved using remote sensing at coarse geographic scales producing data relevant for understanding regional patterns in the conservation status of TDF (Miles et al., 2006; Portillo-Quintero & Sanchez Azofeifa, 2010; Eva et al., 2004; Giri & Jenkins, 2005). Remote sensing techniques have been applied to estimate deforestation rates and to understand the spatio-temporal distribution and extent of early, intermediate and late successional forests (Arroyo-Mora, Sánchez-Azofeifa, Kalácska, & Rivard, 2005; Fajardo et al., 2005; Gasparri and Grau, 2009; Kalacska et al., 2005). These studies have been traditionally focused in specific ecoregions or study sites at finer geographic scales. Providing measurements at geographic scales that are relevant to local or regional decision makers is essential for identifying localities where TDF is being cleared at alarming rates and conservation actions to stop further loss is needed; or areas where deforestation is low and conservation actions could focus on achieving landscape level sustainability.

The implementation of annual or monthly forest monitoring systems based on remote sensing with standardized measuring, reporting and validation (MRV) protocols that directly inform national and local forest management officials has the potential to help decreasing pressure in TDF deforestation hotspots and conserve areas that are experiencing TDF regrowth. Currently, with the exception of the PRODES and DETER systems of the Brazilian Space Agency (INPE), such national forest continuous monitoring systems are lacking in tropical countries. Tropical countries in Latin America have made great advancements in achieving local forest mapping capabilities, but there is still a need for forest cover monitoring capabilities at higher temporal resolutions (Romijn et al., 2012). In North and Central America, national programs for continuous monitoring of tropical forest cover provide decadal or bidecadal trends in deforestation (CONAFOR, 2012; ICF, 2016; Grupo Interinstitucional de Monitoreo de Bosques y Uso de la Tierra, 2014; INAFOR, 2009; Programa REDD/CCAD-GIZ - SINAC, 2015; ANAM, 2012; MARN, 2014). These are intended to inform policy makers for long term planning in natural resources management. Only maps produced by Mexico and Costa Rica environmental authorities include vegetation classes that allows for the distinction between TDF and other types of vegetation. Methods used across countries vary and therefore, using national forest inventories for obtaining region-wide estimates of TDF deforestation products will provide inaccurate, regionally inconsistent and incomplete results.

In a recent effort to provide global continuous fine resolution forest cover change products, the Global Forest Watch (GFW) created a data web portal that provides users with high-resolution datasets (minimum mapping unit of 30 m) of identified areas of tree cover loss for all years between 2001 and 2013. This dataset was produced by combining satellite imagery from the USGS Landsat data Archive and image processing in cloud computing (Hansen et al., 2013). Although, the immediate output from the GFW dataset does not include total TDF loss, it allows the opportunity to analyze, after necessary pre-processing, a standardized annual assessment of tree cover loss at regional scales within tropical dry forest ecoregions and assess potential socioeconomic or political drivers behind the patterns observed. In order to address the current need to understand spatio-temporal trends of TDF loss in North and Central America at finer resolutions, we adapted the GFW forest cover change products to conform with our definition of TDF, eliminating potential misclassification errors (changes in biomass of agricultural crops and plantations) and subsequently analyzed trends in tree cover loss within the boundaries of the most recent regional published tropical dry forest cover map by Portillo-Quintero and Sanchez Azofeifa (2010). The analysis allowed us to provide basic statistics and use spatio-temporal data mining tools in geographic information systems to detect emerging trends of TDF loss for Mexico and Central American countries at the national level. We examine national and subnational trends in the context of potential causative political and socioeconomic factors over the same study period (2001–2013).

2. Methods

2.1. Study area

Our study area encompasses the TDF dominated land covers in Mexico, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama (Fig. 1). TDF dominated land cover in Mexico and Central American countries are present in twelve different ecoregions: a) the Panamanian dry forest ecoregion which is exclusively distributed in the lower and premontane portions of the Pacific slope in the western side of the Bay of Panama, b) the Central American dry forests ecoregion which includes a fragmented strip of dry forests extending from the Pacific Coast of southwestern Mexico, Guatemala, El Salvador, Honduras and Nicaragua to northwestern Costa Rica, c) the Mexican Dry forest ecoregions of the Pacific Coast which includes the Jalisco dry forests; Balsas dry forests; Bajio dry forests; Chiapas Depression dry forests; Sonoran-Sinaloan transition subtropical dry forest; Southern Pacific dry forests; Sinaloan dry forests; and Sierra de la Laguna dry forests, and d) the Mexican Dry forest ecoregions along the Caribbean sea and the Gulf of Mexico which are the Yucatan dry forests and the Veracruz dry forest ecoregions.

2.2. Global Forest Watch dataset

The GFW forest loss/gain dataset has been made available for visualization and download through the www.globalforestwatch.org interactive portal. This dataset was published in 2013 containing high-resolution datasets (minimum mapping unit of 30 m), in grid format, of identified areas of tree cover gain and tree cover loss for all years between 2001 and 2012 produced by Hansen et al. (2013) with only loss allocated annually. This global dataset is divided into $10 \times 10^{\circ}$ tiles. For each tile, the following products are available: tree canopy cover for the year 2000, global total forest loss (2001–2013), global total forest gain (2000–2013) and the "Year of gross forest cover loss event" (lossyear) product which includes the disaggregation of total forest loss to annual time scales. The "lossyear" product is encoded as either 0 (no loss) or else a value in the range 1–13, representing loss detected primarily in the years 2001–2013, respectively. The accuracy of the "lossyear" dataset for the tropics was estimated by its authors to be greater than 83% (Producer's accuracy 83.1%, Overall Accuracy 99.5%). For our analysis, we obtained the corresponding eight tiles of the "lossyear" product covering the extent of the TDF cover layer. We did not analyzed TDF gain since the available product does not disaggregates total forest gain to annual time scales and therefore, does not allow to evaluate dynamic emerging patterns and trends in time.