DETECTING FOREST CHANGE AND DISTURBANCE IN THE TOLEDO DISTRICT

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ABSTRACT

This study utilized Landsat ETM+ imagery from 2009, 2011 and 2012 and new automated remote sensing technique to map and analyze not only forest change but most importantly forest disturbance that occur in the Toledo district from 2009-2012. The results of the forest disturbance and change analysis in the Toledo district show that the total forest cover in the period of 2009-2011 was 308710.38 ha of 425214.58 ha, or 74.94% forest cover. Non-forest cover was 21.96%, while change and disturbance were 3.08% and .02% respectively. For the period of 2011-2012 the results show that the total forest cover was 72.60%, non-forest was 24.43% and disturbance and change cover were .18% and 2.79% respectively. From the results generated by the spatial analysis it can be seen that protected areas are effective to safeguard against forest change but not so effective to safeguard against forest disturbance. The study also highlights the extensive forest change and disturbance that can occur when there is an increase in demand, internationally, for forest timber species from developing counties where monitoring and enforcement capacities are limited. The maps and statistics generated in this study are able to pinpoint the hot spots of where major forest change and disturbance occurred. The methodology presented in this study can be used by NGO`s, CBO`s and GOB`s that are involved in forest monitoring and management to more effectively allocate resources to threatened forested areas.

INTRODUCTION:

In Belize, with the free availability of Landsat images, a large number of studies have been conducted to evaluate local and national levels of forest change. Forest cover and deforestation data indicate that Belize's deforestation rate between 1980 and 2010 was approximately 25,000 acres / year (0.6%) (Cherrington, Ek et al, 2010). Although many studies have assessed deforestation and forest cover in Belize very few have estimated forest disturbance given that, forest disturbance is more complex to assess from satellite imagery, and rates of forest degradation and fragmentation are also difficult to obtain (Panta, Kim et al, 2008). Toledo's forested lands are under increasing pressures from anthropogenic activities that lead to forest change and disturbance. In 2010-2012 the Toledo district forest was intensively harvested of its rosewood stand legally and illegally, Oil exploration and the construction and paving of the Jalacte highway started. Over time, these forest disturbances may cause forest degradation if not mitigated, which will result in limiting the forest's ability to provide environmental services and the extracted resources themselves (Robinson, Albers et al, 2008).

If forest change and disturbance continues unabated in the area this will have a great impact, not only on the environment but on the livelihood of the Mayan communities, which depend on the forest goods and services.

Therefore, identifying forest change but most importantly forest disturbance at different spatial and temporal scales can provide useful information for planning and sustainable management of forests (Panta, Kim et al. 2008).

This study utilized Landsat ETM+ imagery from 2009, 2011 and 2012 and new automated remote sensing technique to map and analyze not only forest change but of utmost importance forest disturbance that occurred in the Toledo district from 2009-2012. Also it provide an easy to implement remote sensing and GIS methodology that can be utilized by forest management organizations to monitor, plan, and execute sustainable forest management practices to address current and arising environmental problem.

STUDY AREA

Toledo, the southernmost district, is the centre of Belize's Mayan population, descendants of the Maya civilization that flourished throughout substantial parts of Mexico and Central America hundreds of years prior to European colonization in the Western Hemisphere (Anaya, 1998). It is 4,421 square km, roughly 95 km north to south and 40 km east to west (Figure 1). The landscapes in Toledo slopes upwards from the sea westwards to 2,600 feet above sea level and is bisected into two distinct regions: the Maya Mountains and foothills and the coastal plain and floodplains (Marcotte, 2003). In the Toledo District, the milpa slash-and-burn agricultural system has evolved in response to local conditions and provides the Kekchi and Mopan Mayans of the region with most of their subsistence needs (Emch, Quinn et al, 2005).

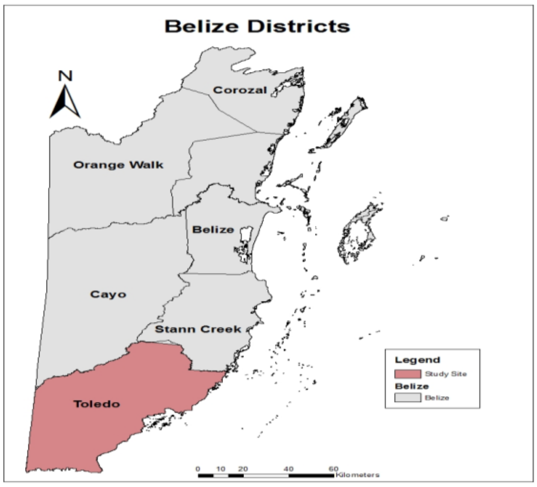

Figure 1: Study Site

The population in Toledo in 1991, 2000 and 2010 was 17,439, 23,297 and 30,538, respectively. The poverty assessment in the country indicates that Toledo is the district with the highest percentage of household an individual indigence of 37.5 % and 49.7 %, respectively (Halcrow and NAT, 2010). With indigence for household almost four times the national average.

METHODOLOGY

In this study forest change and disturbance will be mapped by analyzing Landsat satellite imagery, which is available from the USGS global archives, from 2009, 2011, 2012 (Table 1). In this research forest is defined as pixels where the photosynthetic vegetation cover is ≥ 80 and where bare substrate cover fraction is < 20. Non-forest is referred to pixels where the photosynthetic vegetation cover is < 80 or where the bare substrate cover fraction is > 20 (Asner, 2009).

Table 1: Landsat scenes used in the forest disturbance and change analysis

Imagery	Satellite	Spatial Resolution	Path	Row	Date
2006, 2009, 2010	Landsat-7	30 m	19	49	April 14, 2009 (*working I*) ***January11,2010 (Filled)*** March 21, 2006 *(working II)*
2011	Landsat-5	30 m	19	49	March 27, 2011
2011, 2012	Landsat-7	30 m	19	49	March 21, 2012 *(working I)* ***April 22, 2012 (Filled)*** November 30, 2011*(working II)*

Filling the Gaps of Landsat 7 ETM+ image

On May 31, 2003, the scan-line corrector (SLC) for the ETM+ sensor on board Landsat 7 failed permanently, resulting in imagery with data gaps which comprise about 22% pixels of these images (Chen, Zhu et al, 2011). Except for 2011 imagery, it was necessary to fill the gaps that resulted from the SLC failure. 3 Landsat 7 ETM + images were used to generate filled images for 2009 and 2012 (Table 1). The data from the working images I and II was used to fill the pixels in the filled image.

Pre-processing and Classification of Satellite Imagery

The pre-processing stage for satellite images consists of two basic procedures: the conversion Digital Numbers (DNs) of initial pixels into surface reflectance and the geometric co-registration in order to be spatially comparable to pixel basis (Kolios and Stylios, 2013). The above mention requirements, were done utilizing CLASLITE algorithms which take the raw filled Landsat 7 ETM satellite imagery and produce forest cover change images (Asner, 2009), for 2009, 2011, 2012.

Post-Processing

Following the classification of the CLASlite algorithms, post-processing was performed on the image outputs. The forest cover layers generated for 2009, 2011 and 2012 by the Claslite algorithms were vectorized. All areas that were less than .25 hectares were eliminated from the datasets. The vector layers were reclassified into four classes water, non-forest, cloud, and forest. The cloud pixels and water pixels for each dataset were reclassified into forest or non-forest. The datasets were then re-classified into two classes 1: Forest and 2: Non-Forest. These where rasterized and converted to ENVI classification datasets and change statistics were conducted on the 2009-2011 and 2011-2012 datasets.

Accuracy Assessment

Accuracy assessment is an important feature of land-cover and land-use mapping, not only as a guide to map quality and reliability, but also in understanding thematic uncertainty and its likely implications to the end user (Treitz and Rogan, 2004). For this study ancillary data together with 300 ground truth points for each year were used to develop error matrices. Overall accuracy and Kappa Coefficient for 2009, 2011 and 2012 were 92.33%: .78, 85.66%: .63 and 83.66%: .61 respectively. The overall accuracies, producer accuracies, class accuracies, and user accuracies, exceed the USGS' suggested threshold of 80% cited by Cherrington 2010 which is usually considered acceptable.

RESULTS AND DISCUSSION

The results of the forest disturbance and change analysis in the Toledo district show that the total forest cover in the period of 2009-2011 was 308710.38 ha of 425214.58 ha, or 74.94% forest cover. Non-forest cover was 21.96%, while change and disturbance were 3.08% and .02% respectively. For the period of 2011-2012 the results show that the total forest cover was 72.60%, non-forest was 24.43% and disturbance and change cover were .18% and 2.79% respectively. The results show that in 2011-2012 there was an increase in non-forested areas and disturbance of 2.47% and .16% respectively and a decrease of forest of 2.34% (Figure 2).

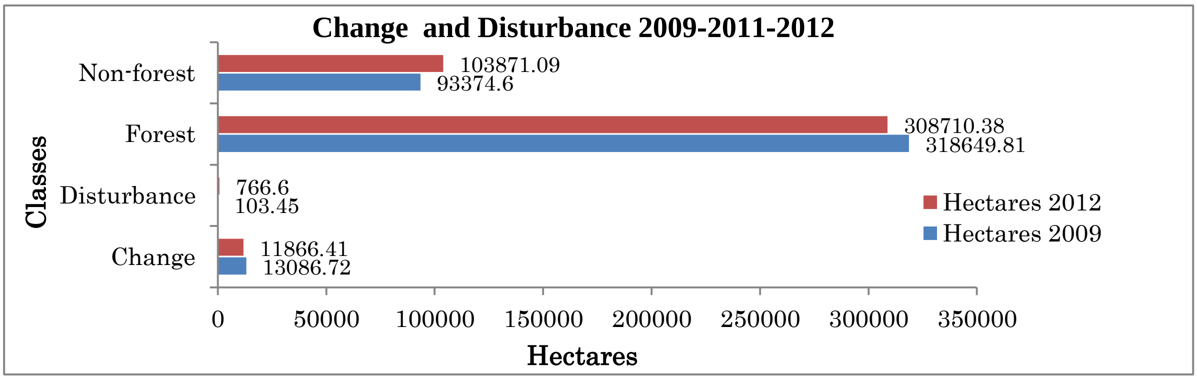

Figure 2: Forest Change and Disturbance 2009-2011-2012

For this study secondary forest regrowth that occurred before 2009 was classified as forest but secondary forest regrowth that occurred between 2009 and 2012 was classified as non-forest.

ArcGIS platform was used to overlay the disturbance and change data layers for 2009-2011 and 2011-2012 and the 2010 protected areas layer to determine where major change and disturbance occurred. This spatial analysis shows that in the period of 2009-2011 out of the 103.45 ha of disturbance 79. 29% occurred in areas that are under no protection status, 11.93% occurred in National Parks and 5.07% occurred in Forest Reserves. In 2011-2012 out of the 766.6 ha of disturbance 60.85% occurred in areas that are under no protection, 33.9% occurred in Forest Reserves and 3.15% occurred in Wildlife Sanctuaries (Figure 3).

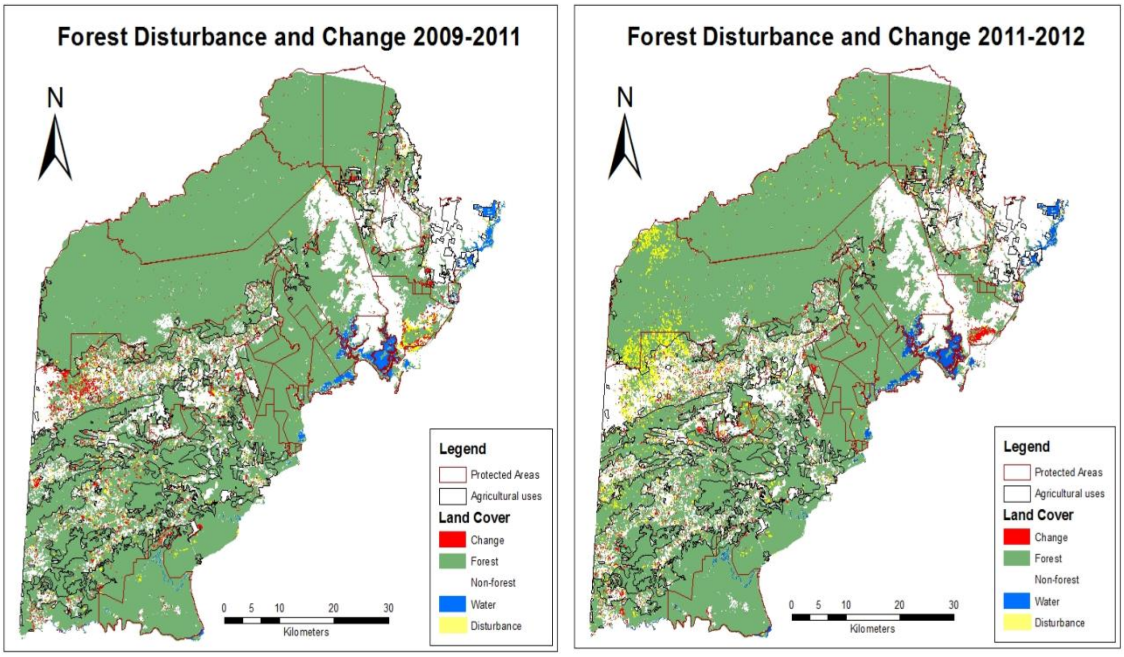

Figure 3: Protected Areas and forest disturbance 2009-2011-2012

The Spatial analysis also indicate that in the period of 2009-2011 out of the 13086.72 ha of change 83.56% occurred in areas that are under no protection status, 8.12% occurred in National Parks and 6.4% occurred in Forest Reserves. In 2011-2012 out of the 11866.41 ha of change 74.72% occurred in areas that are under no protection, 11.96% occurred in Forest Reserves and 7.4% occurred in National Parks. From the results generated by the spatial analysis it can be seen that the majority of change and disturbance for the period of 2009-2011-2012 occurred in areas that are not protected. Even though protected areas are effective to safeguard against forest change, this study shows that protected areas are not so effective to safeguard against forest disturbance (Figure 3). In mid-2010-2012 the Toledo forest was under sever pressures as a result of global rosewood demand; thus, there was an increase of illegal activities. China is reported to have imported over 6000 m2 of rosewood (species not specified) from Belize in the period 2010-2102, over half of this in 2012 (Belize, 2013), which correlate with the increase in disturbance inside protected areas during this period (Figure 3).

In order to be able to assess the ecosystems, location and spatial distribution of the major disturbance that occurred during this period, the disturbance and change data layers for 2009-2011 and 2011-2012 were overlaid with the 2011 Belize Ecosystems map. The spatial analysis revealed that in the period of 2009-2011 out of the 103.45 ha of disturbance 45.03% occurred in Agricultural use areas, 36.61% occurred in Lowland broad-leaved wet forest and 7.34% occurred in Wetland. In 2011-2012 out of the 766.6 ha of disturbance 32.96% occurred in areas of Agricultural use, 36.32% occurred in Lowland broad-leaved wet forest and 26.12% occurred in Submontane broad-leaved wet forest (Figure 4).

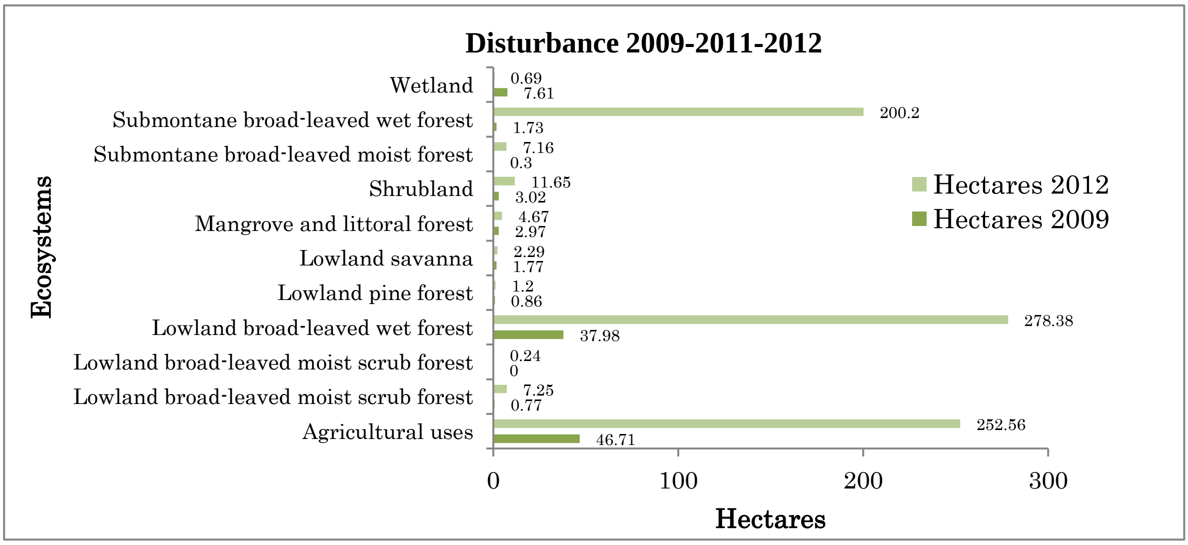

Figure 4: Ecosystems and forest disturbance 2009-2011-2012

The spatial analysis also show that in the in the period of 2009-2011 out of the 13086.91 ha of change 67.17% occurred in Agricultural use areas, 15.5% occurred in Lowland broad-leaved wet forest and 7.49% occurred in Wetland. In 2011-2012 out of the 11866.39 ha of change 53.95% occurred in areas of Agricultural use, 8.26% occurred in Shrubland and 6.99% occurred in Wetland. The disturbance detected by this study particularly in 2011-2012 period are consistent with the habitat distribution of Dalbergia stevensonii (rosewood), which is known to be found in broadleaf evergreen swamp forests (Chudnoff, 1984).

CONCLUSIONS

The main purpose of this study was not to determine the deforestations rates but rather to depict where major forest change and disturbance occurred in the study area as a result of the increased human activities that were reported during the study period. The maps and statistics generated in this study are able to pinpoint the hot spots of where major forest change and disturbance occurred. The methodology presented in this study can be utilized by NGO`s, CBO`s and GOB`s that are involved in forest monitoring and management. In Belize these organizations often operate with limited resources; by utilizing this approach they will be able to efficiently identify and allocate resources to forested areas that are being threatened; thus, being able to more effectively assess and mitigate forest change and disturbance that can lead to the degradation of important forest ecosystems.

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