FOREST COVER AND CHANGE IN BELIZE CIRCA 1990 – 2000 - 2005

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Aguas Turbias Area – Orange Walk District.

Abstract

As part of a regional wide Critical Ecosystems Partnership Fund Project, a forest cover change assessment was conducted utilizing a series of 28.5 m[1] Landsat TM satellite images following a supervised classification of double stacked image composites. As it was not possible to locate cloud free images of the sample years, the closest possible temporal replacements were chosen. Even with these second best options, not all scenes were entirely cloud free. In total, 10 scenes were analyzed (some only partially). For this project, forest is defined as closed canopy, mature natural broadleaf forest and took particular care not to classify secondary growth that was part of an agricultural cycle of slash and burn, as "forest". Also within this definition, pine stands were not classified as "forest" based on their light and open canopy. The study found a steady but very low level of deforestation of approximately 0.5% annually[2]. This figure is substantially lower than found in earlier studies, none of which followed the same methodology.

[1] The actual size of the Landsat TM pixels is 30m, but have been resampled to 28.5m in various cases to preserve detail when the imagery is re-projected. (Source: Lillesand et al 2007: Remote Sensing & Image Interpretation)
[2] With the study having a measured accuracy of 78% before the last round of corrections. No accuracy assessment has been conducted after this last round of corrections.

Introduction

Deforestation, especially tropical deforestation, threatens countless species with extinction and is a major source of anthropogenic greenhouse gas (GHG) emissions (Mittermeier *et al* 2004, IPCC 2007, Mollicone *et al* 2007). Biodiversity and climate change scientists for years have expressed the need for accurate monitoring of regional and global tropical deforestation. Increases in conservation investment, a growing carbon-exchange market and international conventions (e.g. CoP 2004) accentuate the need for such monitoring. The decision by the UN Framework Convention on Climate Change to include credits for reduced deforestation requires countries to precisely monitor deforestation in order to prepare reference scenarios and monitor GHG emissions (UNFCCC 2008).

For Belize, previous assessments of forest/vegetation/land use cover and change were carried out by a number of researchers starting in 1959 (Wright et al.,1959). As satellite images started to become available and with the development of remote sensing techniques, a large number of studies followed (White et al, 1996; Zisman et al, 1998; White et al, 2001; Meerman & Sabido, 2001; DiFiore, 2002; Ek, 2004; Penn et al, 2004; Emsch et al, 2005) These studies followed different methodologies and often focused on limited geographical regions or on specific floristic elements (e.g. Zisman et al, 1998 focusing on Mangroves; DiFiore, 2002 focusing on riparian forest of the Belize River). The current Belize baseline forest cover and change analysis was performed as part of the larger Critical Ecosystem Partnership Fund project, "Refining and monitoring conservation outcomes in Mesoamerica". As such the extend of the greater project included the five southeast states of Mexico (Tabasco, Chiapas, Campeche, Yucatan, and Quintana Roo), Belize and four Key Biodiversity Areas (KBA's) in Guatemala. These areas have all experienced forest loss in recent years and yet, actual estimates of the forest loss have varied greatly. To overcome this variation in reporting, Belize Tropical Forest Studies, with the support of Conservation International (CI) and the Critical Ecosystem Partnership Fund (CEPF) conducted a study to map for Belize the change in forest cover between c.1990, c.2000 and c.2005.

Methodology

For this project, forest is defined as closed canopy, mature natural broadleaf forest. There exist many definitions as to what constitutes "forest", but more and more, forest cover is being defined by what can be detected using remote sensing in combination with the methodologies used. Forest cover and change was mapped by analyzing Landsat satellite imagery from circa 1990, 2000 and 2005 (table1). Most of the images for circa 1990 and 2000 were obtained at no cost from the University of Maryland's Global Land Cover Facility (http://glcf.umiacs.umd.edu). Imagery for circa 2005 was purchased directly from the USGS. To account for the SLC failure that occurred in 2003 resulting in no-data stripping, or gaps, within a Landsat image, the USGS offered gap filled products generated based on a suite of user-defined input SLC-off Landsat images. The spectral images delivered by the Landsat sensors cover all tropical land and clearly reveal forest versus non-forest land cover. The data resolution of 30 m is fine enough to detect clearings or patches of forest smaller than 1 hectare[3].

[3] Based on guidance provided by NOAA's CCAP program, 4 pixels can be applied as the minimum mapping unit for Landsat. As such, that actually equates to an MMU of 0.36ha for Landsat TM data.

Table 1. Landsat tm scenes utilized

Path	Row	Date c1990	Date c2000	Date c2005
19	47	11/20/1990	02/28/2000	10/12/05
19	48	12/27/89	03/28/2000	01/27/2004 & 02/21/2004
19	49	03/28/94	04/30/2003	03/21/06

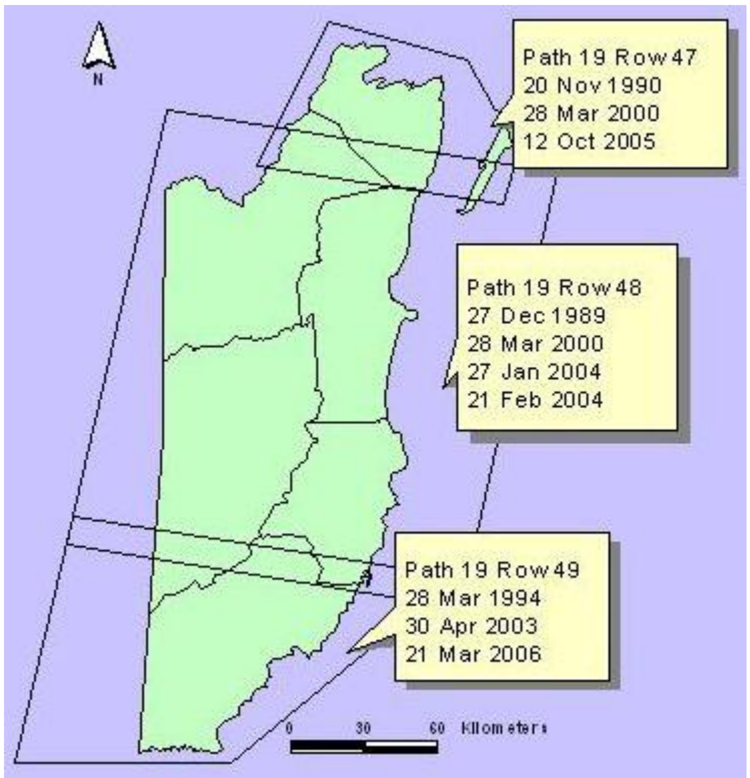


Figure 1. Landsat tm scenes utilized

The analysis was conducted at a spatial resolution of 30 meters and re-sampled to 28.5 meters. The Landsat images from circa 1990 and 2000 were co-registered and the classification of forest cover and change conducted with the multi-temporal data. For the circa 2005 update[4], the images were co-registered with the circa 2000 images and the classification created with the multi-temporal data. To produce the 3-date classification, a matrix was generated using the circa 1990 – 2000 and circa 2000 – 2005 classifications to highlight how the class values of the input files overlapped and recoding, by referencing the input images, performed to yield the final 3-date classification. The classification algorithm applied was a maximum likelihood classifier. In this process, analysts delineate training sites for each land cover of change class, based on visual interpretation and by referring to

[4] Note that for the 19-49 scenes of Belize (Toledo district), no sufficiently cloud free images could be found of the exact 1990-2000-2005 dates. The nearest years with cloud free data were used instead. This inconsistency has consequences for the calculation of the annual deforestation

ground reference data and high-resolution imagery, such as Quickbird, available through Google Earth. Through the automated image classification process, the entire Landsat image is classified based on the statistics of the image data in each class. The final classification was filtered to remove patches of less than 2 hectares. This follows the methodology utilized by Harper et al. 2007[1].

Software used included ERDAS Imagine 9.2 and ESRI ArcGIS 9.2. The overall methodology used for the classification is outlined in Steininger et al. 2006 and constitutes of the following steps:

1. Stacking of layers: Bands 1through 7 were stacked into one .img file
2. Re-projection: Stacked image files were re-projected from WGS84 to UTM NAD 1927 Zone 16N
3. Geo-referencing: All images were geo-referenced using a river dataset of Belize and adjacent Guatemala (Esselman, 2007).
4. Co-registration of images. Considering that the analysis covered 3 different periods and thereby three sets of Landsat images, co-registration Polynomial Geometric Model with a Polynomial order of 2 as to render the scenes to overlap perfectly with an error of < 1 pixel.
5. Create a 2 date layer stack containing the baseline scene and the scene to be analyzed. Layer stack pair of c1990-c2000, c2000-c2005 were thus created for each of the scenes.
6. A stretch was applied to all images using a 4,5,3 (R,G,B) band combination.
7. Subjecting the layer stacked pairs to a band combination of 11,5,5 (R,G,B). Areas that were dark (forest) in the first date and bright (deforested) in the second date will appear in varying tones of red. Thus, forest clearance appears red. Areas that were forest in the first date and cloud in the second date would appear a deeper or brighter red. Areas that were water in the first date and sand in the second date would also appear deep or bright red. Conversely, an area that was cloud in the first date but not in the second date would appear blue-green. And an area that was not clear in the first date but cloud shadow in the second date would appear a darker blue-green.
8. Image interpretation using Supervised Classification using the Maximum Likelihood Classifier (MLC) in ERDAS Imagine. Polygons were classified using the following Cover class Abbreviation Code:

forest	*for*	*1*
nonforest	*non*	*2*
water	*wat*	*4*
cloud	*cld*	*5*
shadow	*shd*	*6*
background	*unclass*	*8*
mangrove	*mang*	*9*

9. Recode classifications based on change between scenes. For example:

Forest -Nonforest	*for-non*	*12*
Forest- Cloud	*for-cld*	*15*
Nonforest-Forest	*non-for*	*21*

10. Combine the c1990-c2000 with the c2000-c2005 raster datasets results in classifications as per the following examples:

Forest-Nonforest-Nonforest	*122*
Forest-Forest-Cloud	*115*
Cloud-Cloud-Nonforest	*552*

11. Confirm consistency between the combined raster datasets. For example: when a certain section identified as mangrove in one year and as forest in another year, which is the correct ID? This entailed checking virtually all pixel groupings or polygons. Particularly complicated were mangrove areas which could give totally different readings based

on whether the scene originated from a wet season or a dry season. Also by comparing the classifications, for each forest/non-forest change it was usually possible to weed out areas of secondary growth.

12. Accuracy of the land cover classification for Belize was further refined by comparing with an extensive ground reference data contained in the Biodiversity and Environmental Resource Data System for Belize (BERDS: http://www.biodiversity.bz). In addition comparison could be made with a 2005 update of the 2001 Belize Ecosystems Map (Meerman & Sabido, 2001). This updated ecosystems map is based on a combination of Landsat Image interpretation and ground truthing data consisting of 125 widely distributed vegetation "plots". In addition, accuracy of the land cover classification for Belize was estimated using high-resolution imagery available on Google Earth. A stratified point grid system (300 control points) was employed to extract a true land cover class from Google Earth compared to the same point in the classification to determine areas of agreement and disagreement. While this method provided a validation of the classification effort, encountered inconsistencies were used as feedback for improvement of the classification, thus increasing the overall accuracy.

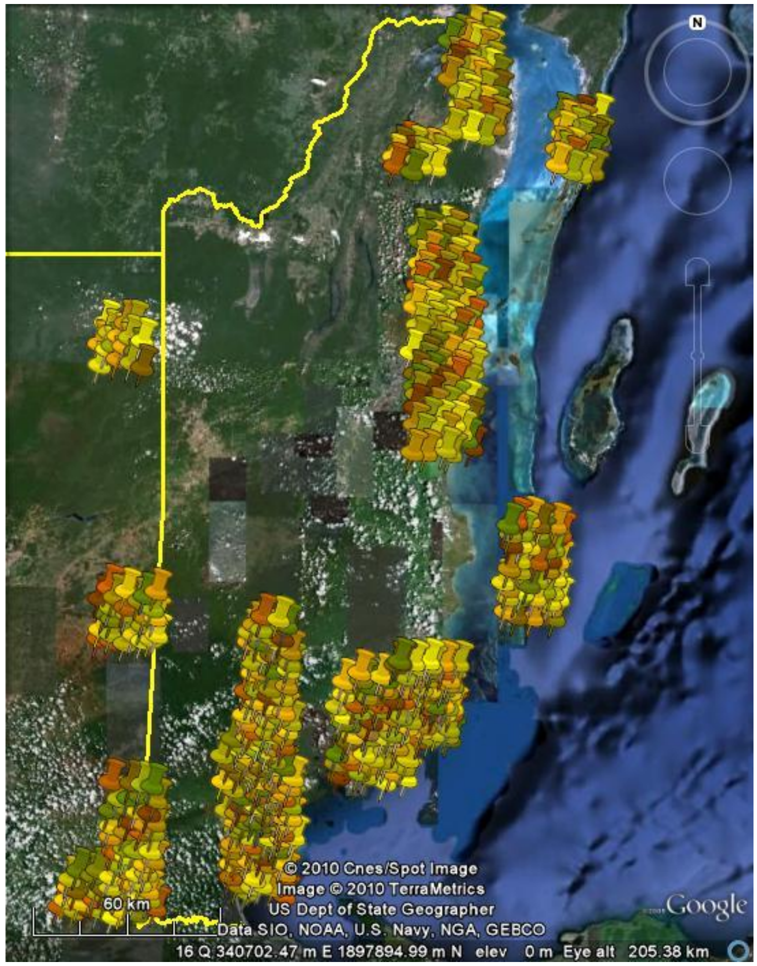


Figure 2 Google Earth Validation Points, distance between points 400m.

Results

The results can be visualized based on two principles:

1) As strict forest cover (figure 3)
2) As areas with recorded change (figure 4)

The differences between the two are subtle but measurable and reflect the overall approach and on how cloud cover is interpreted. The results of the analysis are presented in table 2.

Table 3 summarizes these results and indicates the error caused by cloud cover. A graphical presentation of the forest cover is presented in table 4.

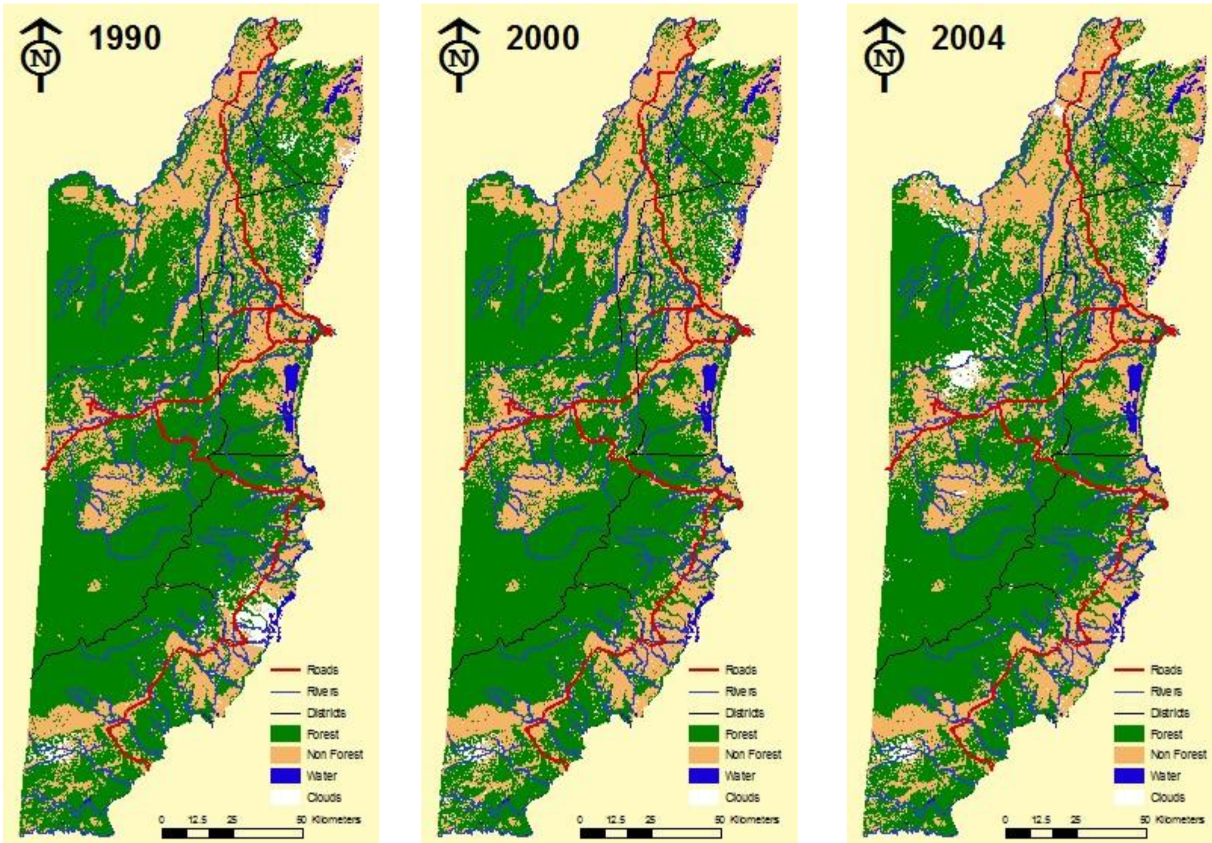


Figure 3. Forest Cover in the 3 analyzed periods. The 3rd period should represent 2005, but since the actual time span between this in the previous period is only 4 years, it is represented as "2004"

Table 2 Results of analysis by land cover classification

Code	Classification	Hectares 1990-2000	Hectares 2000-2005
11	Forest-Forest	1,291,945	1,238,572
12	Forest-Non	71,383	22,718
15	Forest-Cloud	23,827	37,203
22	Non-Non	669,254	744,823
25	Non-Cloud	2,004	16,216
44	Water	48,574	48,574
51	Cloud-Forest	6,549	22,359
52	Cloud-Non	21,401	2,456
55	Clouds	15,813	16,873
59	Cloud-Mangr	327	39
95	Mangr-Cloud	39	1026
99	Mangr-Mangr	45,157	44,459

Table 3. Summary of analysis focusing on forest and outlining error caused by cloud cover.

	1990	2000	2005
Forest[5]	1,432,678	1,343,978	1,305,429
Decline		88,700	38,549
Cloud	44,090	41,683	71,318
Avg. Decline/yr		8870	9637[6]
Total Forest Cover	65.3%	61.2%	59.5%

[5] Including mangrove
[6] Really a 4 year period instead of the intended 5 year span. Average reflects the real number.

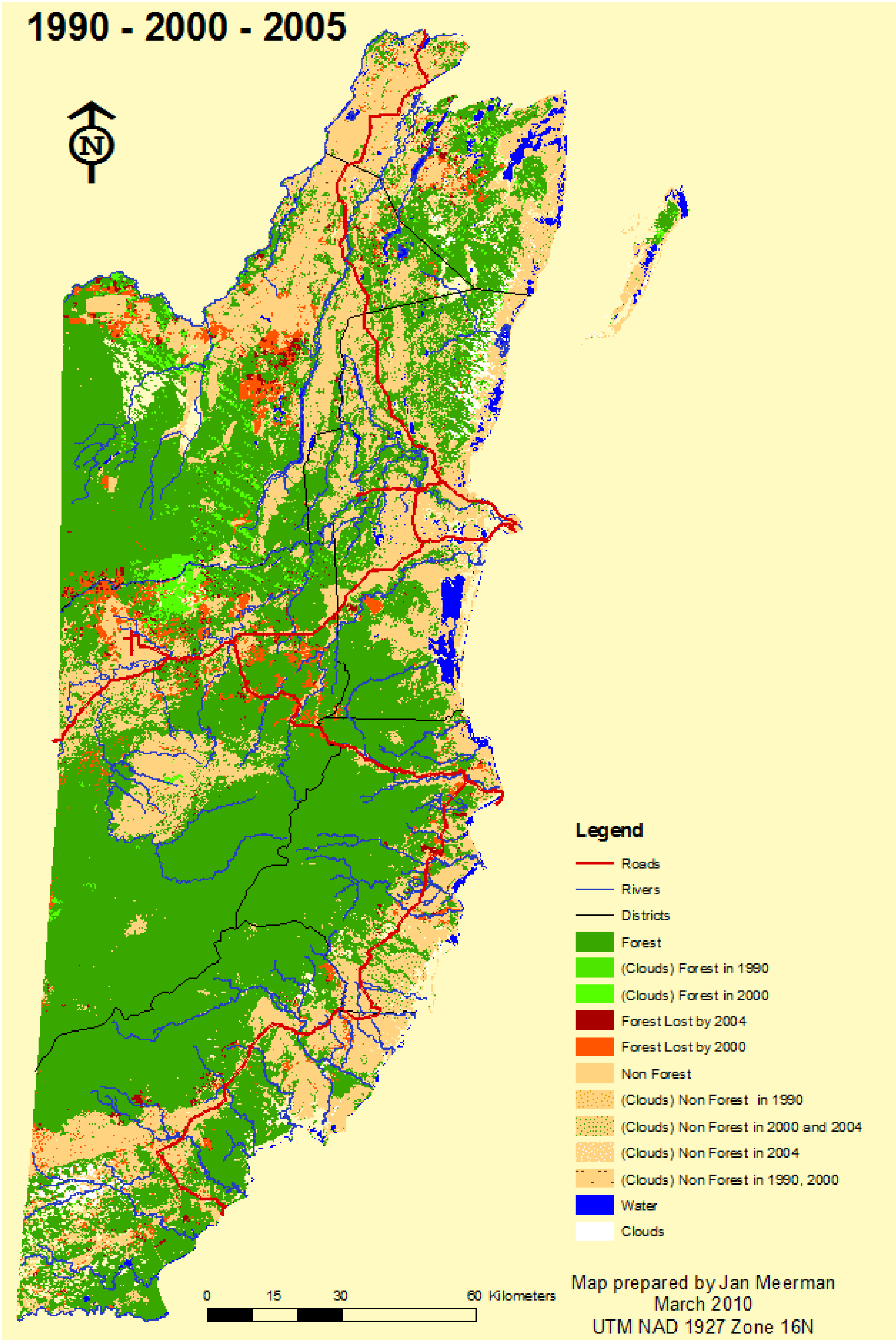
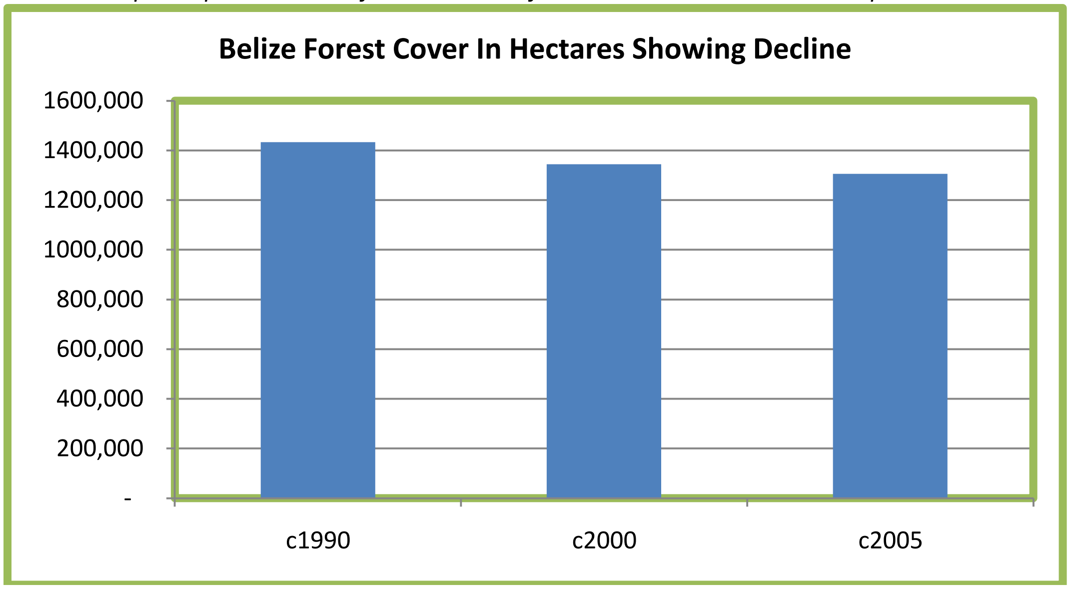


Figure 4. Land Cover Change over the analysis period. Deforestation is in orange and red

The careful conclusion of the analysis is that the average forest decline appears to be steady. However, the figures are substantially lower than the annual figures presented by White et al (25,000 ha/yr) but similar to Ek (8,000 ha/yr [for Central Belize]). Differences should be explained by differences in approach and methodology and in reality the three different efforts should not be compared without taking these differences in account. Some of the more important differences in approach between this and the previous studies are that the current study did not consider Pine with its open and light canopy as "forest" but rather lumps it with spectrally-similar non-forest classes such as savanna. In the case of the study by Ek, this incorporated the he Pine Bark Beetle infestation in the sample period which caused substantial natural mortality under the pine stands of Belize. More importantly, while one of the great problems of a supervised classification is the distinction between secondary growth and "mature" forest, the current study took great effort in classifying rotational agricultural systems ("milpa") as "agriculture". In other words, the substantial areas of secondary forest that dominate the more populated areas of Belize were not counted as forest and thus could not de-forest again. Classifying secondary growth in shifting cultivation systems as forest will automatically lead to higher deforestation rates as annually a fairly large percentage of this secondary growth will be cleared again for the next agriculture cycle.

Table 4. Graphical presentation of the measured forest decline in Belize over the period 1990-2005



Annual rate of deforestation

The above analysis focuses on the loss of forest in hectares. However, deforestation is usually expressed in percentages. The annual rate of change is calculated by comparing the area under forest cover in the same region at two different times and expresses the difference as a percentage. Over time different formulas have been used to calculate the annual rate of change (see Puyravaud, 2003). The most influential is the formula prescribed by the FAO (1995), which states that the annual rate of forest change should be calculated using a formula that is derived from the Compound Interest Law. In an attempt to unify calculation methods and avoid confusion, Puyravaud (2003) devised a new formula which is used here:

$$r \frac{1}{t_2 - t_1} ln \frac{A_2}{A_1}$$

Where $r =$ rate of forest change and A_1 and A_2 is the forest cover at time t_1 and t_2 respectively (the unit: per year or percentage per year).

When this calculation is carried out, the following figures appear (table 5)

Table 5. Annual Rate of deforestation in percentages

1990-2000: r = 0.1 ln 1343978/1432678 = 0.64%
2000-2005: r = 0.25 ln 1305429/1343978 = 0.73%

The above calculation looks at the differences between forest cover as identified in the analysis. Problems arise when considering the cloud cover, which could potentially mask deforestation. Another, subtly different approach could be to look at actually measured deforestation (class 12). Using that approach (summary of figures in table 6), the annual rates of deforestation are slightly different (table 7).

Table 6 Original forest cover and measured deforestation

	c1990	c2000	c2005
Forest	1,432,678		1,361,295
Decline		71,383	22,718
Left		1,361,295	1,338,577

Table 7. Annual rate of deforestation in percentages based on measured deforestation

1990-2000: r = 0.1 ln 1,351,295/1,432,678 = 0.51%
2000-2005: r = 0.25 ln 1,338,577/1,361,295 = 0.42%

The approach in table 5 implies a slight increase in the deforestation rate while the approach in table 7 seems to suggest a slight decrease in the rate of deforestation in the last period.

Summary

This study provides deforestation figures for a period of 15 years which makes it the first integrated long term study on a national scale. Estimating the amount of forest loss in countries that have historically experienced very low rates of deforestation, such as Belize is particularly important given the Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanism under development through the United Nations Framework Convention on Climate Change (UNFCCC) as part of the post-Kyoto climate negotiations. And as such there is a increasing need for comparable forest cover rates and trends. While short term studies can give important insights into the local socio-economic mechanisms behind deforestation, they are usually difficult or even impossible to compare as they may have used different methodologies and definitions.

The current study finds an annual deforestation rate hovering around 0.6% (0.42-0.72%), which is globally a very low rate, which confirms the status of Belize as a High Forest Cover Low Deforestation (HFLD) Country.

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