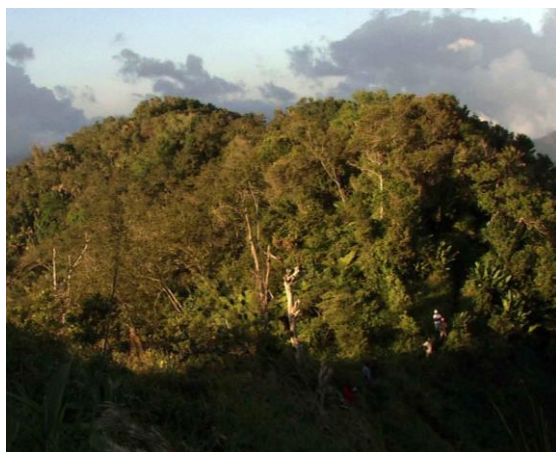
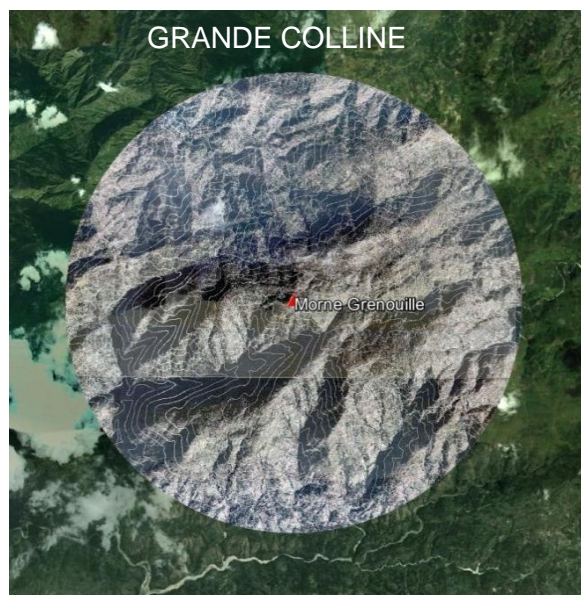
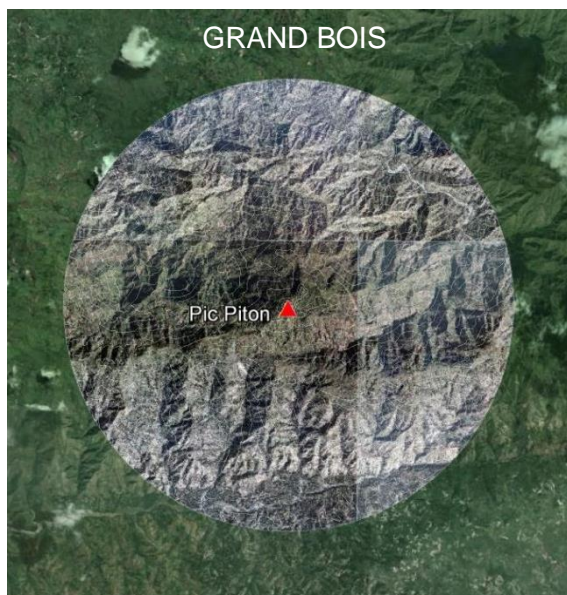


Forest Cover Analysis of Grand Bois and Grande Colline, Haiti

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CRITICAL **ECOSYSTEM**
PARTNERSHIP FUND


SOCIÉTÉ AUDUBON HAÏTI



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ACRONYMS

ANAP	Agence Nationale des Aires Protégées
ArcGIS	Arc Geographical Information Systems (ESRI software)
CEPF	Critical Ecosystem Partnership Fund
CNIGS	Centre National de l'Information Géo-Spatiale
ESRI	Environmental Systems Research Institute
ETM+	Enhanced Thematic Mapper Plus
GE	Google Earth
GIS	Geographical Information System
kml	Keyhole Markup Language
MDE	Ministère de l'Environnement
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
SAH	Société Audubon Haïti
UM	University of Maryland
USGS	United States Geological Survey

SUMMARY

Forest cover is analyzed for two montane sites (Grand Bois and Grande Colline) of the Massif de la Hotte in southwestern Haiti. These areas are noted for an exceptional high biodiversity of endemic flora and fauna. The basis for the forest cover analyses utilized the most available satellite imagery and the University of Maryland *Global Forest Change 2000-2012* database. A sample area of 50 km² at each site was determined for forest cover, forest cover change, fragmentation, patch size and elevation distribution. Only 6 % of the Grand Bois area remains in natural forests which are highly fragmented and occur mostly in elevations above 900 m. The deforestation rate for Grand Bois was estimated at 2.7 % for the 2000-2012 period. Approximately 32% of the Grande Colline area remains in natural forests, though highly fragmented and occurring mostly above 1500 m elevation. The deforestation rate for Grand Colline was estimated at 2.4% for the same period. A remarkable increase in deforestation occurred between 2008 and 2012. Demographic pressure from the lowlands for wood harvests and garden lands are the main threats to the forests of both areas. Urgent response by government and conservation organizations is required to protect what remains of the natural forests and their wealth of endemic biodiversity.

RÉSUMÉ

La couverture forestière est analysée pour deux sites montagneux (Grand Bois et Grande Colline) du massif de La Hotte dans le sud-ouest d'Haïti. Ces zones sont connues pour une exceptionnelle biodiversité endémique tant au niveau de la flore et de la faune. La base pour les analyses de la couverture forestière a utilisé la plus récente imagerie satellitaire et la base de données de l'Université du Maryland (*Global Forest Change 2000-2012*). Une superficie de 50 km² à chaque site a été déterminée pour la couverture forestière, changement du couvert forestier, la fragmentation, la taille des parcelles et la distribution d'élévation. Seulement 6 % de la région de Grand Bois restent dans les forêts naturelles qui sont très fragmentées et se trouvent principalement dans des altitudes supérieures à 900 m. Le taux de déforestation pour Grand Bois a été estimé à 2,7 % pour la période 2000-2012. Environ 32 % de la région de Grande Colline restent dans les forêts naturelles, mais très fragmenté et se trouvent surtout au-dessus de 1500 m d'altitude. Pour la même période, le taux de déforestation pour Grand Colline a été estimé à 2,4 %. Une augmentation remarquable de la déforestation s'est produite entre 2008 et 2012. La pression démographique exercée sur les terres de basse altitude pour l'extraction du bois et les espaces cultivés sont les principales menaces pour les forêts de ces deux domaines. Une réponse urgente aussi bien de la part des organismes publics que du secteur privé est recommandée afin de protéger ce qui reste des forêts naturelles et la richesse de leur biodiversité endémique.

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INTRODUCTION

The high-elevation areas of the Massif de la Hotte in southwestern Haiti contain some of the largest areas of natural forest remaining in Haiti. These primary native forests are small relative to their former extent and are highly fragmented in the mountainous landscape. However, they are especially rich in terms of an endemic biota that is considered as among the most important in the world – the Massif de la Hotte Key Biodiversity Area (CEPF, 2010). This has generated a keen interest among conservation organizations and the scientific community to identify, describe and improve our understanding of the endemic biota and its on-going threats.

Two areas of current interest are Grand Bois and Grande Colline (**Figure 1**). SAH is studying these areas with the objective of establishing baseline data to support and propose their designation as protected areas by ANAP (National Agency of Protected Areas) of the Ministry of Environment. These areas are being analyzed to determine their extent of forest cover and habitat quality, biological richness, and the social, political and economic parameters of the local communities living in and around these forests (Timyan 2015a; Timyan 2015b).

Both areas were initially visited in July 2011 by helicopter with a team led by Dr. Blair Hedges (Temple University). Subsequent visits included a second helicopter expedition in June 2013 followed by overland expeditions by SAH : September 2013, June 2014 and September 2014 to Grand Bois and November 2013, July 2014 and March 2015 to Grande Colline. A preliminary summary of the wildlife found in these areas is provided by Hedges (2012) and a detailed fact sheet for Grand Bois has been published (Hedges and Timyan, 2014). Feature articles covering Grand Bois have been published in the *Philadelphia Inquirer* (Flam, 2011) and *Terre Sauvage* (Lescroart, 2014). A concurrent study of forest cover in Haiti is being conducted by Oregon State University and the US Forest Service (Zhiqiang et al., 2014).

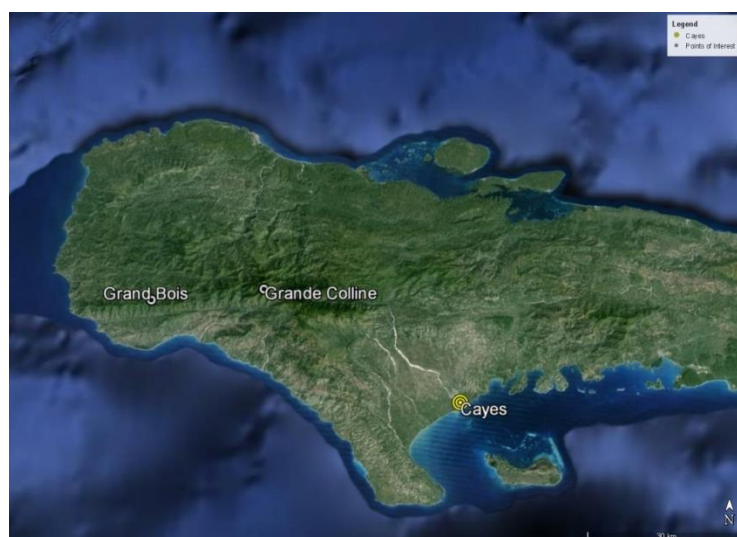


Figure 1. Map showing locations of Grand Bois and Grande Colline areas of the Massif de la Hotte, Haiti.
Source: Google Earth.

METHODOLOGY

A circular area of 50 square kilometers, centered by a prominent peak, was determined by ArcGIS for the analysis of forest cover (**Figure 2**).

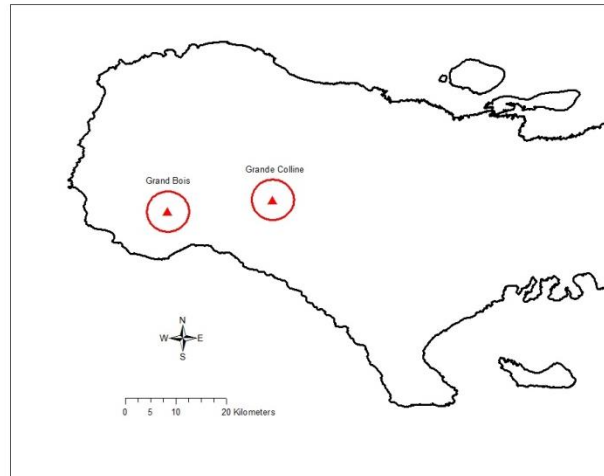


Figure 2. 50-km² areas selected to analyze forest cover of Grand Bois and Grande Colline. **Source :** Société Audubon Haïti.

The Grand Bois elevations within the 50 km² area ranged from below 100 to over 1240 m. The highest peak is approximately 1256 m and is locally known as “ Pic Piton ” (N 18.37091, W 74.30164, **Figure 3**). The Grande Colline elevations ranged from 380 – 2040 m. The peak that is closest to the largest extent of natural forest is approximately 2000 m (Fig. 4), though it is not the highest peak within the 50 km² area. The highest peak lies 1.7 km to the northeast at N 18.40237 and W 74.10100. The lower peak that centers the sample area does not have an official name, but it is known in this report as “ Morne Grenouille ”.

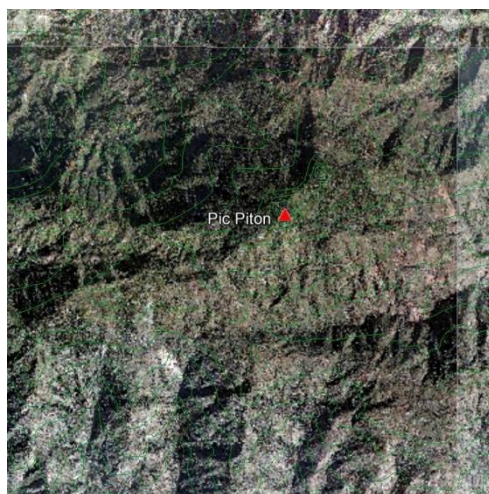


Figure 3. Pic Piton at Grand Bois.

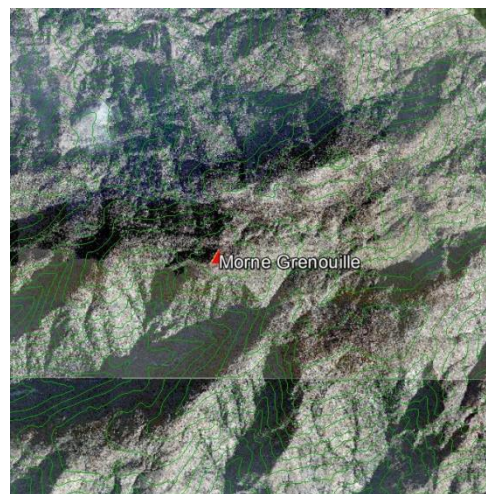


Figure 4. Morne Grenouille at Grande Colline.

University of Maryland Data : The areas were analyzed using the University of Maryland *Global Forest Change 2000-2012* database (Hansen et al., 2013). The data are based on a time-series analysis of Landsat 7 ETM+ images to characterize forest extent and change from 2000 through 2012. Parameters included :

- 1) Tree cover in 2000 ;
- 2) Forest cover loss/gain between 2000 and 2012 ;
- 3) The year of forest cover change.

This database allowed for the estimate of deforestation rates over the 12-year period based on Landsat imagery at a spatial resolution of 30 m (Hansen et al., 2013).

Tree Cover Baseline - 2000 : Trees are defined as all vegetation taller than 5m in height and are expressed as a percentage per 30 m x 30 m grid cell (Hansen et al, 2013b). Four categories of tree cover were analyzed : 0-25 %, 25-50 %, 50-75 % and 75-100 %. For this study, percent tree cover was visually estimated by dividing the Grand Bois area into 16 sections and estimating the area coverage for each of the 4 categories. The estimates were then weighted and an average value for each category was calculated for the entire 50 km² study area.

Forest Change - 2000-2012 : Forest loss and gain was calculated by counting the number of red cells (forest loss) or white cells (forest gain) in the study area. The area covered by each category was determined to estimate forest loss and gain. The net area was divided by the total area to estimate total rate of deforestation during the 2000-2012 period.

Time of Forest Loss : The time of forest loss was calculated by counting the number of grid cells ranging from yellow (2000) to red (2012). The yellow-orange-red color spectrum represents values in the range of 1-12.

CNIGS Data : Twenty-meter (20-m) elevation contours and 30-cm resolution orthophotos from 2010 were acquired from CNIGS. The contours were clipped for each study area to determine the amount of land area by elevation, beginning at the peaks and extending to the lowest elevations. The forest cover was estimated by analyzing the most recent imagery available, including the DigitalGlobe time series available on GE. The orthophotos were used in areas that cloud cover prevented the determination of forest cover on GE.

Two categories of land cover were determined for each 100-m elevation contour : 1) original or relatively undisturbed forest, and 2) deforested lands that included regenerating secondary forests, open canopy agroforestry systems, annual gardens, abandoned gardens, water, built up areas, roads, bare soils and rock. Polygons were drawn on GE and the .kml file converted to an ArcGIS layer. Geometric attributes were added to the layer in order to estimate polygon areas.

RESULTS

Original Forests of Massif de La Hotte

The preliminary findings of Zhigiang et al. (2014) support the fact that very little of the original forest remains in either study areas (**Figure 5**). What remains is under immense pressure of uncontrolled land clearing for lumber, charcoal manufacture and gardens. However, a considerable greater amount of original forest occurs at Grande Colline than at Grand Bois, as indicated by the green areas on the map. The green areas of the map represent areas of forest cover that have essentially remained undisturbed over a period of 30 years (1980 – 2010) as supported by a time series analysis of Landsat satellite imagery.

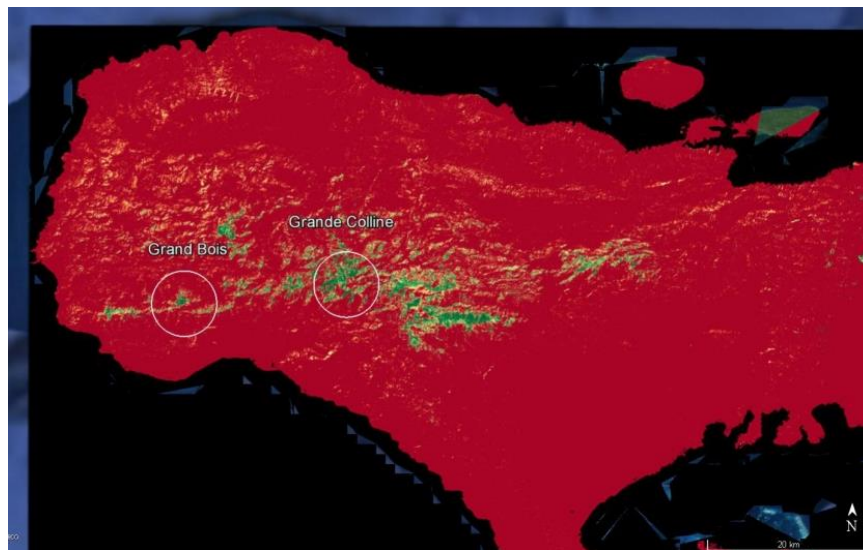


Figure 5. Landsat imagery analysis showing green areas as remaining primary forest in the Massif de la Hotte area of Haiti. White circular polygons indicate 50-km² forest cover study area. **Source :** Zhigiang et al. 2014 ; Google Earth.

Grand Bois

Tree Cover in 2000. The results for the Grand Bois study area are shown in **Figure 6**. This 2000 year map represents the baseline upon which forest loss and gain from 2000-2012 is determined.

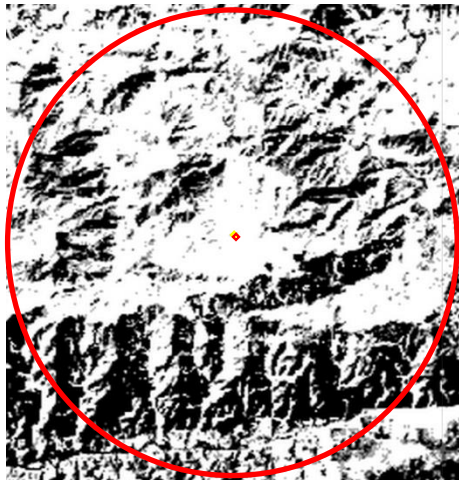


Figure 6. Percent tree cover of Grand Bois area in 2000. **Source :** Hansen/UMD/Google/USGS/NASA, 2015 and SAH, 2015.

Approximately 46 % of the study contained 75-100 % tree cover in 2000. Nine (9) percent of the area had 50-75 % cover ; 4 % had 25-50 % cover ; and 40 % had less than 25 % tree cover, water or no data.

The evidence supports a general deforestation pattern – clear cutting parcels of dense forest to convert to charcoal and gardens (e.g., slash and burn agriculture) with a minority of the land in agroforestry or open canopy tree stands. Most of the deforested lands are disproportionately found in the southern lower elevations above the Tiburon River where population pressure from urban areas (Tiburon and Les Anglais) is the greatest and the land is more accessible. The south facing slopes also suffer from greater exposure to weather (sun, wind, rain) and less likely to recover from land clearing practices.

Forest Cover Change (2000-2012). The change in forest cover is the net of forest loss and gain in the 50 km² study area. Forest loss is shown as red grid cells (**Figure 7**) and forest gain is shown as white grid cells (**Figure 8**) for Grand Bois.

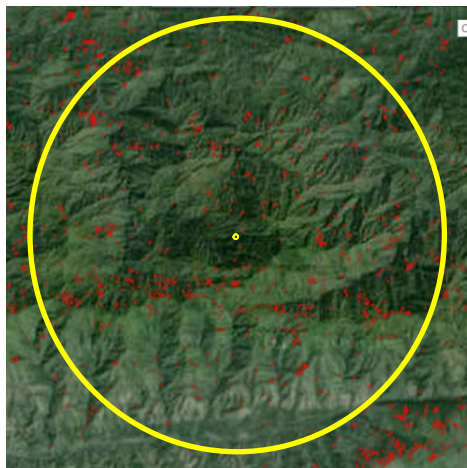


Figure 7 (left). Grand Bois forest cover loss during 2000 – 2012 as shown by red grid cells. **Figure 8 (right).** Grand Bois forest cover gain during 2000 - 2012 as shown by white grid cells. Source: Hansen/UMD/ Google/USGS/ NASA, 2015 and SAH, 2015.

A total of 953 red grid cells, equivalent to approximately 133.4 hectares, show a loss of forest cover during the 2000-2012 period. A total of 5 white grid cells, equivalent to 0.7 hectares, show a gain. The net loss of forest cover during this period is estimated at 2.66% of the study area. A slightly greater amount of deforestation occurred in the south of the study area.

Year of Forest Loss (2000-2012). The multi-colored grid cells (**Figure 9**), ranging from yellow to red, were counted to determine percent forest cover loss during three 4-year periods: 2000-2004, 2004-2008 and 2008-2012. The results show an increasing rate of deforestation : 27 % of the cells represent forest loss during 2000-2004, 32.9 % during 2004-2008 and 40.1 % during 2008-2012.

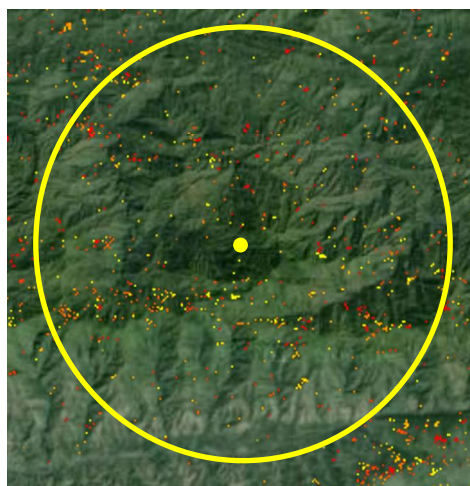


Figure 9. Forest loss years at Grand Bois are shown by colors ranging from yellow (2000) to red (2012). Source: Hansen/UMD/Google/USGS/NASA and SAH.

Forest Patch Size. The primary forests of the 50-km² area are comprised of 24 distinct patches that total approximately 324 hectares (**Annex 1, Figure 1.1**). The patch sizes range from 0.4 to 172 hectares with most of the forest patches less than 5 hectares (**Table 1; Annex 1, Figure 1.2**). The largest single block of forest occurs at the highest elevation and represents over half of the primary forest cover in the sample area. It also has pockets of deforested and secondary shrub vegetation of past and current agricultural activity.

Table 1. Forest patch size distribution in Grand Bois area.

Forest Patch Size (Ha)	N	Total Area (Ha)	Forest Patch Size (Ha)	N	Total Area (Ha)
< 2	5	5	16-32	3	62
2-4	7	21	> 64	1	172
4-8	4	22			
8-16	4	42	Total	24	324

Forest Distribution. The distribution of forest cover by elevation is shown in Table 2. Whereas 6.5 % of the study area is covered by natural forests, only elevations above 900 m have significant amounts of forests remaining. The lower elevations are mostly deforested, ranging between 0 – 7 %. (**Annex 1.3**).

Table 2. Elevation of forests in the Grand Bois area.

Elevation (m)	Total Area (ha)	Forests (ha)	% Forest Cover
< 100	70	0	0
100	285	0.3	0
200	278	18.3	7
300	575	28.3	5
400	718	40.0	6
500	728	13.1	2
600	653	6.6	1
700	626	15.2	2
800	559	37.1	7
900	302	65.1	22
1000	140	56.7	41
1100	53	32.5	61
1200	7	6	90
>1200	6	5	84
Total	5000	324	6.5

Grande Colline

Tree Cover in 2000. The percent tree cover for Grande Colline in 2000 was estimated using the same methods for Grand Bois. **Figure 10** shows the 4 categories of grayscale ranging from black (0-25 % tree cover, water or no data) to white (75-100 % tree cover).



Figure 10. Percent tree cover of Grande Colline area in 2000. **Source:** Hansen/UMD/Google/USGS/ NASA, 2015 and SAH, 2015.

Approximately 46 % of the study area contained 75-100 % tree cover in 2000, the same as Grand Bois. Similar values were estimated for the other categories : 41 % of the area with less than 25 % tree cover, water or no data ; 5 % of the area with 25-50 % tree cover and 7 % of the area with 50-75 % tree cover.

Forest Cover Change (2000-2012). Forest gain and loss during the 2000-2012 period in the Grande Colline area is shown in Figures 11 and 12. An estimate of deforestation rates during this period is calculated by the balance of the two processes within the study area. A total of 870 red grid cells, approximately 121.8 hectares, show a loss of forest cover. A total of 5 white grid cells, approximately 0.7 hectares, show a gain of forest cover. The net loss of forest cover at Grande Colline is estimated at 2.42 %, slightly less than at Grand Bois.

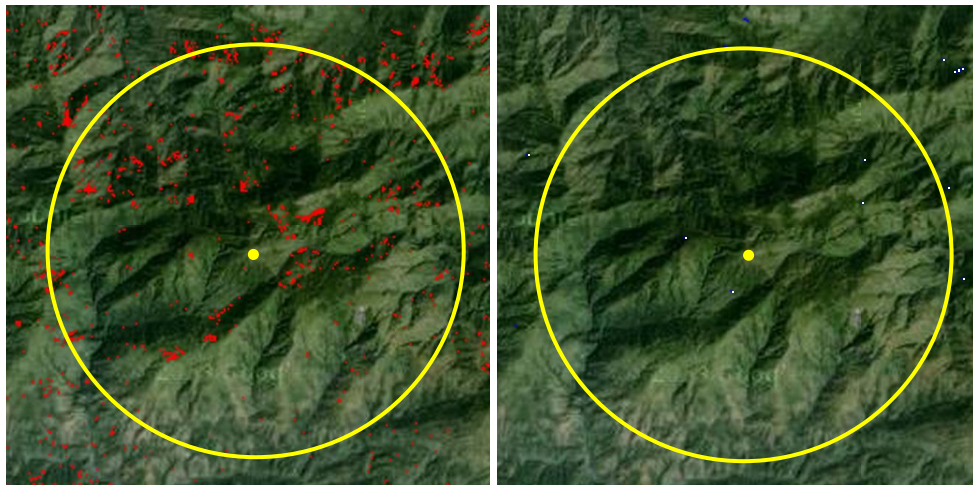


Figure 11 (left). Grande Colline forest cover loss during 2000 – 2012 as shown by red grid cells. **Figure 12 (right).** Grande Colline forest cover gain during 2000 - 2012 as shown by white grid cells. **Source:** Hansen/UMD/Google/USGS/NASA, 2015 and SAH, 2015.

Year of Forest Loss (2000-2012). The multi-colored grid cells (Fig. 13), ranging from yellow to red, were counted to determine percent forest cover loss during three 4-year periods : 2000-2004, 2004-2008 and 2008-2012. As in the case of Grand Bois, the results show an increasing rate of deforestation: 20.8% of the cells represent forest loss during 2000-2004, 25.4% during 2004-2008 and 53.8% during 2008-2012. Rates in Grande Colline have accelerated faster than Grand Bois as indicated by the lower values for the first 2 periods followed by a much higher loss during 2008-2012. This is shown in Figure 14.

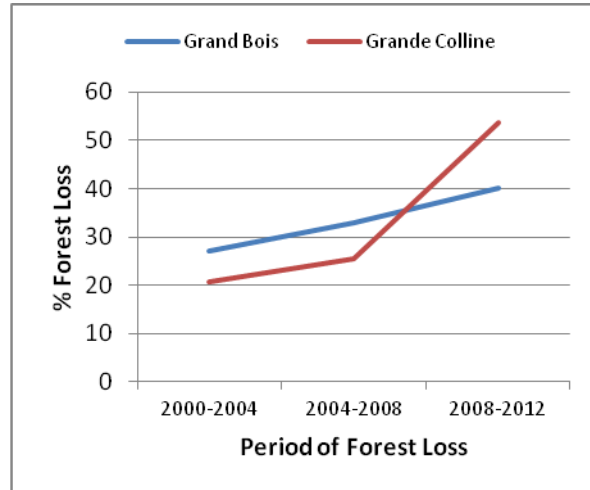
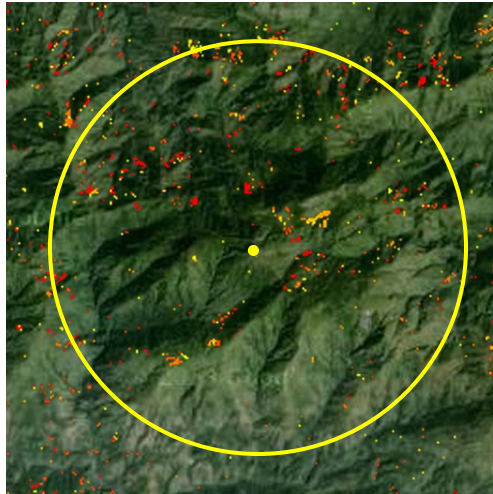


Figure 13 (left). Forest loss years at Grande Colline are shown by colors ranging from yellow (2000) to red (2012). **Figure 14 (right).** Comparison of deforestation rates of Grand Bois and Grande Colline. **Source:** Hansen/UMD/Google/USGS/NASA, 2015 and SAH, 2015.

Forest Patch Size. The primary forests of the 50-km² area are comprised of 33 parcels that total approximately 1607 hectares, more than five-fold the forested area of Grand Bois and covering 32% of the study area (**Annex 2.1**). The forest stand areas range from less than a hectare to the largest block, estimated at 1267 hectares (**Table 3**). Approximately 90 hectares of deforested areas occur within the largest block. The perimeter of this block of forest exceeds 70 km and includes much forest that is highly impacted by edge effects. As in the case of Grand Bois, the majority of the forest patches are extremely fragmented and surrounded by a landscape of garden parcels, clear cuts associated with charcoal production and an herbaceous or shrubby plant community common to various stages of secondary growth and fallows.

Table 3. Forest patch size distribution in Grande Colline area.

Forest Patch Size (Ha)	N	Total Area (Ha)	Forest Patch Size (Ha)	N	Total Area (Ha)
< 2	17	40	25-50	2	62
5-10	5	31	50-75	2	127
10-15	5	62	> 75	1	1267
15-25	1	19	Total	24	1607

Forest Distribution. **Table 4** summarizes the distribution of the forest areas in Grande Colline by elevation. As compared with Grand Bois, the forests are more evenly distributed across elevations (**Annex 2.3**). There is a general increase in forest cover with elevation, particularly beginning at 1300 m and extending to 1800 m.

Table 4. Elevation of forest areas in the Grande Colline area.

Elevation (m)	Total Area (ha)	Forests (ha)	% Forest Cover
< 400	4.4	2.1	48
400	43.5	7.2	17
500	100.0	15.7	16
600	186.2	28.7	15
700	213.7	35.6	17
800	190.0	54.5	29
900	314.6	75.1	24
1000	350.7	83.5	24
1100	431.4	98.2	23
1200	698.9	148.5	21
1300	436.2	103.4	24
1400	517.9	194.4	38
1500	435.4	220.7	51
1600	360.4	170.2	47
1700	405.9	198.3	49
1800	238.8	137.2	57
1900	65.6	31.4	48
2000	4.4	2.1	47
> 2000	2.0	0.5	25
Total	5000	1607.3	32

DISCUSSION

This study aims to determine the current status of natural forest cover in two areas of the Massif de la Hotte.¹ Both areas are under immense deforestation pressure, driven by local demand for agricultural lands and the market for lumber and charcoal (**Figures 15-18**).



¹ There are other areas of the Massif de la Hotte that remain in natural forests (e.g., Deux Mammelles, Bellevue, Morne Mansinte, Morne Bois Pagnol), but these areas are decreasing every year and will disappear in the near future if trends do not change.

Fig. 15 (left). Forest being cleared and burned at Grand Bois for gardens (June, 2014).
Fig. 16 (right). Recently burned forest at Grande Colline (July, 2104). Photo credits: Joel Timyan.



Figure 17 (left). Hispaniolan pine (*Pinus occidentalis*) being sawn for lumber at Grande Colline.
Figure 18 (right). Laurel (*Ocotea* sp.) being prepared for sawing at Grand Bois. Photo credits: Joel Timyan.

Deforestation Rates

The overall deforestation rates of Grand Bois and Grande Colline over a 12-year period are similar (2.7 % vs. 2.4 %) though the periods that forest cover loss occurred were significantly different. While the rate of loss is relatively constant for Grand Bois, the rate of loss in Grande Colline has increased considerably in recent years. This may be due the difference in the amount of natural forest that remains. Grande Colline has a much larger of area of natural forest remaining than Grand Bois, in part due to the extremely steep slopes and higher elevations. Despite such constraints, access to the Grande Colline forests is uncontrolled and is being exploited as unprotected public property.

It appears that a much larger decrease in dense forest cover has occurred in Grand Bois than Grand Colline as reported by the Hansen et al. (2013) study. This is mostly due to the discrepancies and interpretation between the Landsat imagery and the GE imagery, as determined in this study. It is unknown what portion of the “ 75-100 % forest cover ” in Fig. 6 is actually the type of closed canopy forest that is shown in Figure 1.1 of Annex 1. Forest cover data for 2014 was not available from the UMD database, so an attempt was not made to analyze this discrepancy.

Forest Cover

Zhiqiang et al. (2014) and this study both support the fact that very little original forest remains in Haiti and that forest cover analyses need to differentiate between the quality of forest ecosystems and tree cover *per se*. The recent analysis by Churches et al. (2014) continues the confusion by stating that “ approximately 32.3 % of Haiti’s total land area was tree covered in 2010-2011 ”. Closer examination of the data reveals that tree cover is defined as vegetation

greater than 5 m in height with a canopy cover equal or greater than 10 %. No attempt was made to distinguish between natural forests and vegetation cover dominated by introduced species (e.g., mango, citrus, avocado, coconut). The latter systems generally show a remarkable absence of the native biodiversity once found in Haiti.

Forest Fragmentation

The natural forests that remain are highly fragmented and mostly occur at the highest elevation ranges of Grand Bois and Grande Colline. Fragmentation is a concern in both areas since it is associated with a decline in species and their populations (Andr  n, 1994 ; Davies et al., 2000 ; Didham et al., 2007). It is largely unknown what species have already gone extinct in these areas or the status and trends of the endemic species. Those species with extremely restricted ranges, like many of the *Eleutherodactylus* and Orchidaceae species, would be considered Endangered and Critically Endangered by IUCN criteria (IUCN, 2014).

Comparison with Zhiqiang et al. (2014)

A detailed analysis was not possible to compare the results of Zhiqiang et al. (2014) with this study. The areas of natural forest cover that have remained unchanged from 1975 to 2013 are shown in Figures 19 and 20 for Grand Bois and Grande Colline, respectively. These are based on a time series of Landsat imagery. According to the authors, the optimal thresholds have not been determined to minimize errors of commission (incorrect detection of continuous forest cover) and omission (failing to detect continuous forest cover). Currently, the coverage is being analyzed for these errors in an effort to improve the accuracy of the methodology.

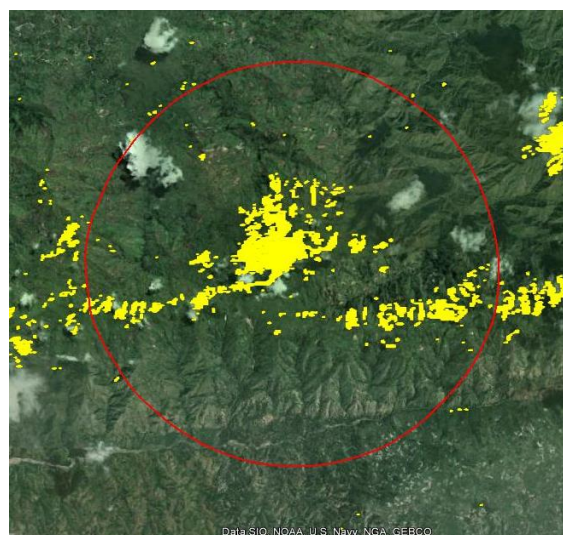


Figure 19 (left). Grand Bois original forests, as determined by Zhiqiang et al. (2014).

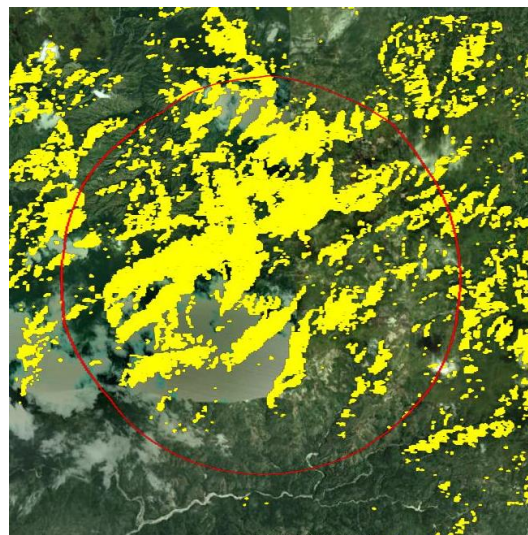


Figure 20 (right). Grande Colline original forests, as determined by Zhiqiang et al. (2014).

CONCLUSIONS

This study focusses on two areas of the Massif de la Hotte where original forests remain despite continuing deforestation. The Grand Bois forests are more threatened than Grande Colline due to their much smaller extent (c. 6 % of the total area) and higher demographic pressure of a locally resident population. The Grande Colline forests are larger in extent (c. 32 %) and less threatened only due to their isolation from a non-resident population. However, it is expected that more Haitian households will establish residency in the area as the fertility of lower elevation slopes are exhausted and the demand for new fertile soils remains high.

Both areas are a repository of an exceptional diversity of the endemic flora and fauna of Haiti. As these original forests become fragmented and exposed to invasive species associated with man-modified landscapes, their survival will depend on a more urgent response by government and non-government organizations. Otherwise, an irreplaceable natural heritage and its component species may be lost forever.

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Annex 1. Grand Bois natural forest distribution and elevation analyses.

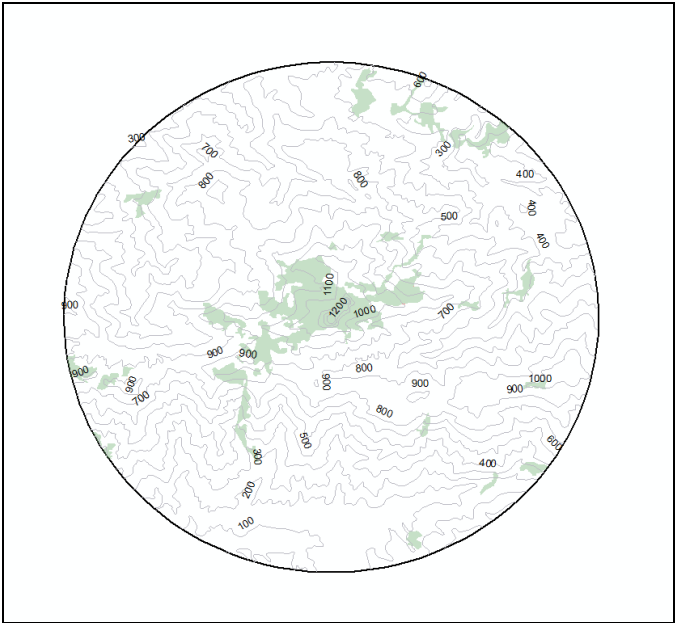


Figure 1.1. Location of natural forests at Grand Bois.

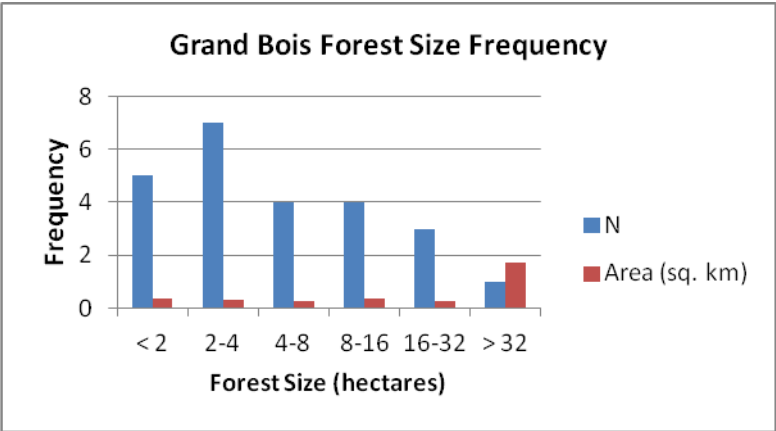


Figure 1.2. Frequency distribution and area of natural forests.

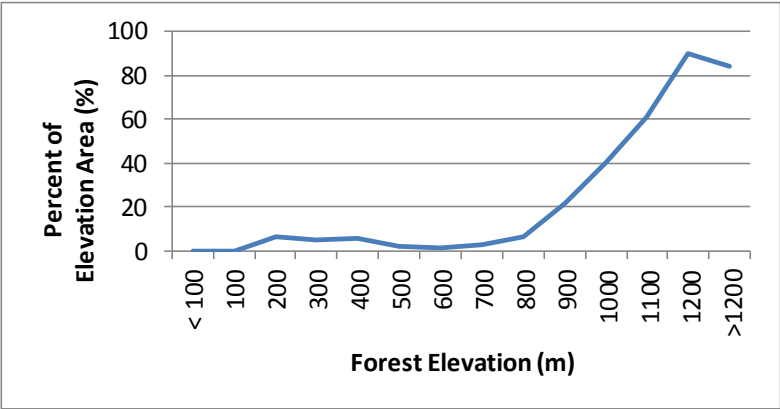


Figure 1.3. Percent forest cover by elevation in Grand Bois area.

Annex 2. Grande Colline natural forest distribution and elevation analyses.

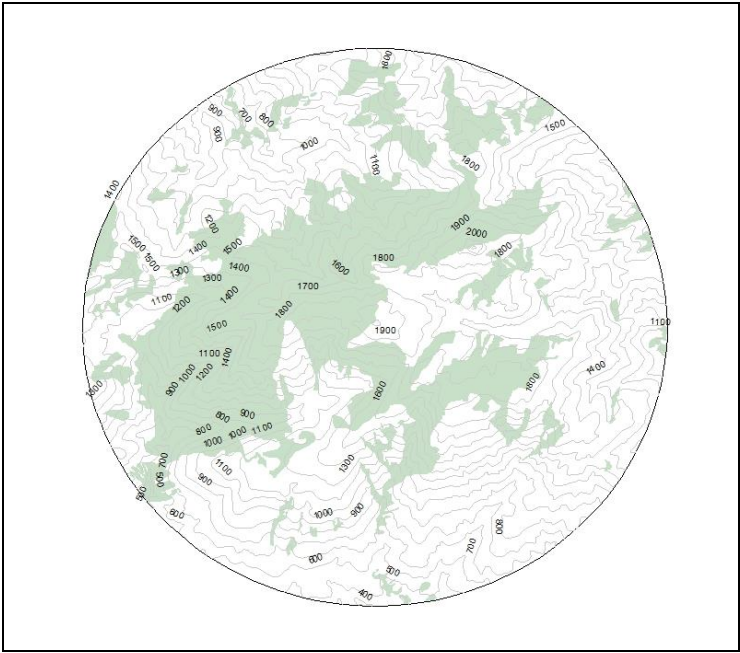


Figure 2.1. Location of natural forests at Grande Colline.

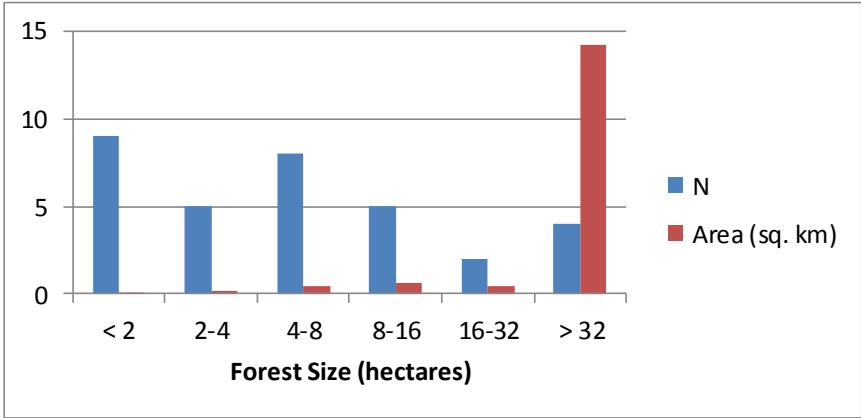


Figure 2.1. Frequency distribution and area of natural forests.

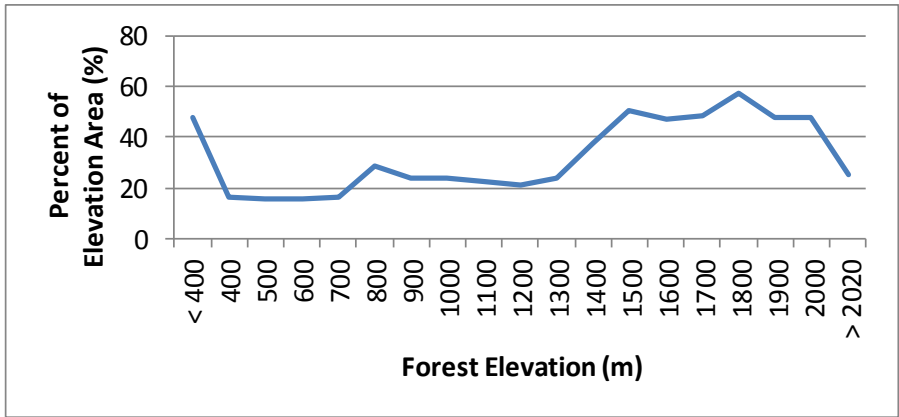


Figure 2.3. Percent forest covert by elevation in Grande Colline area.

