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Mangrove deforestation in the Dominican Republic, 1969 to 2012

Background

Hispaniola was once extensively ribboned with mangroves, especially in embayments, river mouths, estuaries, lagoons and sheltered coastal areas (Horst, 1992). In the Dominican Republic—the eastern two-thirds of Hispaniola—mangroves are still widespread along the northern coast and the Bay of Samaná, although pockets are found along the drier south coast as well (Spalding *et al*., 2010; Giri *et al*., 2011). Four species of mangroves are found in the Dominican Republic, namely, the red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*) and button mangrove (*Conocarpus erectus*) (DREDE, 2011).

Mangrove tourism, in which visitors tour natural channels through mangrove forests, has been popular since the 1960s (Laguna Gris-Gris near Río San Juan), and the use of mangroves for tourist activities has increased since the rise of ecotourism. Ecotourism based on mangrove forests is prevalent in the Los Haïtises National Park at the head of the Bay of Samaná and in other protected areas along the coast.

Despite the importance of mangrove forests to the tourist sector, the Dominican Republic has been among the leaders in percentage loss of mangrove habitat in the Americas since 1980, at ~2.8% per year (FAO, 2007). Reasons for the loss include cutting mangroves for tannin during the 1950s and 1960s (OAS, 1967), for charcoal and firewood (González, 1999; Horst, 1992), for tourism infrastructural development (González, 1999), for agricultural expansion, and for artisanal and industrial solar salt production. However, local populations are increasingly recognizing the value of mangroves in overall ecosystem productivity (Green Antilles, 2011), and rates of loss appear to have slowed.

Within the Dominican Republic, the extent of mangrove protection—as well as overall area of mangroves—is still under contention. The first significant mangrove protection dates to the 1970s when tourism development of the Punta Cana/Punta Bávaro area began to encroach onto mangrove habitat, especially in the vicinity of Laguna Bávaro (18.5943, -68.3297). In the early 1980s, Laguna Bávaro became the centerpiece of a wildlife refuge that remains to the present (González, 1999). A stronger mangrove conservation law was enacted in 1987 when Decree 303 banned activities that destroyed mangroves (Silva, 2003; Wielgus *et al*., 2010). In 2011, government officials proclaimed the existence of at least 29,300 ha of mangroves (DREDE, 2011). However, the FAO (2007) estimated a drop from 34,400 ha in 1980 to about half (16,800 ha) by 2005 (based upon projections from 1998, when 21,215 ha were surveyed).

The twin objectives of this study are to refine our understanding of the changes in mangrove area in the Dominican Republic over the period of rapid tourist expansion and to assess if mangrove forests in tourist locations have been deforested at a similar rate as areas without a dominant tourist sector. Additionally, by analyzing all mangrove forests in the Dominican Republic, including field visitation, this analysis will shed light on the actual areal extent of mangroves that remain in the Dominican Republic and the historic levels required to calculate accurate annual deforestation rates.

Materials and Methods

The delineation of mangrove forests involved the digitization of historical topographic maps. All topographic maps utilized were 1:50,000 scale with mangrove forests delineated as polygons and annotated as such on the map legend. All of the mangrove features on the topographic maps were derived from aerial photography. Of the 223 mangrove stands delineated in the topographic maps, 168 were from aerial photographs taken between 1983 and 1989, and 48 were from aerial photographs taken in 1967 or 1968. The remaining 7 mangrove stands were obtained from more recent post-1989 topographic maps. The topographic maps were digitized using a large format scanner and ~80 control points at the graticule intersections of the map were used to accurately geo-reference each map. From the maps, the mangrove polygons were then digitized and imported into a spatial database.

The current mangrove delineation utilized Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) imagery from 2009 through 2012. Unsupervised classification was performed on the 15 m visible and near infrared (NIR) bands excluding the backwards NIR band. The Idrisi Selva CLUSTER function was utilized to identify regions of similar spectral signatures across all bands. The CLUSTER function itself is a histogram peak technique commonly used for unsupervised classification and signature generation (Richards, 1986).

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Clusters were identified as mangroves from field verification, field photographs, maps, and other mangrove sources such as the World Mangrove Atlas (Spalding *et al*., 2012) and the Mangrove Forests of the World (Giri *et al*., 2011). The output clusters were polygonized into conterminous areas by a GIS analyst. Once all historic and current mangrove forests had been delineated, map algebra was utilized to quantify the change over time in each of the pre-determined locations and for the country as a whole. The change analysis data and the current mangrove areas were imported into the same spatial database as the historic mangrove polygons.

Field verification of mangrove area was conducted in June and July 2012. Ninety percent of the mangrove forest regions in the Dominican Republic were visited and data were collected for use in cluster identification. In addition to collecting information on the location of mangrove forests, the dominant economic use of land in the immediate vicinity was also noted. Eight major mangrove zones were identified along with several smaller clusters (Fig. 1).

Tourism is the major economic activity in Zones 4, 5 and 7; solar salt production dominates in Zones 8 and 2; agriculture covers much of Zone 6 (the Río Yuna delta); and Zones 1 and 3 represent national parks wherein no economic activities currently function as stressors to mangroves (unlike Zone 8 where salt production takes place within the Monte Cristi National Park).

Results and Discussion

The historic level of mangrove forest was calculated to be 25,245 ha (Table 1). Although four percent of the initial survey data is not considered historic, this number is below the FAO (2007) finding of 34,400 ha in 1980. The current mangrove forest cover is calculated to be 18,441 ha (Table 1) as of 2009/2012, which is slightly higher than the 2005 estimate of 16,500 by the FAO (2007) but still far lower than the official government estimate of 29,300 in 2011 (DREDE, 2011). For these reasons, the annual loss was found to be 1.0% annually between 1984 and 2010, or 0.85% annually if calculated back to 1967, both of these numbers are far below the FAO calculated rate of 2.8% annually between 1980 and 2007. Some possible reasons for this difference are slightly differing start and end dates of each survey, that only 53% of our survey have comparable dates to the FAO survey, the higher spatial resolution of ASTER vs. other global sensors, the projected nature of the FAO survey that assumes future deforestation can be estimated from past deforestation, and possible mangrove regeneration since 1998.

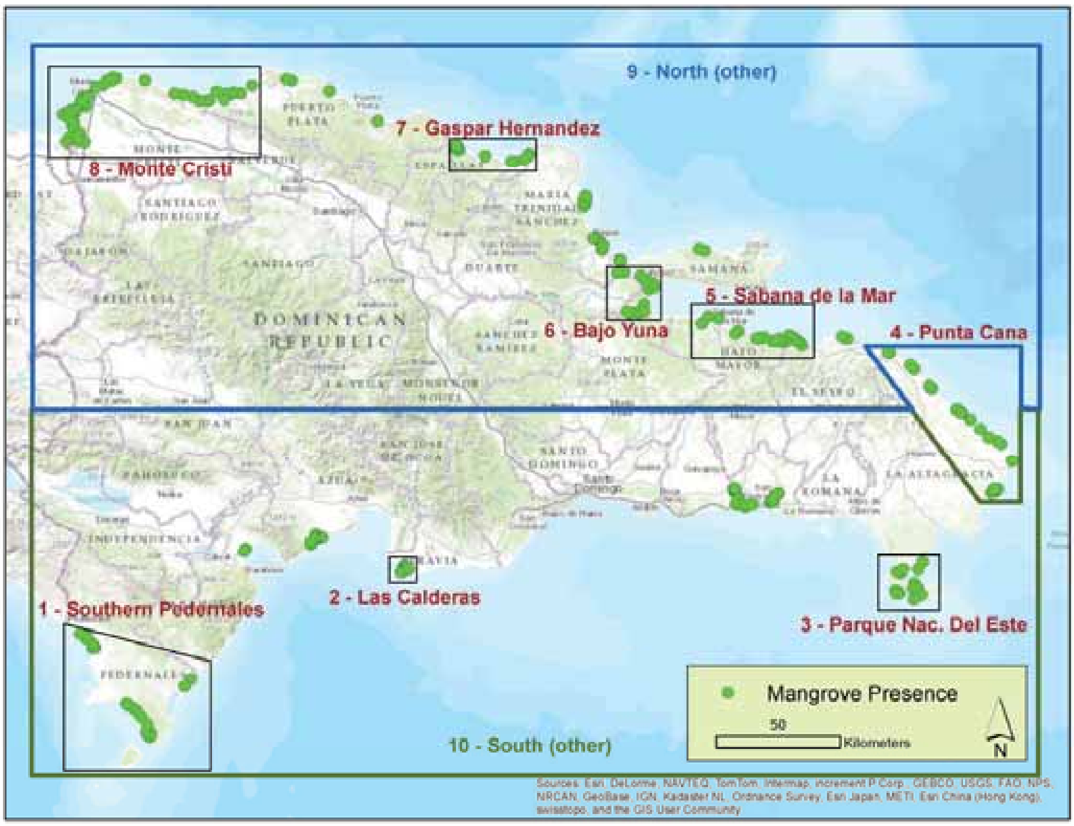

Fig. 1 All mangrove stands in the Dominican Republic from the initial survey and study areas

Table 1 Study areas, land use change analysis results and economic activity information

Site	Location	Classification	Initial survey (ha)	Final survey (ha)	Change (ha)	% Change
1	Southern Pedernales	Protected	2,450	1,891	-559	-22.8
2	Las Calderas	Salt	28	31	+3	+11.1
3	Parque Nac. Del Este	Protected	1,387	947	-440	-31.7
4	Punta Cana	Tourism	1,218	936	-282	-23.2
5	Sabana de la Mar	Tourism	3,231	2,338	-893	-27.6
6	Bajo Yuna	Protected	7,570	3,794	-3,777	-49.9
7	Gaspar Hernandez	Tourism	770	628	-141	-18.4
8	Monte Cristi	Salt	6,841	6,214	-627	-9.2
9	North (other)	NA	965	812	-153	-15.9
10	South (other)	NA	785	850	+65	+8.3
	Dominican Republic	NA	25,245	18,441	-6,804	-27%

The areas of greatest mangrove deforestation are Zones 3 and 6 (Fig. 1) with mangrove losses of 32% and 56%, respectively (Table 1). Both areas have a large relative area of initial mangrove cover suggesting that the results are not merely large percentage conversion of relatively small areas. Interestingly, both of these mangrove areas are wholly inside designated protected areas listed as national parks in the original topographic maps and in the World Protected Areas Database (IUCN & UNEP, 2009). Perhaps the parks were, in part, established to minimize further mangrove destruction—such as by agricultural expansion in the case of Zone 6—or protected status has not been all that effective. Further research is needed to explain the high rates of mangrove loss.

The areas of most tourism development (Zones 4, 5 and 7 – Fig. 1) have relatively lower levels of mangrove deforestation than wholly protected areas but higher levels of deforestation than the salt pond dominated regions (Table 1). In one example, west of Río San Juan, a gated resort community now exists where the topographic maps indicate a 100 ha mangrove forest once existed (19.6200, -70.1365). The resort appears to be directly located in the former mangrove forest with only 42 ha of mangrove remaining on the fringes of the resort. In the Punta Cana/Punta Bávaro area (Zone 4), we also noted that certain mangrove forests (such as those in the Laguna Bávaro Wildlife Refuge) are no longer accessible to the general public as they can only be accessed *via* private gated roads with security guards. Although the mangroves remain and constitute a touristic attraction (e.g. ecotours), the economic livelihood and food security benefit they provide local communities is greatly reduced.

The lowest rate of mangrove deforestation was in the regions of salt pond activity (Zones 2 and 8). This runs counter to the worldwide pattern of other types of ponds—such as aquaculture ponds—being responsible for high levels of mangroves deforestation both regionally and globally (Hamilton, 2013), and findings in other nations that equate mangrove deforestation in part to salt pond expansion (Primavera, 2000). This indicates that salt ponds in the Dominican Republic may not have the same impact on mangrove forests as similar ponds elsewhere or that mangrove destruction in the salt zones predated the oldest mangrove surveys used in this study. Again, further analysis on salt ponds and mangrove deforestation is required both within the Dominican Republic and beyond to verify this provisional finding.

Conclusion

The results of the analysis and field inspection demonstrated that mangroves are distributed in several distinct zones within the country, and that the impacts upon them varied over space and time. Most of the current expanse of mangroves, and historic losses, are within national parks. In spite of a long record of mangrove tourism at the Gris-Gris Lagoon and revitalized mangrove ecotourism at Los Haïtises and elsewhere, tourism infrastructural development has been a major stressor of the mangrove environment at Punta Cana/Punta Bávaro as well as along the north coast and also—to a lesser extent—along the south shore of the Samaná Bay. Other zones of tourism development, such Las Terrenas in the Samaná Peninsula, contain few mangrove habitats. In the northwest of the country, the climate is dry and solar salt production is widespread. In the past, many mangroves were likely converted to salt ponds in this area, and today, it appears there is an uneasy neighborly relation between the salt operations and the mangrove forests, with salt pond areas having the lowest levels of mangrove loss.

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