GIS Vegetation Mapping of the Jama Coaque Reserve
Third Millennium Alliance

Rachel Karlov
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Introduction

Tropical rainforests provide a significant amount of resources relative to any other ecosystem on Earth and because of their fragility they are the subjects of important conservation efforts. Biodiversity conservation efforts are also important due to the forests' high number of endemic species and human-caused habitat loss (Helmer et al., 2002). The importance of tropical rainforests can be exemplified in several ways. Their high species richness offers a higher opportunity and capacity for change that is important in the unpredictable environment of the rainforest (Brunig, 1977). In addition, tropical forests play a main role in the nutrient cycle because the vegetation acts as a filter of food and nutrients. Stands of long living trees both store a large amount of nutrient in their trunk and release nutrients through the annual fall of leafy wood litter (Brunig, 1977). Their efficiency in conserving and filtering nutrients is evident by the low amounts of bioelements in the stream water (Brunig, 1977).

Human interference has had a negative effect on tropical rainforests. Degradation of rainforests by deforestation cannot be reversed and depending on the crop that is planted, it may take hundreds of years to rebuild the soil's ecosystem (Brunig, 1977). In many cases the complex nutrient cycle once held in place by the rainforest can never be attained (Brunig, 1977). Simple man-made forests with a reduced canopy cover will alter the capacity of exchange with the environment, therefore altering the delicate balance tropical rainforests have created over many years (Brunig, 1977). Less vegetation cover results in reduced cloud contact and increased evapotranspiration (Lawton et al., 2001). This along with warmer temperatures created by climate change will affect the location of cloud forests and all the endemic species that live within them (Still et al., 1999). If humans convert forests to vegetation cover types with a lower biomass, then large amounts of carbon dioxide will be released into the atmosphere affecting not just local areas, but regional and global ones as well (Brunig, 1977).

This study focuses on the forests located in the Jama Coaque Reserve in the coastal province of Manabí, Ecuador. The reserve is a biodiversity hotspot and is home to some of the last remaining patches of both the tropical moist evergreen forest and the premontane cloud forest. Tropical moist forests are richer in biodiversity than cloud forests and occur at lower elevations. They are the most structurally-complex and diverse of the land ecosystems and are found in regions where the average temperatures of the three warmest and three coldest months do not differ by more than 5°C ("What is a tropical rainforest," 2015). Rainfall is evenly distributed which allows for the growth of broad-leaved evergreen trees ("What is a tropical rainforest?," 2015). However, many tropical moist forests have distinct dry and rainy seasons. Another important characteristic of tropical moist forests is their multiple layers of vegetation from understory shrubs to trees of more than 40m in height (“What is a tropical rainforest?,” 2015).

Cloud forests are a subset of tropical rainforests that occur where mountains are frequently enveloped by orographic clouds and convective rainfall (Still et al., 1999). Their immersion in clouds reduces solar radiation, increases humidity, and reduces transpiration (Lawton et al., 2001). They are also particularly important in local and regional watersheds because they regulate the seasonal release of precipitation (Still et al., 1999). For example, horizontal precipitation on vegetation provides a source of water during the dry season by allowing water droplets to condense directly on plants that are surrounded by clouds (Still et al., 1999).

Vegetation mapping, which is the main focus of this project, is important because it provides information for managing landscapes in order to sustain their biodiversity and the structure and function of their ecosystems (Helmer et al., 2002). Maps are critical for biodiversity planning because vegetation is linked to species composition and habitat types and as ecosystems change over time so will their inhabitants. Vegetation mapping at the Jama Coaque Reserve is also important because it will aid in the planning and executing of future research projects.

The problems with mapping tropical cloud forests, however, is that typical methods such as remote sensing and satellite imagery are difficult to use for a few reasons. First, these forest environments typically have a complex topography. This means that ecological zones and illumination angles change over small areas leading to spectral confusion in which varied vegetation communities have similar spectral signatures (Helmer et al., 2002). Second, the persistent and intermittent cloud cover requires the use of satellite images from different dates further complicating image-based mapping (Helmer et al., 2002). Finally, the tendency to group similar but distinct ecological zones together may extend the apparent distribution of endemic species with narrow distribution (Helmer et al., 2002).

The first goal of this project is to create a map that delineates the boundaries between the five main types of vegetation cover at the Jama Coaque Reserve (JCR): primary and secondary tropical moist evergreen forests, primary and secondary premontane cloud forests, and agroforestry plots. Finally, the second goal is to determine the average elevation at which the cloud forest begins. It has previously been predicted by members of the reserve that the boundary occurs at approximately 525m of elevation.

Methodology and Data Analysis

The first step in the mapping process was learning how to identify the five different forest types in the reserve. Table 1, created by the Fall Session of 2014 intern Justine Revenaz, demonstrates how to recognize the differences between the main vegetation types in the field. In addition to the identification table, both the EcoHike and hikes led by the local trail guide helped with learning how to recognize the different forest types.

TABLE 1. Description of the five different forest types at the Jama Coaque Reserve.

		Moist tropical evergreen	**Premontane cloud forest**
Primary	Ground	Shrubs, fallen leaves and trees. Looks easy to walk through.	Shrubs, fallen leaves and trees. Large and diverse amount of fern-like shrubs. Presence of the ancient genus and fern ally *Selaginella*. Looks easy to walk through.
	Understory	Rich and diverse tree composition and mostly "old" trees. Large number and diversity of epiphytes.	Rich and diverse tree composition of mostly "old"trees but they are smaller and farther away from each other. Large and diverse amount of epiphytes and a lot of moss covering trees.
	Canopy	Little sunlight shines through. High canopy.	Little to no sunlight shines through. Canopy is lower than in moist forest.
Secondary	Ground	Shrubs, fallen leaves and trees, saplings. Looks difficult to walk through.	Shrubs, fallen leaves and trees, saplings. Presence of fern-like shrubs and *Selaginella*. Looks difficult to walk through.
	Understory	Diverse tree composition of mostly "new" trees, young trees, and saplings. Epiphytes are present but less diverse and in smaller quantities.	Tree composition is mostly "new" trees, young trees, and saplings. Some epiphytes and large amounts of moss.
	Canopy	Lower canopy than primary forest, some light shines through.	Some light shines through.
Agroforestry	Ground	Shrubs and saplings, fallen leaves.	
	Understory	Banana, cacao, tagua, coffee, and orange trees. Some trees are decaying.	
	Canopy	Sunlight shines through.	
"Old" trees	Moral fino, caoua, lengua de vaca, mangle, igueron, guion, caucho, hasta, cedro, cative		
"New" trees	Bamboo, palm trees, tagua, secropia		
Agroforestry patch trees	Banana, tagua, coffee, cacao, orange, lime		

Modified from Justine Revenaz (2014).

The primary tropical moist evergreen forest is characterized by larger, older trees and a high canopy. It also has a short understory that is relatively easy to walk through. On the other hand, the secondary tropical moist forest is composed of mostly young trees and saplings. It has a lower canopy than the primary moist forest and an impenetrable understory. The transition to the premontane cloud forest occurs with the increased presence of moss and epiphytes on trees and an increased amount of ferns and shrubs on the ground**.** *Selaginella*, an ancient genus and a fern ally, is abundant in the reserve and is a common understory plant (Kricher, 1999). In the cloud forest the canopy is dense and the trees are smaller allowing little to no sunlight to shine through. The secondary premontane cloud forest has a slightly reduced amount of epiphytes. The trees tend to be smaller allowing more light to shine through the canopy. Groupings of crop plants mark the agroforestry plants. Usually these include stands or rows of banana, cacao, orange, citrus, lime, or coffee plants.

Mapping began by hiking the trails within the reserve. Every five minutes a GPS waypoint was marked denoting the type of forest surrounding the trail. The vegetation type at the point was analyzed based on Table 1, and the data was stored in the GPS according to Table 2. If the type of forest changed within those five minutes the time would stop and a waypoint of the new vegetation type would be marked. The counting would then be reset to time zero and a new point would be taken after an additional five minutes. If an agroforestry patch was only composed of a few trees then only one point would be marked in the middle, but if it was a larger plot a waypoint would be marked at both ends.

TABLE 2. GPS Waypoint Forest Classifications

Primary tropical moist evergreen	TMP
Secondary tropical moist evergreen	TMS
Primary premontane cloud	PC
Secondary premontane cloud	PS
Agroforestry patch	AGR
Transition zone	TRNS

Modified from Justine Revenaz (2014).

In order to create the final maps the waypoints were entered as a vector layer into the QGIS software and combined with other layers of the reserve such as trails, elevation, and the theorized cloud forest. The forest type layers were created by first overlapping the trail and GPS waypoint layers. The split tool was then used to divide the trail layer into multiple layers wherever one forest section stopped and a new one started. This was determined by looking at the GPS waypoints.

Results

Two vegetation maps were created of the reserve. The first (Fig. 1) is a map of the trails of the reserve color-coded by forest type and it includes all of the GPS waypoints taken. It also includes the area previously theorized by reserve members to be the cloud forest. The area of theorized cloud forest is considered any area above 525m. The second map (Fig. 2) is similar to the first but does not include the waypoints. A box plot was also created that shows the range in elevation for each forest type (Fig. 3).

The beginning of the cloud forests ranges from 450.21m to 560.95m and begins at an average of 518.38m. On both the Ronquillo and Emergentes trails on the north side of the reserve, the cloud forest begins at a much lower elevation than the theorized value (Figure 1). Removing those two data points, the average beginning of the cloud forest is 542.08m.

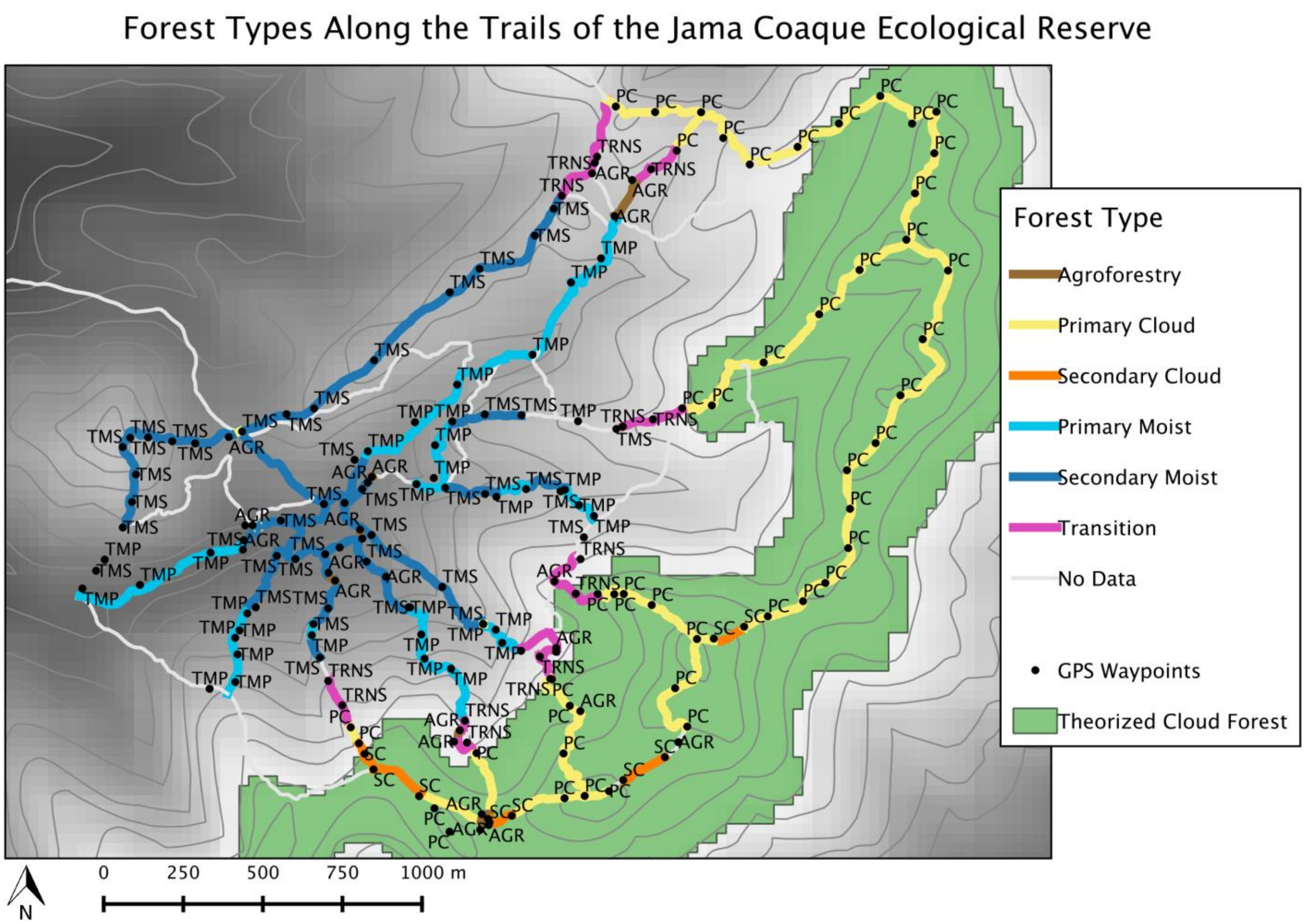

Figure 1. Map of the Jama Coaque Reserve Trail System color coded by vegetation type. Included are all of the GPS waypoints taken during data collection and the area that is theorized to be cloud forest. The forest color-coding was created by connecting the data collected by the GPS.

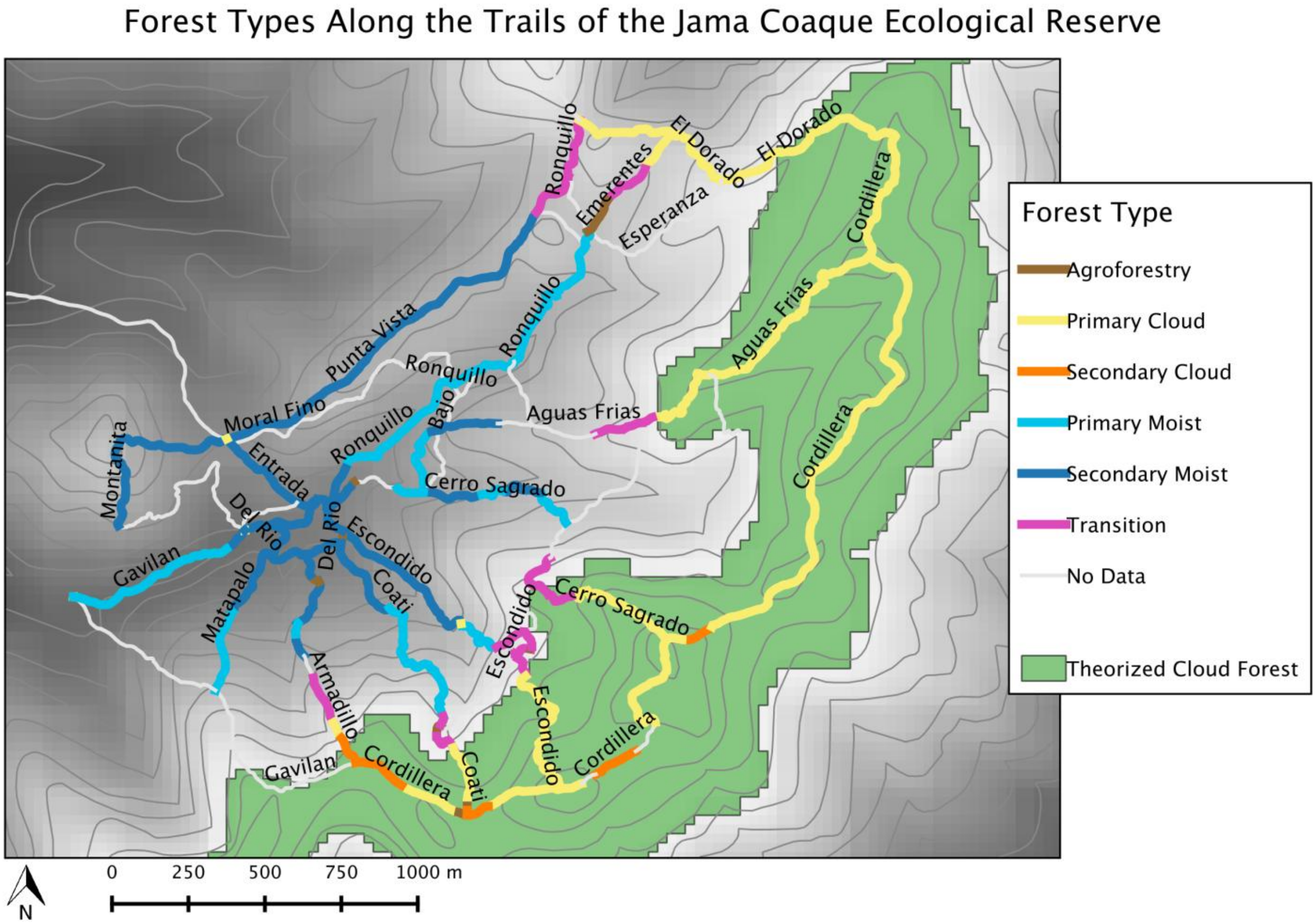

Figure 2. Map of the forest types along the trails of the Jama Coaque Reserve without the waypoints.

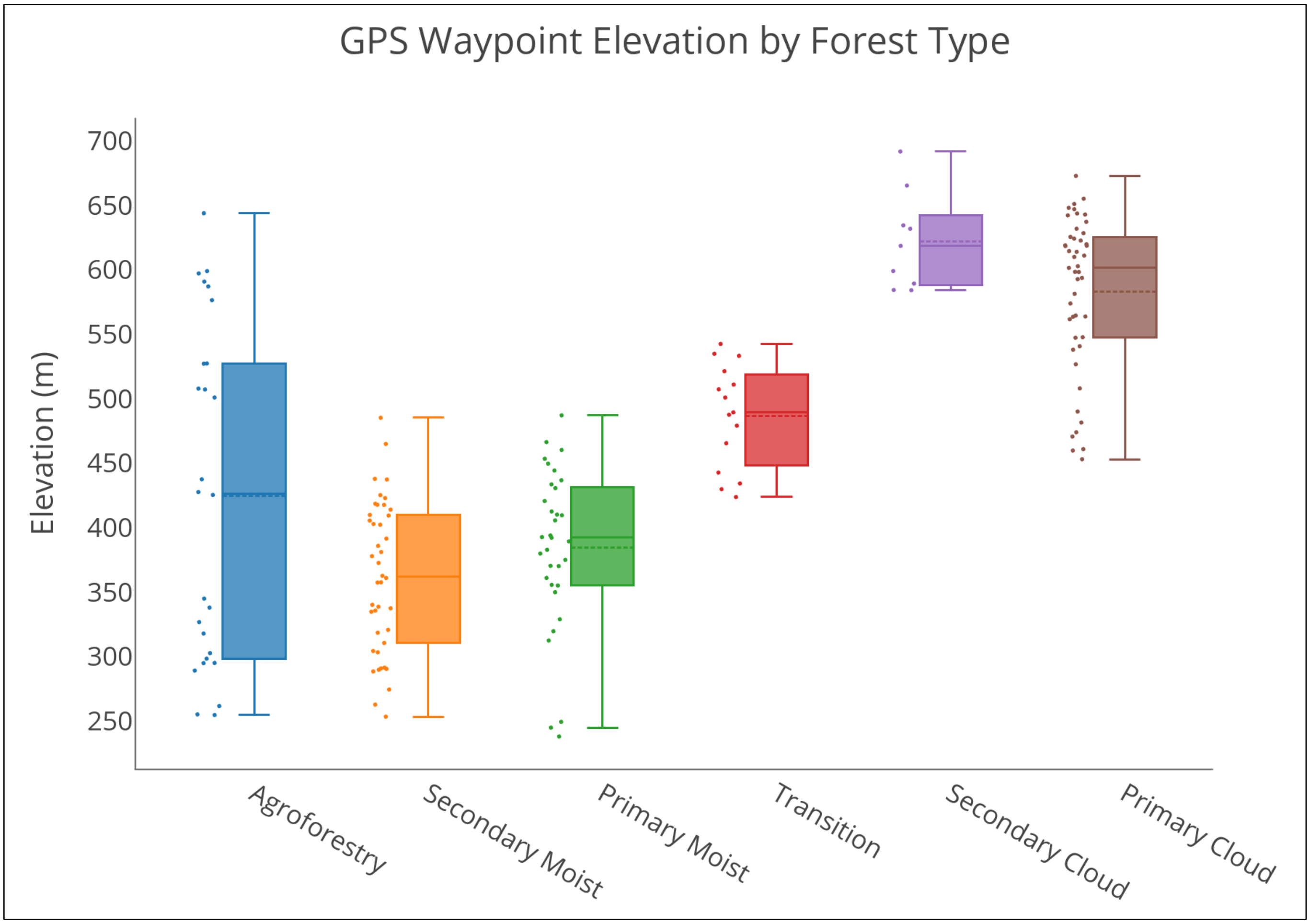

Figure 3. Box plot showing the range in elevations for each forest type. The points on the left of each box represent each of the GPS Waypoints taken for that forest type. The median is shown as a dark line and the mean is shown as a dashed line within the box. The whiskers represent the minimum and maximum values of the datasets. The average for agroforestry is 421.57m, for secondary moist is 359.18m, for primary moist is 381.48m, for transition is 484.04m, for secondary cloud is 619.23m, and for primary cloud is 579.97m.

Discussion and Conclusion

The average beginning of the cloud forest at 518.38m agrees with the previous predictions that the cloud forest begins at around 525m. This trend does not apply to the trails at the north side of the reserve. For example, at the Emergentes trail the cloud forest begins at 450.21m and at the intersection of the Ronquillo and El Dorado trails the cloud forest begins at 467.83m. One possible explanation is that the mountain ridge is lower at this part of the reserve. This means that orographic precipitation may also occurs at a lower elevation therefore affecting the location of the cloud forest. Another possible explanation is that wind patterns on the northern end of the reserve are different enough that they lead to cloud formation at a lower elevation. More research is needed in order to provide a more detailed explanation.

Both the box plot and the maps display a general pattern of increasing elevation amongst the different forest types. From lower to higher elevation the pattern goes secondary tropical moist forest, primary tropical moist forest, transition zone, primary cloud forest, and secondary cloud forest. The secondary cloud forest overlaps with the primary cloud forest but is still located at higher elevations. This is due to the fact that the highest points in the reserve are located at the ridge, which in many locations is also the border of the reserve. The secondary cloud forest is mostly located in these areas of high elevation where there is a neighboring pastureland or agricultural field.

Future research can be done in order to create a more detailed map of the reserve. The type of mapping that has been done in this paper, which involves collecting GPS points along the trails, has illuminated vertical patterns of forest change. In the future, mapping in between the trails is needed in order to see if any patterns emerge laterally. One possibility is to use the same method and collect GPS points by foot, but this time traveling in between the trails. The main problem with this method is accessibility since much of the forest floor is too dense to traverse by foot. Another possibility is the use of a drone or unmanned aerial vehicle (UAV). Sugiura et al. (2005) developed a system that involved mounting an imaging sensor on a UAV in order to generate a map regarding crop status. Lucieer et al. (2010) also successfully used a UAV that provided ultra-high resolution spatial data to map moss beds in Antarctica. In order to map the Jama-Coaque reserve using drones and UAVs the variable topography and vegetation of the region would need to be taken into account first.

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