The Effects of Anthropogenic Disturbances on the Structure and Composition of Rain Forest Vegetation

by Tendro Ramaharitra, MFS 2005

Introduction

The tropical forests of Madagascar, which shelter thousands of plant and wildlife species, have a well-known reputation for their unique biodiversity. Approximately 80% of the plant species are not found elsewhere in the world (Lowry et al. 1997; Schatz 2001; Gautier and Goodman 2003). A recent study by Schatz (2001) revealed that up to 96% of the large shrubs and trees in Madagascar are endemic, which is estimated to consist of over 12,000 species. Capuron stated that "any given hectare of forest cannot be compared to its neighboring one's, and at anytime, community composition changes dramatically" (Gautier and Goodman 2003). This statement illustrates the complexity of the ecosystem and, at the same time, confirms its vulnerability. A specific example is the rain forest of Ranomafana, which represents one of the last remaining strips of primary vegetation in the eastern escarpment of Madagascar. Though unique, a large part of the forest has been destroyed due to deforestation; the loss was estimated by Green and Sussman (1990) to be around 80% of the original cover. The forest of Ranomafana was classified as a protected area in 1995, which required all human populations to move out of the designated boundaries. At present, about 110 villages are located in the peripheral zone of the park, subsisting mainly on agriculture and hunting and gathering practices. About 10 years after the park's designation, much of the forest in the peripheral zone has been transformed into agricultural land; there is little to no forest acting as a buffer zone separating human settlement from the park. Resources in the park are protected, but locals continue to claim their right to use the forest by illegally exploiting the timber and non-timber forest products for commercial and domestic uses (Peters 1999).

This research assesses the impact of human settlement around the park on rain forest vegetation. I aimed to uncover and understand the dynamism of the forest over time and space and how this change relates to human uses through the analysis of patterns between middle altitude evergreen rainforest vegetation structure and composition and the presence of anthropogenic disturbances, such as wood extraction, selective logging, and trails for non-timber forest product harvesting. The main hypothesis is that increased human accessibility to the forest leads to increased disturbance. This implies that: (a) the forest edge has a more open canopy due to increased cutting for fuel wood and other uses, (b) the number of vines diminishes as we move to the forest edge, and (c) the trail system density is higher at the forest edge. It is important to assume that the natural gap formation in the forest is not significantly affecting the forest community structure and composition.

Tendro Ramaharitra attended the Agronomy School at the University of Antananarivo, Madagascar, where he began working on various projects in Ranomafana National Park. He continued working with Ranomafana at the Yale School of Forestry and Environmental Studies and obtained a Masters of Forestry in 2005. He is currently working as a consultant for the Wildlife Conservation Society in Madagascar and will pusue a doctoral degree at Berekley's School of Natural Resources in the fall.

Figure 1. Shannon diversity index (*H'*) and the evenness index (*J'*), where H_{max} = ln(*S*), *S* as the total number of species, *p* the proportion of all individuals in a sample belonging to the *i* th species

$$H' = \sum_{i=1}^{s} (pi)(\ln pi) \qquad J' = \frac{H'}{H \max}$$

Methods

This study is based on a biological inventory of the forest in Ranomafana National Park. Field measurements were entered and statistically analyzed using Minitab 14 and SAS v8. ESRI ArcMap 9 mapping software was utilized for spatial analyses.

I quantified the vegetation structure and composition from the forest edge to the interior by looking at the different forest layers and by estimating the Shannon diversity index (*H'*) and the evenness index (*J'*) (Pielou 1975; Krebs 1989; Magurran 1988) (Figure 1). I then measured the following parameters to quantify human disturbances: percent of canopy cover, quantity of vines and trees cut in each botanical plot, and trail density inside each plot. I performed both linear and quadratic regression analyses relating all human and vegetation values with the distance of the plots from the forest edge to illustrate the spatial pattern in each stratum; I then used the disturbance parameter values to predict the diversity and evenness of the study plots through regression analysis as well.

The study site encompasses 3.36 ha of forest, which was subdivided into 21 botanical plots of 40 meters by 40 metres and distributed along three transect lines. Trees in each botanical plot were clustered into four categories: (1) seedlings less than 25 cm in height or less than 1 cm in diameter, (2) small shrubs between 1 cm and 5 cm in diameter, (3) mid-canopy trees less than 10 cm in diameter, and (4) canopy trees greater than 10 cm in diameter. The botanical materials were identified using the identification keys of Turk (1997) and Schatz (2001). Updates on certain species names were verified through many authors, using mostly Goodman and Benstead (2003).[1]

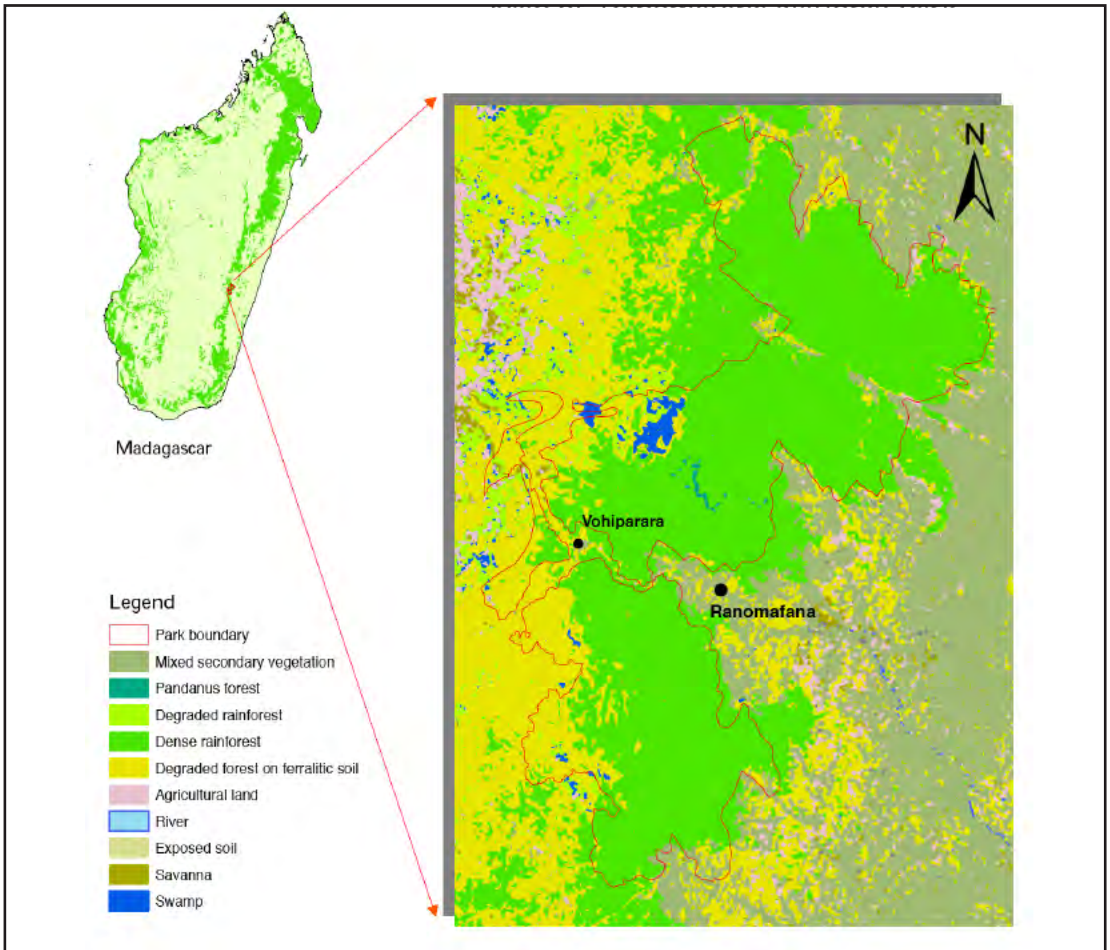
Background

Ranomafana National Park (RNP) is located in the eastern escarpment of Madagascar at latitude 21°15'S and longitude 47°27'E (Figure 2). The elevation ranges from 600 m to 1,375 m above sea level. The temperature is moderately tropical, with an average annual temperature of 19°C and a low of 6°C during the winter. Precipitation typically falls more than 280 days a year, leading to an annual accumulation of 4,000 mm.[2] The forest in Ranomafana National Park was classified as evergreen, humid mid-elevation by Du Puy and Moat in 1996. The forest is subdivided into three strata: (1) the forest canopy, reaching 25 m on average, (2) the high shrub and mid canopy trees, and (3) the understory vegetation and forest floor, covered with moss and lichen. The canopy trees are characterized by a series of *Weinmannia sp.* (Cunoniaceae) and *Tambourissa sp.* (Monimiaceae) (Lowry et al. 1997; Du Puy and Moat 1996). The vegetation cover changes over the landscape from tree savanna to savanna pseudosteppe with increased human activity (Humbert and Cours-Darne 1965).

Results

A total of 194 locally known species were found in the three sites, including 23 scientifically unknown species. These species belong to 46 families and 103 genera; I could only iden-

Figure 2. Map of Ranomafana National Park



Source: metadata from FTM Madagascar and Royal Botanic Gardens, Kew

tify 80 trees to the species level and the others to their respective genera. The number of stems per hectare of canopy trees varied from 688 to 881, while understory trees reached a maximum of 30,000 stems/ha. The canopy trees were dominated by the Cunoniaceae family and the understory vegetation was dominated by the Rubiaceae family.

Plant diversity significantly increased (p<0.05) from the edge of the forest to the interior (Figure 3). Following this trend, the evenness index value was higher in the forest core than in the edge. It is necessary to note that the evenness index ranged from 0.60 to 0.96, where the maximum at which a forest community is designated as totally even is set at 0.99 (Pielou 1975).

I performed linear and quadratic regression analyses between the distance from the forest edge and the four disturbance indicators. There was a significant decrease (f=13.6, p=0.002) in the number of trees cut from the edge to the interior of the forest. This shows the use of the forest edge by local villagers (Figure 4). There was no visible pattern in the number of lianas or trails from the edge of the forest to the interior. Percent canopy cover was found to decrease towards the exterior of the forest, but this trend is not statistically significant. There is high variability in percent canopy cover due to the presence of forest gaps in the study plots.

Correlation analyses show that the diversity and evenness index values are positively correlated with the number of lianas for canopy trees and low shrubs (f=15.89, p<0.001;

f=15.32, *p*<0.001, respectively). Thus, the number of lianas can explain forest structure at some level of significance, while none of the three disturbance indicators left can significantly predict the diversity and evenness of the forest (Table 1). In addition, percent canopy cover predicts the diversity of both low shrub vegetation and canopy trees.

Discussion

Two major types of human disturbance were identified in the forest. First, there is evidence of direct physical disturbance, such as the formation of forest gaps and the removal of valuable species. In this study, a link was not established between the designated disturbance parameters and the structure and composition of the forest community. However, results do confirm that the forest structure and composition are altered at the forest edge and that there is more extraction at the forest edge than in the interior. Yet there is no evidence suggesting that the number of trees cut per hectare, which increases when moving from the interior to the edge of the forest, is affecting the diversity and evenness of the vegetation. Similarly, the results show that the number of lianas per hectare affects the diversity and evenness of the forest community, but there is no significant pattern from this parameter across space that would suggest human use.

Second, there are the edge effects created by human deforestation outside of the park. The change in structure and composition of the forest might be a consequence of changes in the biotic and abiotic conditions created by edge effects (Laurance and Yetsen 1991; Murcia 1995; Ozanne et al. 2000) and not from the cutting of trees. Consequently, we cannot confirm that selective logging and other forest extraction practices alone altered the diversity and structure of the forest by diminishing the canopy cover near the edge. In addition, a low evenness index value was found in the forest edge, which reveals the dominance of opportunistic species or a species that can adapt better to the ecology condition. This may create a favorable environment for heliophilous vegetation and decrease the chance of regeneration for shade tolerant species. This may be considered harmless to the forest, as

Figure 3. Correlation between distance from the forest edge and the diversity Index values

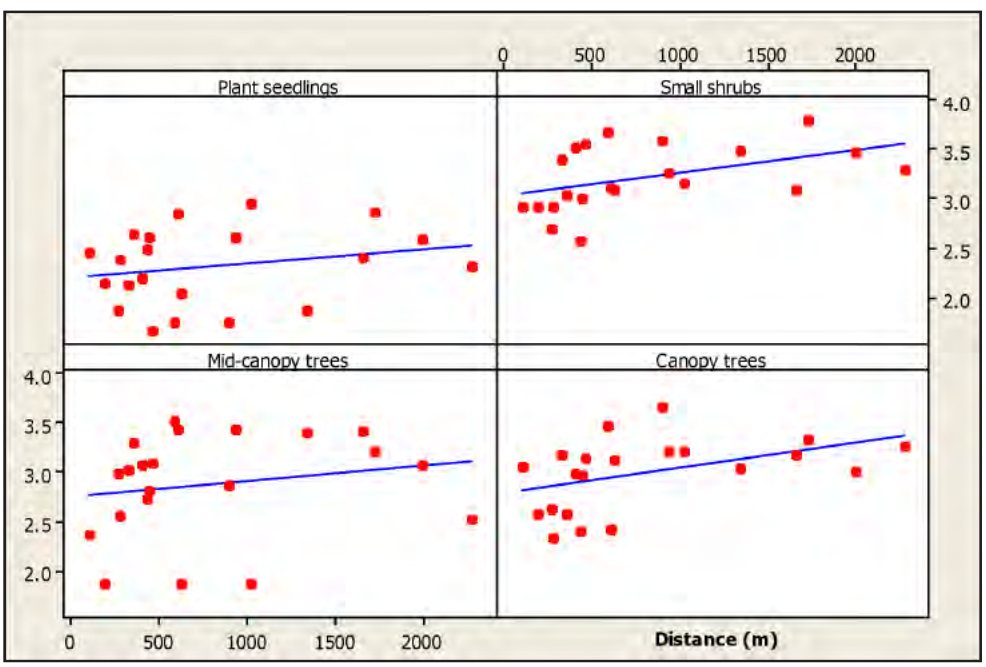
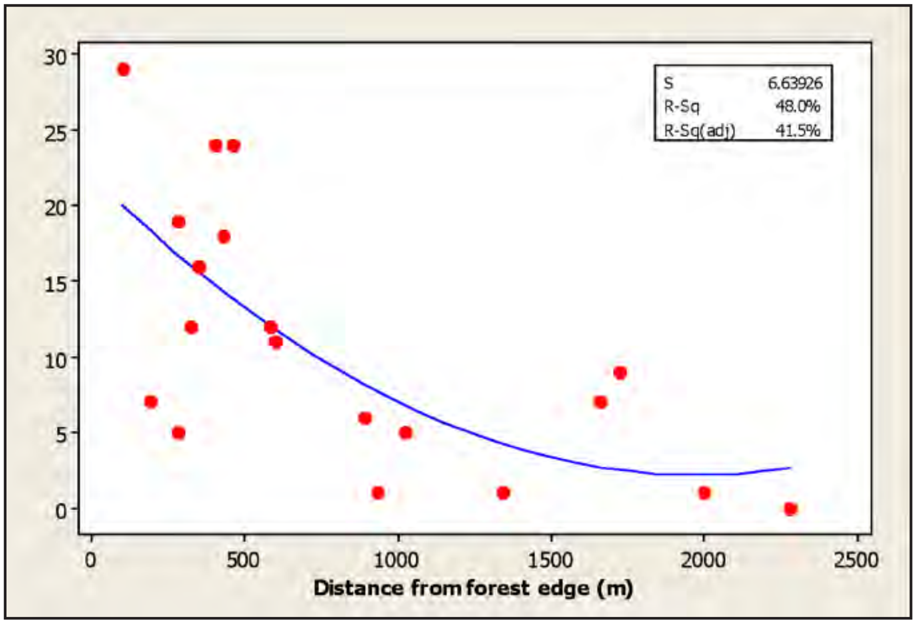


Figure 4. Fitted line plot of number of trees cut per hectare versus distance from forest edge



these pioneer species disappear as soon as the forest reaches its climax (Lowry et al. 1997 in Goodman and Benstead 2003). On the contrary, the establishment of some invasive species, such as the Chinese guava, *Psidium cattleianum* (Myrtaceae), is considered to be a threat to the forest. This species has already colonized most of forest gaps in Ranomafana (Binggeli et al. 2003 in Goodman and Benstead 2003).

Conclusion

Despite the low significance of some studied parameters, the forest pattern suggests that human disturbances have significantly altered the vegetation composition around the edge of the forest. These impacts, direct human manipulation or indirect edge effects, are translated largely into a change in the proliferation of some shrub species and the loss of canopy trees on the forest edge. These changes may not be as menacing as slash and burn agriculture or timber forest harvesting, but they are indicators of ecosystem health and the ability of the forest to assume its functions (Rapport 1995). Moreover, it is certain that if villagers continue to travel deeper into the protected rain forest of Ranomafana for food and supplies, the core of the park, a primary forest, will change radically into an ecosystem that reflects the peripheral zone of the park. This situation will eventually leave nothing for the people living around the park to use, and will impact also the conservation of the primary forest. This problem needs to be addressed by both the local community and park management so it does not

Table 1. Significance of the regression analysis indicators vs. diversity index

	Seedlings		Low shrub		Mid canopy trees		Canopy trees	
	F stat	P values	F stat	P values	F stat	P values	F stat	P values
Trees Cut/Ha	0.100	0.757	0.800	0.393	0.040	0.853	0.660	0.429
Trails	0.040	0.851	1.670	0.211	0.510	0.483	0.000	0.966
Lianas/Ha	4.390	0.050	15.320	0.001	0.450	0.511	15.880	0.001
% Canopy Cover	0.840	0.370	7.430	0.013	0.280	0.601	14.450	0.001

jeopardize the future of Ranomafana National Park.

Endnotes

1 Plant identifications and descriptions are distributed from the following authors in Goodman and Benstead 2003: Leguminosae (Fabaceae): Labat and Moat p. 346; Sapotaceae: Gautier p. 342; Moraceae: Dalecky et al. p. 322; Annonaceae: Thomas and G. Aymonin p. 316; Melastomataceae: Almeda p. 375; Euphorbiaceae: Hoffmann and McPherson p. 379; Anacardiaceae: Randrianasolo p. 398; Rubiaceae: David and Bridson p. 431.

2 Data from the research station at Ranomafana.

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