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Effects of selective logging on dynamics and composition of woody seedlings in a tropical secondary forest

Álvaro Redondo Brenes [1]
Robin L. Chazdon [2]
Braulio Vílchez Alvarado [3]

Abstract

This study was conducted in a logging road in a 28 years old secondary forest in the Atlantic lowlands of Costa Rica. We gathered information from three different microhabitats: track road, edge road and an adjacent logged forest. The main objective was to study the dynamics and composition of woody seedlings ≥ 20 cm height and < 1 cm dbh. Sets of 5 m^2 quadrats were laid out at 15 meters intervals in the logging road (320 m long). Data were collected at 12, 19 and 25 months after logging. The author registered density, species richness and diversity, height growth rate, recruitment and mortality. Seedlings growing in the road quadrats had the highest density, growth rate and recruitment. Seedling density in the logging track and edge road did not differ significantly. Mortality rate did not differ significantly among the three microhabitats. Species diversity, based on Shannon's and Simpson's index, was highest in the logged forest quadrats, but the road quadrats had the highest species density. The most abundant species in the track road were *Vochysia ferruginea* (Mart) *Hampea appendiculata* (Donn Sm) Standl, and *Ossaea brenesii* (Standl). *V.ferruginea* accounted for more than half of the density per plot. The microhabit conditions created by logging activities, especially in the track and edge road may have favored the establishment of pioneer and other light-demanding species in these open areas regarding the adjacent logged forest. Long-term studies should be conducted in logged secondary forests of different ages to understand processes of forest recovery after anthropogenic disturbance. Furthermore, the role of soil conditions and light availability in these processes needs to be investigated in more detail.

Key words: Tropical secondary forest, Secondary succession, Regeneration, Height growth, Mortality, Recruitment, *Vochysia ferruginea, Hampea appendiculata, Ossaea brenesii,* Sarapiquí, Costa Rica.

[1] School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA , alvaro.redondo@yale.edu
[2] Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT, USA, chazdon@uconn.edu
[3] Escuela de Ingeniería Forestal , Instituto Tecnológico de Costa Rica, Cartago, Costa Rica, vilchez@itcr.ac.cr

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Resumen

Efectos de corta selectiva en la dinámica y composición de brinzales leñosos en un bosque secundario tropical. Este estudio fue llevado a cabo en un camino de extracción de madera en bosque secundario en las tierras bajas del Atlántico de Costa Rica. Se reunió información de tres diferentes micrositios: el centro de camino, el borde del camino y el bosque secundario madereado adyacente. El objetivo principal fue estudiar la dinámica y composición de brinzales = 20 cm de altura y < 1 cm de dbh. Parcelas de 5 m^2 fueron establecidas a intervalos de 15 m en el camino de extracción (320 m de largo). La información fue recolectada a los 12, 19 y 25 meses después que el camino fue abandonado. Se registraron densidad de individuos, densidad y diversidad de especies, crecimiento de la altura, ingresos y mortalidad. Se encontró que los brinzales creciendo en el centro del camino presentaron la mayor densidad, crecimiento y reclutamiento. Sin embargo, no se encontraron diferencias significativas con los brinzales creciendo en el borde del camino. Tampoco se encontraron diferencias en la mortalidad para los tres sitios. De acuerdo con los índices de Shannon y Simpson, el sitio con mayor diversidad fue el bosque adyacente, pero las parcelas en el centro del camino presentaron el mayor número de especies. Además, se encontró que las especies más abundantes fueron: *Vochysia ferruginea* (Mart), *Hampea appendiculata* (Donn Sm) Standl, y *Ossaea brenesii* (Standl). De las tres especies estudiadas, *V. ferruginea* presentó más de la mitad de la densidad de individuos por parcela. Las condiciones microclimáticas creadas por las actividades de extracción, especialmente en el camino forestal pudieron haber favorecido el establecimiento de especies pioneras y demandantes de luz en las áreas abiertas con respecto al bosque madereado. En general, se recomienda estudios a largo plazo, los cuales serán útiles para determinar la recuperación del bosque después de la intervención humana. Además, se recomienda hacer estudios de suelos y de luz para evaluar estas variables con respecto a los procesos de sucesión.

Palabras clave: Bosque secundario tropical, Sucesión secundaria, Regeneración, Crecimiento de la altura, Mortalidad, Reclutamiento, *Vochysia ferruginea*, *Hampea appendiculata*, *Ossaea brenesii*, Sarapiquí, Costa Rica.

INTRODUCTION

Tropical rain forests are subject to several forms of anthropological disturbance, such as forest burning, logging, and shifting cultivation, which cause serious forest destruction (Luna *et al*, 1999). The design and execution of logging impact studies and long-term monitoring programs are critical to evaluate the role of forest management in biodiversity conservation (Lindenmayer, 1999). Logging changes light levels and soil conditions through the creation of gaps and soil disturbance (Vieira, 1995). In selectively logged tropical forest, extraction roads can disturb a considerable proportion of soil and canopy cover during timber harvesting (Uhl and Vieira, 1989; Guariguata and Dupuy, 1997), creating distinct sites for plant establishment. Forest recovery in abandoned road tracks may be substantially retarded due to substrate compaction by machinery use and lack of on-site plant propagules after topsoil removal (Guariguata and Dupuy, 1997; Uhl *et al,* 1982; Malmer and Grip, 1990; Pinard *et al*, 2000). Tropical secondary forests are an abundant and important forest resource, which is valuable not only for their abundance, compared to other forest ecosystems, but also because they provide environmental goods and services for the society (Chazdon and Coe, 1999; Berti, 2001; Redondo *et al,* 2001). For instance, in Costa Rica there are 425,000 ha of secondary forest and 200,000 ha of primary productive forest (CCT, 1997; Segura *et al,* 1997). The scarcity of primary productive forests and the demand for wood products have compelled people to start managing the secondary forest in Costa Rica.

There is limited knowledge on vegetation recovery in primary forest logging roads after disturbance (Guariguata and Dupuy, 1997), and even less information for secondary forests, which the threshold of the research in these ecosystems started last couple of decades.

In this paper, the authors examine vegetation recovery in a recent logging road and in an adjacent logged area of 28 years old secondary forest in the Atlantic lowlands of Costa Rica. Monitoring of replicated quadrats was carried out at 12, 19 and 25 months after disturbance to estimate the change in the dynamics and composition of seedlings in the logging road and disturbed forest. Replication of this logging road study was not possible due to two principal reasons: there was only a single logging road in this forest and lack of logged secondary forests nearby our study site. (Essentially, this was a restricted, small-scale logging operation).

The authors hypothesized that there would be increased abundance, dynamics (mortality and recruitment) and growth among seedlings growing in the road track and road edge compared to those in the disturbed forest, due to increased light availability. We also expected to see effects of the logging road on species composition.

METHODS

Study site

The study was carried out in the Atlantic lowlands of Costa Rica, Sarapiquí County (10°12′-10°47′N, 84°09′-84°45′W); as part of a larger project on vegetation dynamics, species composition and ecosystem processes in secondary forests. This is a long-term monitoring project funded by the Andrew W. Mellon Foundation that began in 1997. The natural vegetation in this area is classified as Tropical Wet Forest (Holdridge, 1978). Annual rainfall and temperature records from La Selva Biological Station (OTS, 2004), located within this life zone, average 3,721 mm (period from 1997 to 2000) and 25,3 °C, respectively. There is a season with least precipitation on January and February (Quirós and Finegan, 1994). Soils are derived from weathered volcanic deposits and alluvial processes, and included primarily Inceptisols and Ultisols (Guariguata and Dupuy, 1997) and the pH varies between 3.9 and 4.5 (Quirós and Finegan, 1994).

The logged area is located in a 28 years old secondary forest, which area is approximately 15 ha in extent (Diaz, 2002). This forest was the first primary forest; then the forest was cut in the early 1970s and briefly used as cattle pasture before abandonment. The landscape matrix is composed of cattle pastures and secondary forests and there are no remnants of primary forest nearby (Redondo *et al,* 2001). The forest was selectively logged in August 2000 using a bulldozer to open the road. Road planning, directional feeling and long distance log winching were implemented (Diaz, 2002). On average, six trees were cut per ha. Most of them were *V. ferruginea* (Mart) above 50 cm of DBH.

Methods

The logging road where this study was conducted was 320 m long and 3,2 m wide, on average, and it was located on the ridgetop. Our sampling differentiated three main microhabitats, hereafter called road, edge and forest. Quadrats of 1 x 5 m were laid out in each microhabitat at 15 m intervals along the study site, with a total of 15 quadrats in each microhabitat. The forest quadrats were located at 10 m into adjacent logged forest, aligned with the road and edge quadrats. The road quadrats were located in the middle of the road, 1 m from the edge plots. Edge and forest quadrats were assigned alternate locations on either side of the logging road at successive distance intervals.

At each plot location marked and identified all the woody seedlings (trees, shrubs, palms and lianas) above 20 cm of height and below 1 cm of diameter at the breast height (dbh).

Three censuses were conducted at 12, 19 and 25 months after logging.

In the first census (12 months), were marked every individual, measured its height, and identified it to species. For the second and third census (19 and 25 months), were re-measured these individuals to compute the difference in height, and recorded mortality. In addition, were marked, identified and measured newly recruits individuals during the second and third census.

It was calculated mean abundance, species richness and diversity, and height for the three censuses for each microhabitat. Moreover, were computed the growth, mortality and recruitment for the second and third census. For the third census was conducted a specific analysis of the three species more abundant in the three microhabitats in order to compare abundance, growth, mortality and recruitment regarding the rest of the species.

Statistical analysis

All the data for this study are in average per plot (5 m^2). We used one-way ANOVA and Turkey's post-hoc tests to evaluate effects of plot location on abundance of stems ≥ 20 cm height and < 1 cm of dbh, number of species, height growth and recruitment. For the analysis of abundance and recruitment was used a square root transformation to normalize these values.

Binary logistic regression was used to test for plot location effects on mortality. It was used two-way ANOVA to test effects of microhabitat on abundance, height, and growth for the three most abundant species: *Vochysia ferruginea* (Mart), *Hampea appendiculata* (Donn Sm) Standl, and *Ossaea brenesii* (Standl).

It was used the Shannon's and Simpson's index to measure species diversity (Magurran, 1988); and compared microhabitat differences using the nonparametric, Kruskal–Wallis test (N=15 per site).

Analyses were performed with MINITAB and SAS, and statistical significance was fixed at P < 0,05. Residual plots were analyzed in order to ensure that model assumptions were satisfied.

RESULTS

Abundance, species richness, height growth and dynamics

Seedling density was significantly lower in the logged forest quadrats than in the road and edge microhabitats for 19 and 25 months after logging, but not after 12 months. (ANOVA, P < 0,05). Tukey's test (P < 0,01) showed that there were no differences in seedling density between the edge and road quadrats at any census. The high recruitment values computed at 19 and 25 months in the edge and in the road quadrats compared to the low recruitment values in the forest quadrats can explain this pattern (Table 1).

Table 1. Density of seedlings in the track and the edge of an abandoned logging road, and an adjacent logged secondary forest, Sarapiqui, Costa Rica. The values correspond to the squared-root of seedling density.

Location	12 months (stems 5 m^{-2})	19 months (stems 5 m^{-2})	25 months (stems 5 m^{-2})
Edge	3,3 (2,0)^{a}	5,9 (3,8)^{a}	6,8 (3,8)^{a}
Forest	2,6 (0,7)^{a}	2,7 (0,8)^{b}	2,9 (0,7)^{b}
Road	3,6 (2,3)^{a}	6,8 (3,7)^{a}	7,6 (3,7)^{a}

Value in parenthesis corresponds to the Standard Desviation. Within location, values followed by different superscripts denote a statistical location effect for the square root of density at P < 0,01 (Tukey's test)

The species density (number of species per quadrat) was higher in the road quadrats than in the other two locations (Table 2). There was an increment in the number of species per plot at every measurement point (from 12 to 25 months), which was related to the recruitment patterns. At 12 and 19 months, there were no statistical differences in the number of species per location, but at 25 months, there are differences for this variable among microhabitats (ANOVA, P < 0,01). However, this study did not find differences between the edge and road (Tukey's test P < 0,05). On the other hand, species diversity determined by Shannon's and Simpson's Index was highest in the adjacent logged forest (Table 3). But, not statistical differences were found for both variables among sites (Kruskal-Wallis test, P < 0,01).

Table 2. Species density per 5 m^2 plot in the track and in the edge of an abandoned logging road, and in an adjacent logged secondary forest, Sarapiqui, Costa Rica.

Location	12 months (density 5 m^{-2})	19 months (density / 5 m^{-22})	25 months (density / 5 m^{-22})
Edge	6,0 (3,9)^{a}	11,5 (7,0)^{a}	15,1 (7,8)^{a}
Forest	4,7 (2,2)^{a}	5,2 (2,9)^{a}	5,5 (2,8)^{b}
Road	6,2 (5,8)^{a}	12,4 (9,3)^{a}	14,8 (9,5)^{a}

Value in parenthesis corresponds to the Standard Desviation. Within location, values followed by different superscripts denote a statistical location effect at P < 0,01 (Tukey's test)

Table 3. Shannon's and Simpson's Index to determine species diversity in the track and in the edge of an abandoned logging road, and in an adjacent logged secondary forest at 12 and 25 months after logging, Sarapiqui, Costa Rica. Values correspond to 65 m^2 plot.

Index	Forest		Edge		Road	
	12 months	25 months	12 months	25 months	12 months	25 months
Shannon	2,92 [a]	3,33 [a]	2,75 [a]	2,33 [a]	2,61 [a]	2,40 [a]
Simpson	0,90 [b]	0,93 [b]	0,83 [b]	0,68 [b]	0,80 [b]	0,69 [b]

Within location, values followed by different superscripts denote a statistical location effect at P < 0,01 (Kruskal-Wallis test)

The height growth (cm month^{-1}) for the seedlings was determined at 19 and 25 months. The highest growth value for both censuses was for the seedlings growing in the road quadrats, then the ones in the edge quadrats. The smallest rate was obtained in the adjacent logged forest (Table 4). For both censuses, it was found that there are statistical differences among locations (ANOVA, P < 0,05). However, these differences in the mean of height growth were significant between the stems in the adjacent logged forest and the ones in the road and edge quadrats (Tukey's post-hoc test, P < 0,01). There were not statistical differences for this variable between road and edge quadrats.

Table 4. Average height growth of seedlings (cm month^{-1}) in the track and the edge of an abandoned logging road, and an adjacent logged secondary forest, Sarapiqui, Costa Rica.

Location	19 months (cm month^{-1})	25 months (cm month^{-1})
Edge	3,1 (2,2) [a]	2,6 (1,3) [a]
Forest	0,8 (1,0) [b]	0,9 (0,8) [b]
Road	3,7 (2,3) [a]	3,1 (1,4) [a]

Value in parenthesis corresponds to the Stanadrd Desviation. Within location, values followed by different superscripts denote a statistical location effect at P < 0,01 (Tukey's test)

The average recruitment per quad reached a maximum between the 12 and 19 months, when its mean was from 1,3 to 41,9 new seedlings per plot, in the adjacent logged forest and in the track road, respectively. Then, the values decreased between the 19 and 25 months period. For instance, in the edge and track road the values decreased almost three times its previous number (Table 5). The analysis of the mean of square roots for recruitment values depicted that there are statistical differences among locations (ANOVA, P < 0,05). However, there are not statistical differences between the recruitment in the edge and road quadrats (Tukey's test, P < 0,01).

Table 5. Average recruitment of seedlings in the track and the edge of an abandoned logging road, and an adjacent logged secondary forest, Sarapiqui, Costa Rica. Values correspond to the squared-root of the recruitment data.

Location	19 months (stems 5 m^{-2})	25 months (stems 5 m^{-2})
Edge	4,9 (3,5) [a]	3,1 (1,4) [a]
Forest	0,8 (0,8) [b]	0,6 (0,9) [b]
Road	5,6 (3,2) [a]	3,7 (1,2) [a]

Value in parenthesis corresponds to the Standard Desviation. Within location, values followed by different superscripts denote a statistical location effect for the square root of recruitment values at P < 0,01 (Tukey's test)

The values for mortality presented its highest score for the measurement at 19 months. This high mortality percentage in the specific case of the forest quadrats was caused by a dead tree, which fell down on a plot (Table 6). Overall, the mortality rates were similar, and location was not a significant predictor of mortality (Binary Logistic Regression, P < 0,05).

Table 6. Mortality of seedlings in the track and the edge of an abandoned logging road, and an adjacent logged secondary forest, Sarapiqui, Costa Rica.

Location	19 months (stems 5 m^2)	25 months (stems 5 m^2)
Edge	10 (4,7)^a	24 (3,3)^a
Forest	13 (11,9)^a	2 (1,7)^a
Road	16 (5,9)^a	39 (4,4)^a

Value in parenthesis corresponds to the percentage of mortality. Within location, values followed by different superscripts denote a statistical location effect at P < 0.05 (Binary Logistic Regression)

Species more abundant for the three locations

For this section, we selected the three species that were more abundant in the different locations and performed an analysis at 25 months after logging activities for density and growth of these species regarding the rest of the species (Table 7). For both variables, density and height growth, there are statistical differences among species and among locations ANOVA, P < 0,05). In addition, for density there are interaction between location and group of species. For height growth there are not interaction between location and species (ANOVA, P < 0,05).

Table 7. Density and height growth of seedlings in the track and the edge of an abandoned logging road, and an adjacent logged secondary forest, Sarapiqui, Costa Rica. Values for stem density correspond to squared-root of the density data.

Species	Density (stems 5 m^{-2})	Height growth (cm month^{-1})
Hampea appendiculata	0,7 (0,9)^a	0,9 (2,0)^a
Ossaea brenesii	0,7 (1,3)^a	1,3 (2,4)^a
Vochysia ferruginea	3,1 (3,8)^b	1,3 (1,6)^a
Rest of the species	3,9 (1,8)^b	2,6 (1,9)^b

Value in parenthesis corresponds to the Standard Desviation. Within variables, values followed by different superscripts denote a statistical location and species effect at P < 0,05 (Tukey's test)

For density, there are not significant differences between *H. appendiculata* and *O. brenesii*, as well as between *V. ferruginea* and the rest of the species (Tukey's test, P < 0,05). The height growth did not present significant differences among *H. appendiculata, O. brenesii*, and *V. ferruginea.* Overall, the species *V. ferruginea* is the most abundant species with approximately half of the average density per plot in the three microhabitats.

DISCUSSION

Forest recovery after human interventions, such as logging, depends on the severity of the disturbance (Whitmore, 1998). Changes in light, shade and darkness are important features of the tropical forests (Longman and Jenik, 1987; Whitmore, 1998). These changes are related to openings in the forest canopy which may be relatively restricted (branch or tree fall, selective logging) or extensive (landslide, hurricane damage, or clear cutting (Chazdon *et al,* 1996). Various intensities of light and variation in its spectral composition affect plant growth, reproduction, primary production, and thus indirectly the structure of the forest (Longman and Jenik, 1987). Although logging disturbances increase light availability in ways similar to natural tree falls, logging does not necessarily mimic natural disturbances and these effects need to be examined in more detail (Guariguata and Pinard, 1998).

Density, species richness and height growth rates

Seedling density as well as species density per plot increased from the measurement at 12 months to censuses at 19 and 25 months after disturbance, especially in the road and edge quadrats. In Bolivia, Fredericksen and Mostacedo (2000) found a significant increase in seedling and sapling density 14 months after selective logging in a primary forest. They also mentioned that the highest density and greatest initial height growth rates of tree regeneration were observed on areas with the greatest amount of soil disturbance and light transmittance, including log landings and logging roads.

Similar patterns were observed in Sarapiquí, Costa Rica. The quadrats located in the sites with greatest amount of soil disturbance and light penetration showed the highest values for density and height growth rates (Tables 1 and 4). Most of these quadrats are located in open areas due to the gaps produced by the canopy removal and on ridgetop. Guariguata and Dupuy (1997) found in the Atlantic lowlands, Costa Rica, that density of stems $\geq$ 1 m tall $\leq$ 5 cm dbh in a primary forest was higher in the road edge quadrats than either the track or logged forest. In addition, they mentioned that in two nearby, recently logged forest ($\leq$ 3 years old at the time of this study), no woody seedlings along 300 m of sampled road tracks were observed, while at the edge, shrubs and light-demanding tree saplings had already established.

However, in this study site, the situation was different. Seedlings growing in the track road presented the highest density, height growth rate and number of species per plot regarding to seedlings in the edge road and logged forest quadrats. But, it is important to notice that although, stems in road quadrats had the highest density, height growth rate and number of species per plot, there were no statistical differences between this group and the edge quadrats. Furthermore, even though the highest species density was in the road and edge quadrats, the logged forest quadrats showed the highest species diversity. But the species composition patterns reflect strong effects of stem density on species density.

At least during the first years after abandonment, natural regeneration in road tracks may depend much more on post-logging seed dispersal than on stored seeds, due to topsoil removal (Uhl *et al,* 1982). An advantage that this forest had was that nearby the logged area there was a not logged area approximately of 4 ha at no more than 50 m. Most of the regeneration of this logged area may come from this secondary forest. This forest has more than 1200 stems, 120 species and 30 m^2/ha of basal area (woody individuals dbh = 5cm) (Redondo *et al,* 2001).

Another factor that may have affected a better development of seedlings in the track road than either in the edge road or in the logged forest is light availability. Chazdon *et al* (1996), mentioned that light availability would be higher in the center of the gap (i.e. in the middle of the roads) than in the gap edge or in the understorey of a forest. Furthermore, Guariguata and Pinard (1998) cited that some tree species can only regenerate after seed germination is triggered by canopy and/or soil disruption, or if their seedlings benefit from high light environments for sustained growth. In our study site, a secondary forest, where most of the canopy species are light-demanding (Redondo *et al,* 2001) the light availability is a factor that may have a big influence in species establishment and growth rates (Fredericksen and Mostacedo, 2000). Even though, in the study did not measure light availability in the field, it was clear for personal observations that the road quadrats received more light than the ones in the edge road or in the logged forest quadrats. The former had more openings due to canopy removal and for chopping/buldozing of vegetation to clear road for tree removal.

More abundant species, recruitment and mortality

The three most abundant species in these quadrats were *Vochysia ferruginea* (Mart)*, Hampea appendiculata* (Donn Sm) Standl and *Ossaea brenesii* (Standl)*.* According to Jimenez *et al* (1996), all of them are light-demanding species. *V. ferruginea* and *H. appendiculata* are very abundant trees which grow in secondary forest and open areas (Guariguata, 2000; Redondo *et al,* 2001). *O. brenesii* is a shrub, common in open areas (Jimenez *et al,* 1996). Previous works have noted dense stocking of a few dominant, usually light-demanding tree species on logging roads surfaces soon after timber harvesting (Abdulhabi *et al,* 1981). For instance, Fredericksen and Mostacedo (2000) reported that the high increment in abundance in logging road in their study in Bolivia was mostly due to two species: *Anadenanthera colubrina* (Vell Conc) Brenan and *Astronium urundeuva* (Fr Allem) Engl.

The density of dispersed seeds and distance from source trees influence early seeding survivorship in disturbed forests (Guariguata and Pinard, 1998). Overall, in our study site, *V. ferruginea* was the most abundant species, especially in the road and edge quadrats, where they affect the recruitment because of their high germination rate (Guariguata, 2000) in these quadrats.

V. ferruginea constituted approximately half of the average density per plot. A factor that may have favored the high recruitment was the high light availability due to canopy openings as well as the proximity of seed sources. In the adjacent unlogged forest there were more than 12 *V. ferruginea* per ha over 30 cm of dbh Redondo *et al* (2001). The fruiting period of *V. ferruginea* is from April to June in this forest (Vilchez *et al,* 2004). Moreover, Guariguata (2000), pointed out that *V. ferruginea* (wind-dispersed) and *H. appendiculata* (vertebrate-dispersed) have seeds which possess very little dormancy and which site colonization may be possible only a few weeks after seed dispersal. This author also mentioned that both species show low survival rates after canopy closure. Thus, these species may have been favored for site conditions and germination systems to colonize these particular logging road quadrats than the forest quadrats.

For the successional stage of the evaluated seedlings in this study, it was observed a low rate of seedling mortality. In fact, microhabitats showed no significant differences in mortality rates. The recruitment rate, decreased over time from 19 to 25 months and this factor would be related to the occupancy of the space and establishment, which may start the competition among individuals for resources at this level (Fredericksen and Mostacedo, 2000).

The lack of replication as well as lack of measurement of soil and light conditions, limit the scope of this study. Thus, the results obtained in this logging road cannot be generalized to all secondary forests in the region. But this study does provide a useful approach for future researches of forest recovery after logging activities.

CONCLUSIONS

Microhabitat conditions created by logging activities, especially in the logging road and edge areas favored the establishment of pioneer and other light-demanding species compared to the adjacent logged forest areas. Although, seedlings growing in the logging road were the more abundant, they had the greatest height growth and in general the best development regarding the other two locations, these variables did not differ significantly with those measured in the edge microhabitats. This research did not find statistical differences in mortality among microhabitats. Mortality values were less than 5% in most of the cases.

The high rate of recruitment in this study was due principally to three species: *V. ferruginea, O. brenesii,* and *H. appendiculata.*

V. ferruginea stems presented more than half of the density for the three locations in plot average. In addition, these three species did affected the height growth rate, because the rest of the species had the highest height growth rate.

Data obtained in this study were compared with data from primary forest due to scarcity of information of forest recovery for secondary forest after logging activities. This research recommend long-term studies in logged and intact tropical secondary forests to evaluate their recovery after harvesting and estimate the real impact of these anthropogenic disturbances. In addition, it is recommended studies of soil and light availability in order to evaluate these factors in recruitment processes.

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