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Assessing success of forest restoration efforts in degraded montane cloud forests in southern Mexico

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ASSESSING SUCCESS OF FOREST RESTORATION EFFORTS IN DEGRADED MONTANE CLOUD FORESTS IN SOUTHERN MEXICO

By

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Abstract

Assessing success of forest restoration efforts in degraded montane cloud forests in Southern Mexico

Montane cloud forests are home to great biodiversity. However, non-sustainable anthropogenic activities have led to the loss of forest cover in southern Mexico. Increasing conservation, restoration and sustainable use of forest resources prevents the loss of cloud forests. In this study, success of forest restoration was evaluated in a degraded forest of Highlands Chiapas. The goal of this study was to assess the structure and composition of native tree species. We evaluated vegetation composition at three sites that had undergone enrichment plantings. Floristic composition and structure of the herbaceous, seedling, sapling, and overstory layers were measured. A total of sixty-six native tree species were recorded. Enrichment planting was found to have increased tree diversity. Moreover, 54% of the planted species were found in the understory, indicating that they were successfully recruiting. In conclusion, enrichment planting can aid in the conservation of forest cover in degraded areas.

1. INTRODUCTION

The biodiversity of montane cloud forests can be very high. For example, Rzedowski (1996) identified approximately 2500 plant species in the montane cloud forest of Mexico. In addition to high biodiversity, they also contain a large number of endemic plant species (750 species), reptiles (102 species), amphibians (100 species), birds (201 species) and mammals (46 species) (Challenger 1998). This high biodiversity and endemism in cloud forests are in part due to the combination of high humidity and cold temperatures creating an environment for the coexistence of both temperate and neotropical flora (Williams-Linera 2007).

Montane cloud forests are also important timber sources in many parts of the world, e.g. pine and oak species are economically important species of Mexico (Challenger 1998). Moreover, montane cloud forests provide many ecosystem services such as water uptake, protection from erosion, flooding (Manson 2004), and atmospheric carbon fixation (Jong et al. 1999). In addition, they provide useful and medicinal plants for people that live within the montane cloud forests (Hynes et al. 1997; Kappelle et al. 2000).

However, montane cloud forests are often highly degraded from human use (e.g., firewood collection, unsustainable forestry, grazing, development) and natural disturbances (e.g., fire, flooding, windstorms, landslides) (González-Espinosa et al. 2006) which modify forest structure and function (Ramírez-Marcial et al. 2001; Camacho et al. 2002; Galindo-Jaimes et al. 2002).

The deforestation in Mexico is a problem that has arisen from pre-Columbian times, and has increased dramatically in recent years. The annual rate of deforestation in southern Mexico is about 1.3% (Cairns et al. 1995). For the Highlands of Chiapas, the estimated annual deforestation rates until 2000 were: pine-oak forest (1.6%), oak forest (7.3%), pine forest (4.9%), and cloud forest (18.9%). These high rates of deforestation have led to forest fragmentation and impoverished floristic composition with the loss of 3-12 total species depending on the forest type (Cayuela, Benayas, et al. 2006; González-Espinosa et al. 2007)

The montane cloud forest in the state of Chiapas, Mexico has high species diversity due to geographic position, geology, and topography, all of which contribute to high numbers of flora and fauna species (Breedlove 1981; González-Espinosa et al. 2005). This diversity has a high value for the maintenance of ecosystem function and services that have been altered by unsustainable human activities causing forest fragmentation. Forest fragmentation from human activities such as livestock grazing, firewood collection, timber harvesting, and slash-and-burn milpa agriculture (Ramírez Marcial 1996) have led to the loss of forest cover with a decrease in tree species. Moreover, changes in species composition, population dynamics and community structure may be highly affected (Ochoa-Gaona et al. 2000). When a forest is disturbed (by natural or human activities) a gap is often created, which can affect microenvironmetal conditions that can alter species abundance and recruitment (Barik et al. 1996; Romero-Nájera 2000).

There is an increasing interest in the conservation, restoration and sustainable use of forest resources (Pulido 2002; Ramírez-Marcial et al. 2005). Although it is very difficult to restore forests to their original condition (Vázquez-Yañes et al. 1996) there are viable strategies for recovery of forest communities, i.e. to generate a greater variability in habitat conditions and microclimates that promote the seed dispersal and regeneration of a greater diversity of species (Guariguata et al. 1995).

Single plantation forests are typically less favorable as habitat than naturally regenerated forests or under an enrichment planting. Thus, plantations can have a highly diverse understory of native species leading to improved vegetation structure, microclimate, and soil (Pedraza et al. 2003; Ramírez-Marcial et al. 2005). In Mexico, reforestation programs implemented by the government have focused primarily on using exotic tree species (e.g. *Cupressus* spp., *Pinus* spp., *Eucalyptus* spp.) rather than native species because they tend to have higher growth rates and survival than natives (Vázquez-Yañes et al. 1996; Vázquez-Yanes et al. 1999). However, the use of exotic species has been shown to lower native habitat values, therefore, the selection and use of native tree species should be adopted because native tree species promote the recovery of biodiversity and function of ecological systems (Ramírez-Marcial 2003; Ramírez-Marcial et al. 2005).

Enrichment planting is defined as the reintroduction of additional species to disturbed forests without the elimination of species already present (Weaver 1987; Montagnini et al. 1997). Enrichment planting can be useful as a restoration technique in degraded forests because many plant species typical of montane cloud forests are considered intermediate or late successional; that is, they require preexisting tree cover for their establishment and growth. Thus, the reintroduction of mid- and late-successional species within degraded forests might be the best option for attempting to restore forest diversity (Ramírez-Marcial et al. 2010). However, long-term success of enrichment plantings in montane cloud forests is not well known. Therefore, we resampled three degraded forests in the Highlands of Chiapas, Mexico that have undergone enrichment planting between 6-20 years ago (Camacho et al. 2002; Quintana-Ascencio et al. 2004; Ramírez-Marcial 2003; Ramírez-Marcial et al. 2005; Ramírez-Marcial et al. 2008; Ramírez-Marcial et al. 2010).

The objectives of this study were: 1) to systematically assess the structure and composition of native tree species (overstory, understory) in degraded forests that have undergone enrichment planting; and 2) to describe the diversity of non-trees (herbaceous and shrubs) under enrichment planting.

2. METHODS

2.1 Study area

This study was located in the highlands of Chiapas, Mexico. We resampled enrichment plantings at three sites: 1) Rancho Merced-Bazom; 2) Cerro Huitepec Nature Reserve; and 3) Lagunas de Montebello National Park (Figure 1). Some of these plantations were established around 20 years ago, while others were established six years ago. Around 60 species of native tree species were used for the enrichment plantings.

2.2 Site descriptions

2.2.1 Rancho Merced-Bazom

Rancho Merced-Bazom (Bazom) is located near the municipality of Huixtán (16°44'N, 92°29'W). The area of the municipally is 342.21 km^2. The elevation is ~2400 m; the climate is cool (mean annual temperature is 12-14°C) and humid (mean annual rainfall is 1200-1500 mm) (García 1988). The soils are generally loamy derived from limestone rock, and are moderately deep. The remaining original vegetation includes several forest types such as evergreen cloud forest, oak forest, pine forest, and pine-oak forest (Breedlove 1981; González-Espinosa et al. 1997; González-Espinosa et al. 2005). The slash and burn of traditional agriculture is the main driver of the transformation of forest cover (González-Espinosa et al. 1991).

Approximately 2,552 individuals of twenty-six native tree species were planted at this site between 2000-2005: *Arbutus xalapensis*, *Clethra chiapensis*, *Cornus disciflora*, *Olmediella betschleriana*, *Prunus rhamnoides*, *P. serotina* subsp. *capuli*, *Quercus crassifolia*, *Alnus acuminata* subsp. *arguta*, *Cornus excelsa*, *Liquidambar styraciflua*, *Persea americana*, *Quercus laurina*, *Q. rugosa*, *Ternstroemia lineata*, *Drymis granadensis*, *Acer negundo*, *Buddleia cordata*, *Magnolia sharpii*, *Photinia microcarpa*, *Prunus lundelliana*, *Quercus crispipilis*, *Styrax magnus*, *Quercus segoviensis*, and *Q. candicans* (González-Espinosa et al. 2008). These trials occupy approximately twenty-one 400-m^2 areas. The initial conditions before the plantings were: old-field fallow, grassland, shrubland, early-successional forest, mid-successional forest, and mature forest (González-Espinosa et al. 1991; González-Espinosa et al. 2006).

2.2.2 Cerro Huitepec Nature Reserve

Cerro Huitepec Nature Reserve (CHNR) is located 4.5 km west of San Cristóbal de Las Casas City (16°44’38’’ N, 92°40’15’’W). The area of this reserve is 136 ha. The elevation is variable between 2230 and 2710 m; the mean annual temperature is 14-15°C with an average annual rainfall of 1300 mm. Soils in this area have a sand texture and are classified as vertic and gleyic cambisols (Ramírez-Marcial et al. 1998). The predominant vegetation is oak forest, with smaller areas of pine-oak forest. Ramírez-Marcial et al. (1998) evaluated six successional communites within CHNR and reported 315 vascular plant species. *Quercus* dominated the overstory; in some areas these trees have developed from sprouts of stems (Morón-Ríos et al. 2006).

During the months of June-July of 1989, 727 saplings of seven species of native trees were planted: *Oreopanax xalapensis*, *Myrsine juergensenii*, *Rhamnus sharpie*, *Ternstroemia lineata*, *Abies guatemalensis*, *Pinus ayacahuite*, and *P*. *pseudostrobus*. The total area of the plots was 6000 m^2. These species were planted in three successional stages: old-growth oak forest, mid-successional oak forest, and grassland (Quintana-Ascencio et al., 2004).

2.2.3 Lagunas de Montebello National Park

Lagunas de Montebello National Park (LMNP) is located in the south-southeast of Chiapas and northwestern Guatemala (16° 04’ 40’’ – 16°10’20’’ N, 91°37’40’’ – 91°47’40’’ W). The total area is 6,425 hectares. Elevation is around 1500 m; the mean annual temperature is 16-18°C and the average annual rainfall is 1862 mm. The soils are lithosols, gleysols, fluvisols, acrisols, vertisols, and rendzinas. The vegetation of the park includes pine forest, pine-oak-sweetgum forest, and cloud forest. *Pinus oocarpa* is the most representative species in the park (CONANP 2007); however, this species is associated with disturbed sites and tolerates extreme temperatures (Ramírez-Marcial

2003). LMNP is home to 4% of the total species richness for butterflies, amphibians, reptiles, birds, and mammals for the country (CONANP 2007).

In the summer of 2003, eight areas (20,000 m^2) of enrichment planting of 16 native tree species with a total of 3030 individuals were established in the park in areas that were affected by forest fires in 1998. The 16 native tree species were: *Liquidambar styraciflua*, *Morella cerifera*, *Quercus sapotifolia*, *Q. trinitatis*, *Rhamnus capraeifolia* var. *grandifolia*, *Ilex vomitoria*, *Nyssa sylvatica*, *Oreopanax xalapensis*, *Randia acuelata*, *Turpinia tricornuta*, *Olmediella betschleriana*, *Prunus brachybotria*, *P. lundelliana*, *Styrax magnus*, and *Synardisia venosa* (Ramírez-Marcial et al. 2010).

2.3 Data Collection

In this study, during the summer 2011 and spring 2012 floristic composition and structure were measured on 17 plots across these three forested sites by using nested circular plots (1000 m^2 each). Within each nested plot, the overstory was measured following size categories: 1) large trees (> 30 cm DBH-diameter at breast height) in one plot of 1000 m^2; 2) medium trees (10-30 cm DBH) in one subplot of 500 m^2; and 3) small trees (5-10 cm DBH) within one subplot of 100 m^2). Saplings (> 0.5 m height and < 5cm DBH) were measured within four circular plots of 8 m^2, and seedlings (< 50 cm height) were measured within four circular plots of 2 m^2 (Figure 2; (Ramírez-Marcial et al. 2001).

In each 1000-m^2 plot, an average of percent canopy cover of the forest overstory was estimated with a concave spherical crown densiometer (Forestry Suppliers, TM) at four positions (N, S, E, and W) within the 500-m^2 subplot. These values were averaged to get an average percent canopy cover per plot.

The herbaceous layer was identified and measured within the 500-m^2 subplot in each sample plot. The four quadrat subplots (1 m^2 each) were located at four positions (NE, SE, SW and NW) (Figure 2). Within each quadrat, all herbaceous species were identified to species and cover estimated by class: a) 0-1%, b) 1-5%, c) 5-10%, d) 10-25%, e) 25-50%, f) 50-75%, and g) 75-100% (following Campione 2011).

2.4 Data Analysis

Tree species were classified into three species types: *Pinus* spp. (in addition to *Abies guatemalensis* and *Podocarpus matudai*), *Quercus* spp., and Broad-leaved excluding *Quercus* (Ramirez-Marcial et al., 2001). Non-tree species were classified into ten groups according to growth form: 1) Fern, 2) Shrub, 3) Forb, 4) Graminoid, 5) Liana, 6) Subshrub, 7) Orchid, 8) Forb/Aquatic, 9) Shrub/creeper, and 10) Epiphyte (USDA 2012; Campione 2011).

The overstory structure was characterized in several ways. Small, medium, and large trees were categorized into diameter classes to construct diameter distributions by site. Structural variables (Kent et al. 1992) calculated for the overstory by plot include the following: 1) basal area per tree or per hectare, 2) relative basal area (dominance) by species, 3) density, 4) relative density, 5) frequency, 6) relative frequency, and 7) relative importance values (RIV's).

Relative importance values (RIV's) were based on Mueller-Dombois et al. 1974), where

$$\boldsymbol{RIV} = Relative\ basal\ area\ +\ Relative\ density\ +\ Relative\ frequency$$

Plot-level data was averaged across each site to obtain site-level averages.

Species richness (total number of species present), Shannon's diversity index (one of the most commonly used indices of diversity as it counts all the species according to their frequency), and evenness (the manner in which abundance is distributed among species) of the overstory, sapling, and seedling layers were calculated using trees per hectare while percent coverage was used for herbaceous species. Shannon's diversity index (H') was estimated using the following formula (Magurran 1988)

$$H' = -\sum \frac{\mathrm{Pi}}{\mathrm{Pt}} * \ln\left(\frac{\mathrm{Pi}}{\mathrm{Pt}}\right)$$

where:

Pi = cover of species

Pt = total of species richness for all species in the plot

ln = natural logarithm

The value of H' usually falls between 1.5 and 3.5 and rarely reaches 4.5.

Evenness (E) was calculated using the following formula (Magurran 1988)

$$E = \frac{H'}{\ln(S)}$$

where:

H'= Shannon's diversity index

ln= natural logarithm

S= species richness

The value of E is between 0 and 1, with 1 indicating complete evenness.

3. RESULTS

3.1 Tree composition and structure

A total of 66 woody species, 47 genera, and 35 families were recorded across the three sites. Forty-nine species were identified as overstory trees, and 49 species as understory trees (seedlings and saplings). The families with the most species were Fagaceae (8 species), Pinaceae (6 species), Rosaceae (5 species), and Compositae (4 species). The most abundant species registered for all plots were *Pinus oocarpa*, *Quercus laurina*, *Myrsine juergensenii*, and *Cupressus tusitanica*. A complete list of overstory and understory species recorded can be found in Appendix A and B (Table A; Table B).

The average diameter at breast height (DBH, 1.37m) of canopy trees was 19.8 cm. The largest dbh trees were *Quercus crassifolia* (109.3 cm) in Rancho Merced-Bazom, and *Crataegus pubescens* (108.4 cm) in Cerro Huitepec Nature Reserve.

Mean basal area (pooled species type per site) of *Pinus* spp. was highest in Rancho Merced-Bazom (12.76 m^2/ha), and lowest in Cerro Huitepec Nature Reserve (9.49 m^2/ha; Figure 3). *Quercus* spp. basal area was highest in Cerro Huitepec Nature Reserve (23.50 m^2/ha), and lowest in Lagunas de Montebello National Park (1.83 m^2/ha). Broad-leaved species showed the biggest mean basal area in Cerro Huitepec Nature Reserve (7.33 m^2/ha), and smallest basal area in Lagunas de Montebello National Park (3.08 m^2/ha).

Figure 4 illustrates mean basal area by size class for each site. Small trees in Cerro Huitepec Nature Reserve and Lagunas de Montebello Natural Park showed very similar basal area (11.93 m^2/ha and 11.99 m^2/ha respectively) and the site Rancho Merced-Bazom was lowest (5.25 m^2/ha). Medium trees showed very little difference in the amount of basal area between the sites. Large trees in Cerro Huitepec Nature Reserve had the highest basal area with 37.79 m^2/ha and Lagunas de Montebello National Park had the lowest with 8.21 m^2/ha.

Comparing the overall total mean basal area between the three sites (Table 1), LMNP was highest (64.68 m^2/ha), followed by CHNR (50.31 m^2/ha), and the lowest was Bazom (39.13 m^2/ha).

Relative importance value (size class per site) of large trees was highest in Lagunas de Montebello National Park (100%), followed by Rancho Merced-Bazom (30%), and Cerro Huitepec Nature Reserve (25%); medium trees showed the highest value in Lagunas de Montebello National Park (23%), followed by Cerro Huitepec Nature Reserve (17%), and Rancho Merced-Bazom (14%); and small trees were highest in Lagunas de Montebello National Park (25%), followed by Rancho Merced-Bazom (19%), and Cerro Huitepec Nature Reserve (17%).

Overstory species that showed the highest relative importance values were *Pinus oocarpa* (39%), *Quercus laurina* (32%), and *Quercus crassifolia* (20%), and lowest relative importance values occurred for *Eupatorium ligustrinum*, *Citharexylum donnell-smithii*, and *Saurauia latipetala* (< 1%) (Table D).

The greatest canopy coverage was measured in Cerro Huitepec Nature Reserve (92%), followed by Rancho Merced-Bazom (87%), and Lagunas de Montebello National Park (81%). These results suggest a low percentage of gaps in the canopy for all sites (Table 1).

The average diameter distributions (>5 cm DBH) of each site are shown in Figure 5. All three sites had high variability in trees between 6-30 cm. All trees measured at Lagunas de Montebello Natural Park were below 50 cm DBH. Rancho Merced-Bazom and Cerro Huitepec both had trees above 60 cm DBH.

The number of saplings and seedlings accounting for regeneration across the three sites was quite variable. In the sites Rancho Merced-Bazom and Lagunas Montebello Natural Park, saplings of *Pinus* spp. and *Quercus* spp. were scarcer (< 400 saplings/ha), but in Cerro Huitepec Nature Reserve no saplings of pine and oaks were observed. Broad-leaved species were more numerous in Rancho Merced-Bazom (> 8000 saplings/ha) and less numerous in Cerro Huitepec Nature Reserve (< 400 saplings/ha) (Figure 6).

Seedlings of *Pinus* spp. and *Quercus* spp. (< 200 seedlings/ha) were found in Lagunas de Montebello National Park, but in Rancho Merced-Bazom the number of *Pinus* spp. was zero and *Quercus* spp. was < 700 seedlings/ha. Broad-leaved seedlings were highest in Rancho Merced-Bazom (> 5000 seedlings/ha) and lowest in Lagunas de Montebello National Park (< 1000 seedlings/ha). Cerro Huitepec Nature Reserve did not show any species in the seedling class (Figure 7).

3.2 Woody species diversity

Overstory species richness (S) of the three sites in the Highlands of Chiapas was greatest in Cerro Huitepec Nature Reserve (28 species) and lowest in Lagunas de Montebello National Park (14 species). Richness was also considerably lower in Lagunas de Montebello National Park compared with Rancho Merced-Bazom (27 species). Shannon's diversity index (H') revealed a trend across the sites (Table 2). Rancho Merced-Bazom site showed the highest index value (2.02) compared with the lowest at Lagunas de Montebello National Park (0.99). Similar trends are observed in evenness. The site Lagunas de Montebello National Park has the lowest evenness value (0.58) with the biggest value in Rancho Merced-Bazom (0.80).

Richness, Shannon's diversity index and evenness values based on saplings and seedlings were highest in Rancho Merced-Bazom. The site Cerro Huitepec Nature Reserve has the lowest sapling richness, Shannon's diversity index and evenness. Moreover, seedling species were not found at this site (Table 2).

3.3 Non-tree composition

A total of 65 non-trees species were identified across the three sites (Table C). Forbs (32 species) were most numerous followed by lianas (9 species), shrubs (9 species) and graminoids (5 species).

The average percent cover of non-tree species was 18%. *Hydrocotyle umbellata*, *Passiflora foetida*, *Coccocypselum hirsitum*, and *Arthraxon quartinianus* were the only species with 100% coverage in the quadrats. The non-tree layer was not similar among the sites. Thirty-two species were rarely present due to each of them being found in only one plot. However, *Hydrocotyle umbellata* was common across the three sites.

The greatest percent cover of non-tree species was in Lagunas de Montebello National Park (40%), and lowest in Cerro Huitepec Nature Reserve (20%) (Table 1).

In the site Rancho Merced-Bazom, *Bomarea hirtella* had the highest percent coverage (35%), while *Passiflora foetida* (52.5%) had the greatest cover at Cerro Huitepec Nature Reserve, and *Cocccypselum hirsutum* (42.14%) was highest in Lagunas de Montebello National Park.

3.4 Non-tree diversity

Non-tree species richness was observed across all three sites with 35 species at Cerro Huitepec Nature Reserve, and 22 species at both Lagunas de Montebello National Park and Rancho Merced-Bazom. The percent cover of non-tree species was not similar across the three sites (Table 1).

Shannon’s diversity index in Cerro Huitepec Nature Reserve showed the highest value (1.53) across the three sites. Evenness was also greatest in Cerro Huitepec Nature Reserve (0.71) (Table 2).

3.5 Enrichment planting

Overall, we observed successful survival in all plots. For the overstory layer, Cerro Huitepec Nature Reserve showed 100% survival of planted species compared to Lagunas de Montebello National Park (31%). On the other hand, the highest survival of planted tree species in the understory layer was at Rancho Merced-Bazom 62% (Table 3).

Total basal area of the sites under enrichment planting was found to be very similar between sites. The enrichment planting in Rancho Merced-Bazom contributed 9.83 m^2/ha to the total basal area registered for that site (Table 4).

Relative importance values of planted tree species found at Lagunas de Montebello National Park was lowest (7.2%), in contrast with Rancho Merced-Bazom which had the highest value (18.8%).

4. DISCUSSION

The primary objective of this study was to assess the structure and composition of overstory and understory vegetation in degraded forests that have undergone enrichment planting. Over time, the structure and function of forests are in constant change. There are several factors that are involved in this transformation, such as climate change, soils, human and natural disturbances (Noss 2002). In this study, we observed changes in current structure and species composition in the Highlands of Chiapas in the overstory, seedling, and sapling layers even though the years and numbers of native trees species of enrichment plantings were different across the sites.

Changes in landscape structure, composition and rates of deforestation through time have been observed in the Highlands of Chiapas (González-Espinosa et al. 1991; González-Espinosa et al. 1995; Ochoa-Gaona et al. 2000; Cayuela, Golicher, et al. 2006; Cayuela, Rey Benayas, et al. 2006). The three sites include different proportions of floristic elements based on geographic position. The overstory and understory canopy layer of forests in southern Mexico can change their species composition and structure after any disturbance, especially if the stands have been influenced by human disturbance (Ramírez-Marcial et al. 2001). Therefore, the predominance of small trees across the three sites is visible, mostly of trees between 6-30 cm DBH (Figure 5). The absence of large trees is likely because they have gradually been removed for firewood or for charcoal (González-Espinosa et al. 1995; González-Espinosa et al. 2008; Ramírez-Marcial et al. 2001). The current trend of climate change also contributes to elimination of large trees in tropical forests (Nepstad et al. 2008). However, the recovery process is clearly observed at these sites; we found that most tree species are early- and mid - successional status, suggesting that regeneration is occurring in clearings or under open canopies (González-Espinosa et al. 2005).

Previous evaluations on tree density and seedling recruitment (González-Espinosa et al. 2009) in the highlands of Chiapas have proposed enrichment planting as a forest restoration technique that can decrease the floristic impoverishment by increasing the recruitment of oaks and broad-leaved species. The limited recruitment of pine seedlings (Figure 7) might suggest that these stands have the conditions to prevent the recruitment of new seedlings of pine. A forest soil with pine-dominated species are more compacted and less fertile (Galindo-Jaimes et al. 2002); this condition can be associated with the predominance of forest fires (Jardel-Peláez et al. 2008). On the other hand, broad-leaved species have increased in the seedling and sapling size classes in these stands we measured (Figure 6 and 7).

Tree species diversity (Shannon's diversity index and evenness) did not differ among the three sites. Moreover, the values of Shannon's and evenness showed in this study are similar to other studies in the cloud forest (Kappelle et al. 1996; Shi et al. 2009; Omoro et al. 2010).

During the last 20 years, trials such as this one have been made to understand the response of planted native tree species in different environmental conditions. The trials have been carried out at different times and conditions, without any consideration for statistical design. Over the years, around 60 native tree species were used for the enrichment plantings across nine sites in the Highlands of Chiapas. Due to limited time, only three sites could be evaluated in this study. Thirty-two species (overstory and understory) that were used for enrichment planting were found across the three sites. Most previous research has focused on assessment of plant performance (survival and growth at seedling stage), with this study looking at longer-term impacts on forest structure.

The initial conditions for the planting trials of the three sites were different. In Rancho Merced-Bazom the initial conditions were old-field fallow, grassland, shrubland, early-successional forest, mid-successional forest, and mature forest (González-Espinosa et al. 1991; González-Espinosa et al. 2006). At the Cerro Huitepec Nature Reserve there was a combination of old-growth oak forest, mid-successional forest, and grassland (Quintana-Ascencio et al. 2004), whereas all plots at Lagunas de Montebello Nature Park were affected by forest fires in 1998 (open areas, shrubland, and early-successional forest;

(Ramírez-Marcial et al. 2010). All plots at the three sites have undergone some human disturbance at some point in time.

Unfortunately, there is little pre-enrichment planting data for Rancho Merced-Bazom or Cerro Huitepec Nature Reserve sites, making it more difficult to compare the success of enrichment planting in those areas. However, in 2003 there was a previous plant assessment of the enrichment planting at Lagunas de Montebello National Park (Ramírez-Marcial et al. 2010). Nine years after the initial planting, overstory tree species *Liquidambar styraciflua*, *Clethra suaveolens*, *Cupressus lusitanica*, *Quercus sapotifolia*, and *Morella cerifera* were present both before and after planting. On the other hand, *Viburnum jucundum*, *Ilex* spp., *Oreopanax xalapensis*, *Clethra chiapensis*, *Eupatorium nubigenum*, *Cornus disciflora*, *Quercus candicans*, *Quercus skinerii*, and other *Quercus* spp. were present only in the most recent measurement, which might indicate that these species established since the last sampling. Over time, there was a decrease in overstory species richness with 17 species in 2003 and 14 species in 2012. The same pattern of decreasing species richness is shown for saplings (Tables 2 and 5). Moreover, Shannon's diversity index and evenness were higher in the stands before the enrichment planting. The number of plots may influence this decrease in species richness at the time of measurement (N= 8 in 2003 and N=6 in 2012) as well as differences in plot size for seedlings (100 m^2 in 2003 and 8 m^2 in 2012) and saplings (250 m^2 in 2003 and 32 m^2 in 2012; Table 5). The number of plots measured was different as two plots in 2012 showed signs of disturbance by fire and were therefore not measured. Moreover, the season of data collection could potentially affect the results.

We can make inferences about the success of enrichment planting at Cerro Huitepec Nature Reserve. Only seven species of native trees were planted in this site and we observed that all of them survived through this most recent measurement.

Our research has shown that conifers did best in open areas, while broad-leaved species did better establishing under a closed canopy (Quintana-Ascencio et al. 2004). We also found that enrichment planting not only increased biodiversity, but also helped recover the population of endangered species; for example, we found individuals of *Abies guatemalensis* and *Litsea glaucescens* growing on the sample plots at this site.

Cerro Huitepec Nature Reserve is a protected area and activities such as fuelwood collection or agriculture are illegal. However, saplings and seedlings of pines and oaks were not observed in this area (Figure 6 and 7). The lack of saplings and seedlings may be due to the soil litter being dominated by a thick layer of pine needles. The needles of pines may affect species recruitment because the needle layer facilitates lower cation exchange capacity, nitrogen, and organic matter, making it difficult for the germination and emergence of seeds. Shading could also be an issue as seedlings and saplings under a closed forest canopy can have very low numbers or be absent (Facelli et al. 1991; González-Espinosa et al. 1991; Galindo-Jaimes et al. 2002; Bueno et al. 2011). Moreover, another factor that affects the performance of saplings and seedlings is herbivory because plant species have varying palatability to different herbivores (Schädler et al. 2003).

Even though initial data is not available for Rancho Merced-Bazom, the type of forest where the enrichment plantings were introduced are actually considered to be in the mid-advanced successional stage for the area, having more medium and large trees than the other two sites. We can deduce some of the original species are part of the overstory having an important role in the forest, e.g. some of the planted trees are home to a great diversity of epiphytes (orchids, bromeliads, ferns; Wolf 2005) as well as the original vegetation.

5. MANAGEMENT IMPLICATIONS

Measuring the success of ecological restoration is not straightforward. There is evidence that enrichment plantings help improve organic matter, biomass C, nitrogen cycling, and soil biological activities (Karam et al. 2012). The occurrence of small mammals (bats, rodents) and birds suggest that biodiversity is improving (Robinson et al. 2002; Zhuang 1997; Lamb 2002). However, we cannot ignore the social component; humans cannot be treated as outsiders to forest restoration efforts as they play an important role in the preservation of species (Lamb et al. 2005). The participation of rural communities is crucial to achieve the success of ecological restoration (Van Diggelen et al. 2001). Moreover, ecological restoration requires developing methods to quantify the ecosystem services provided to demonstrate the economic value that forests provide to society (Lamb et al. 1997; Viana et al. 1997).

Forest recovery will require silvicultural treatments to be implemented over time, and the social and political aspects play an important role in the conservation of forests of southern Mexico. Long-term evaluation is required to document the potential benefit to the ecosystem; for example, the recruitment of new plant and animal species. We can deduce these practices will yield better performance in terms of survival, compared with typical practices of reforestation.

The results of this research showed that these enrichment plantings had some degree of success. Over several years in the Highlands of Chiapas, the reintroduction of native tree species in degraded forests is an important tool to accelerate the secondary succession of forests (Camacho & Gonzalez, 2002; Quintana-Ascencio et al. 2004; Ramírez-Marcial, 2003; Ramírez-Marcial et al., 2005; Ramírez-Marcial et al., 2008; Ramírez-Marcial et al., 2010). Thus, enrichment planting may influence overstory, understory (seedling/sapling density), and herbaceous species richness (Otsamo 2002; Otsamo 2000b, 2000a). Furthermore, because each landscape has different ecological and social conditions, the enrichment planting cannot follow the same pattern everywhere. This should result in enhanced sustainability and help maintain ecosystem health in this region of Mexico.

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Table 1

Average basal area, percent coverage of the canopy, and non-tree species (±1 SE) of the 17 plots by site at the Highlands, Chiapas, Mexico.

Site	N	Basal area (m^2/ha)	Canopy cover (%)	Non-tree cover (%)
1) Rancho Merced-Bazom	6	39.13 ± 5.00	86.78 ± 2.19	26.08 ± 3.87
2) Cerro Huitepec Nature Reserve	5	50.31 ± 7.43	91.78 ± 0.93	20.29 ± 5.75
3) Lagunas de Montebello National Park	6	64.68 ± 9.60	81.41 ± 2.65	39.87 ± 10.84

Table 2

Species richness, Shannon's diversity index, and evenness of overstory, saplings, seedlings, and herbaceous species (±1 SE) of the three sites across the Highlands, Chiapas, Mexico.

	Richness	Shannon's diversity index	Evenness
Overstory			
1) Rancho Merced- Bazom	27	2.02 ± 0.10	0.80 ± 0.03
2) Cerro Huitepec Nature Reserve	28	1.96 ± 0.79	0.79 ± 0.03
3) Lagunas de Montebello National Park	14	0.99 ± 0.20	0.58 ± 0.09
Saplings			
1) Rancho Merced- Bazom	36	2.15 ± 0.12	0.73 ± 0.02
2) Cerro Huitepec Nature Reserve	8	0.63 ± 0.38	0.37 ± 0.23
3) Lagunas de Montebell National Park	12	0.95 ± 0.30	0.56 ± 0.18
Seedlings			
1) Rancho Merced- Bazom	23	1.80 ± 0.05	0.84 ± 0.06
2) Cerro Huitepec Nature Reserve	-	-	-
3) Lagunas de Montebello National Park	11	0.47 ± 0.31	0.25 ± 0.17
Non-trees			
1) Rancho Merced- Bazom	20	1.36 ± 0.17	0.65 ± 0.05
2) Cerro Huitepec Nature Reserve	35	1.53 ± 0.13	0.71 ± 0.13
3) Lagunas de Montebello National Park	22	0.99 ± 0.27	0.50 ± 0.11
All woody species			
1) Rancho Merced- Bazom	43	2.33 ± 0.07	0.73 ± 0.02
2) Cerro Huitepec Nature Reserve	29	2.02 ± 0.08	0.80 ± 0.03
3) Lagunas de Montebello National Park	23	1.46 ± 0.11	0.67 ± 0.04

Table 3

Percent survival of tree species in enrichment plantings of the three sites across the Highlands, Chiapas, Mexico.

Site	No. species planted	Overstory	Understory
1) Rancho Merced-Bazom	26	46	62
2) Cerro Huitepec Nature Reserve	7	100	29
3) Lagunas de Montebello National Park	16	31	50

Table 4

Average trees/ha, basal area (±1 SE), and relative importance value (RIV) of planted tree species of 17 enrichment planting plots by site at the Highlands, Chiapas, Mexico.

Site	Trees/ha	Basal area (m^2/ha)	RIV
1) Rancho Merced-Bazom	72	9.8 ± 3.0	18.8
2) Cerro Huitepec Nature Reserve	120	8.1 ± 3.9	8.0
3) Lagunas de Montebello National Park	94	8.3 ± 7.1	7.2

Table 5

Species richness, Shannon's diversity index, and evenness of overstory, saplings, and seedlings (±1 SE) for the site Lagunas de Montebello Nature Park prior to enrichment planting.* N= Number of plots.

Strata	N	Richness	Shannon's diversity index	Evenness
Overstory	8	17	1.12 ± 0.16	0.67 ± 0.10
Saplings	8	22	2.48 ± 0.09	0.84 ± 0.02
Seedlings	8	11	1.57 ± 0.16	0.87 ± 0.02

* The source of this data is in Rodriguez Sanchez (2006)

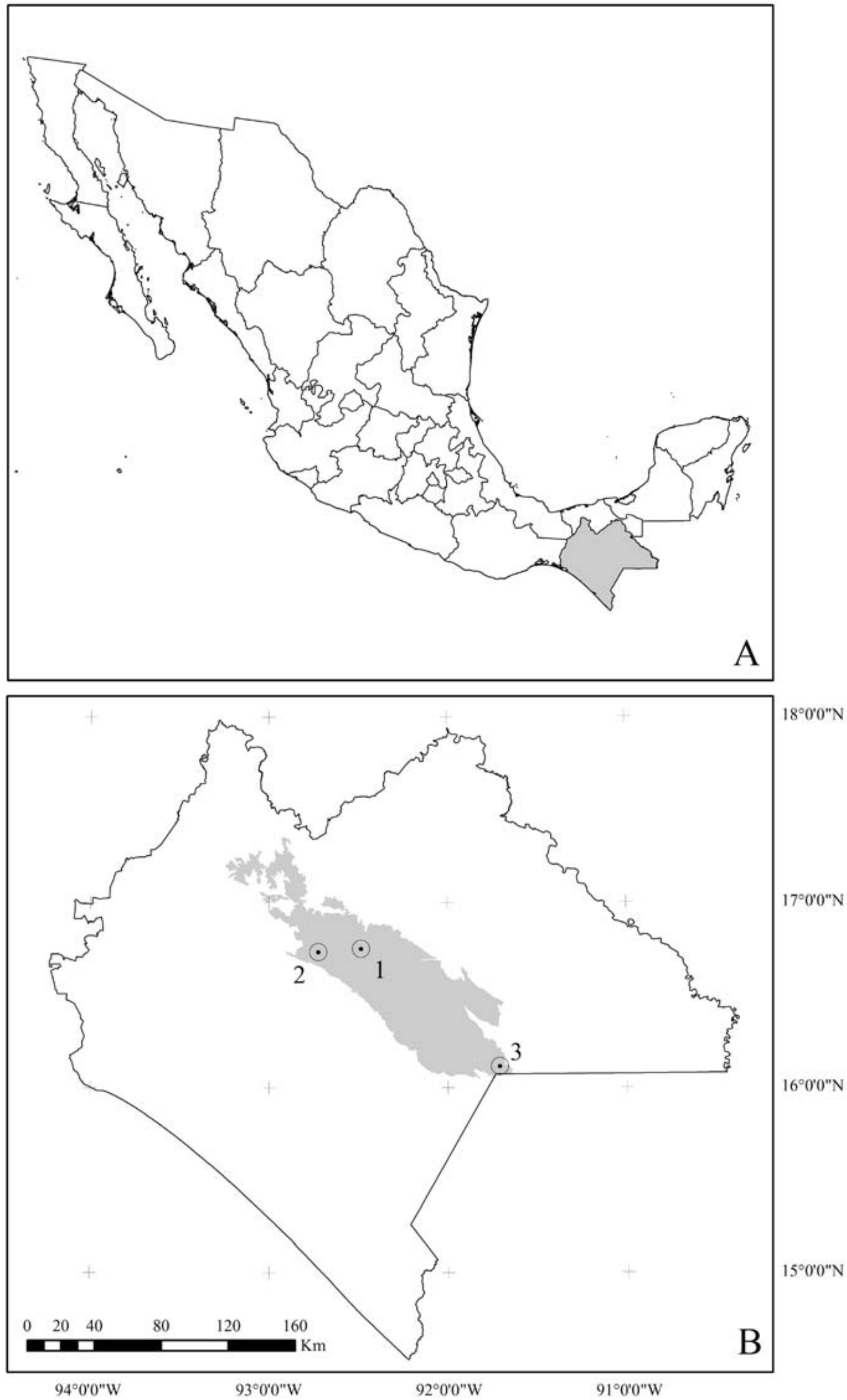

Figure 1. A) Location of the state of Chiapas in Mexico. B) Location of study sites in the Highlands of Chiapas, 1) Rancho Merced-Bazom; 2) Cerro Huitepec Nature Reserve; 3) Lagunas de Montebello National Park.

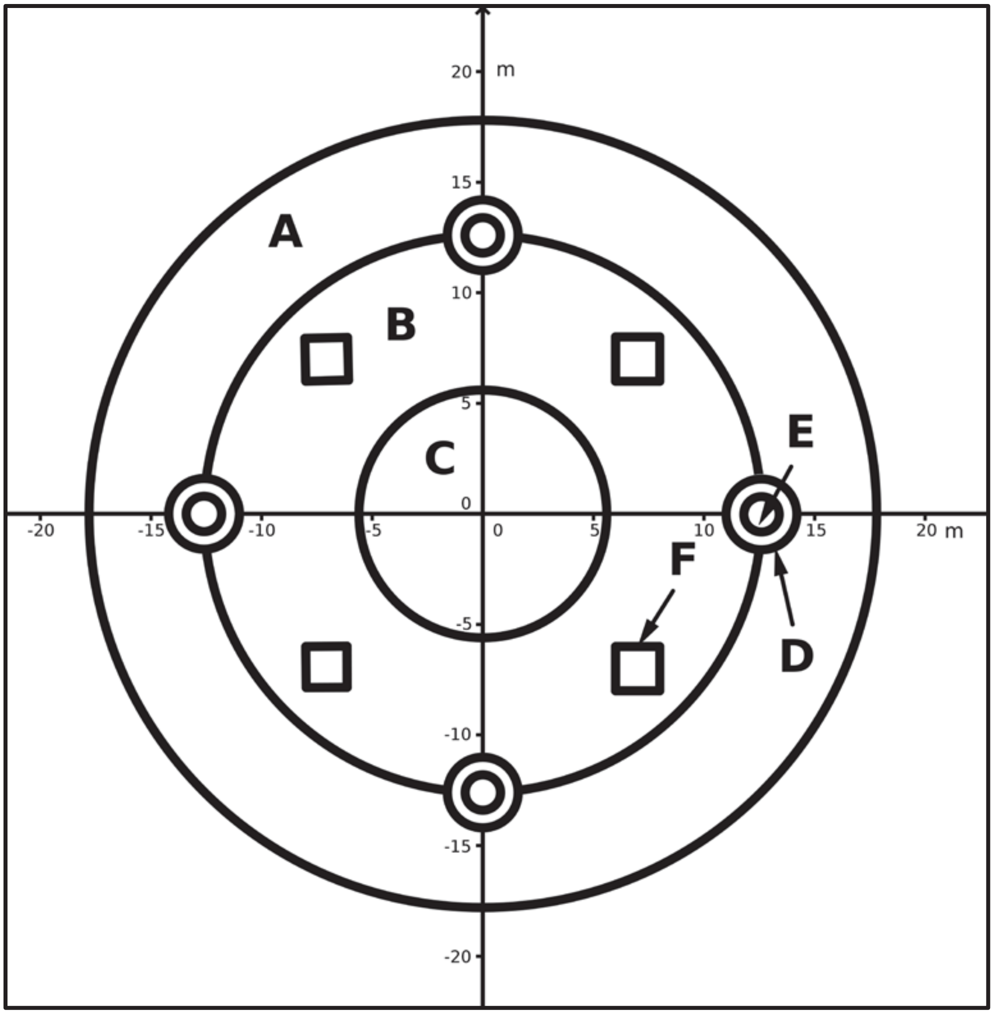

Figure 2. Design of the plot used for forest inventory following (Ramírez-Marcial et al. 2001). A: large trees (1000 m^2); B: medium trees (500 m^2); C: small trees (100 m^2); D: saplings (8 m^2); E: seedlings (2 m^2); F: Herbaceous (1 m^2).

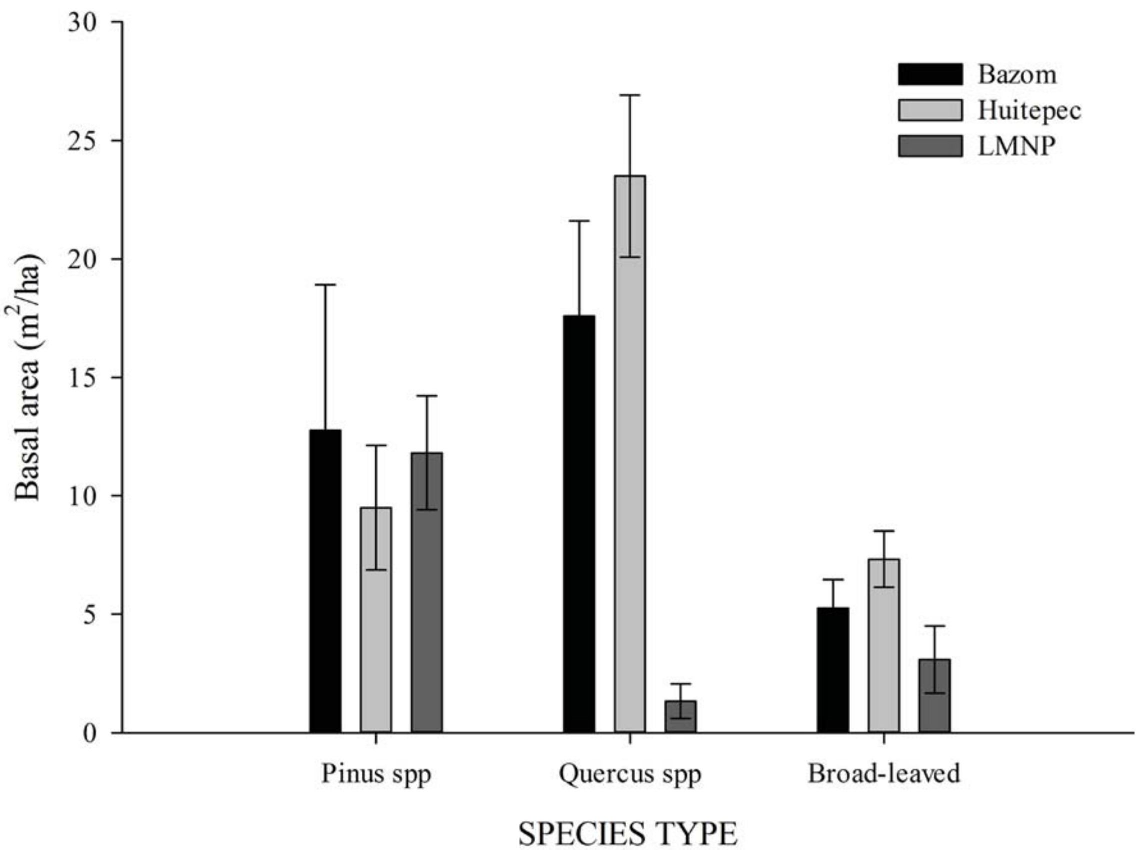

Figure 3. Mean basal area per hectare (±1 SE) by tree type and site.

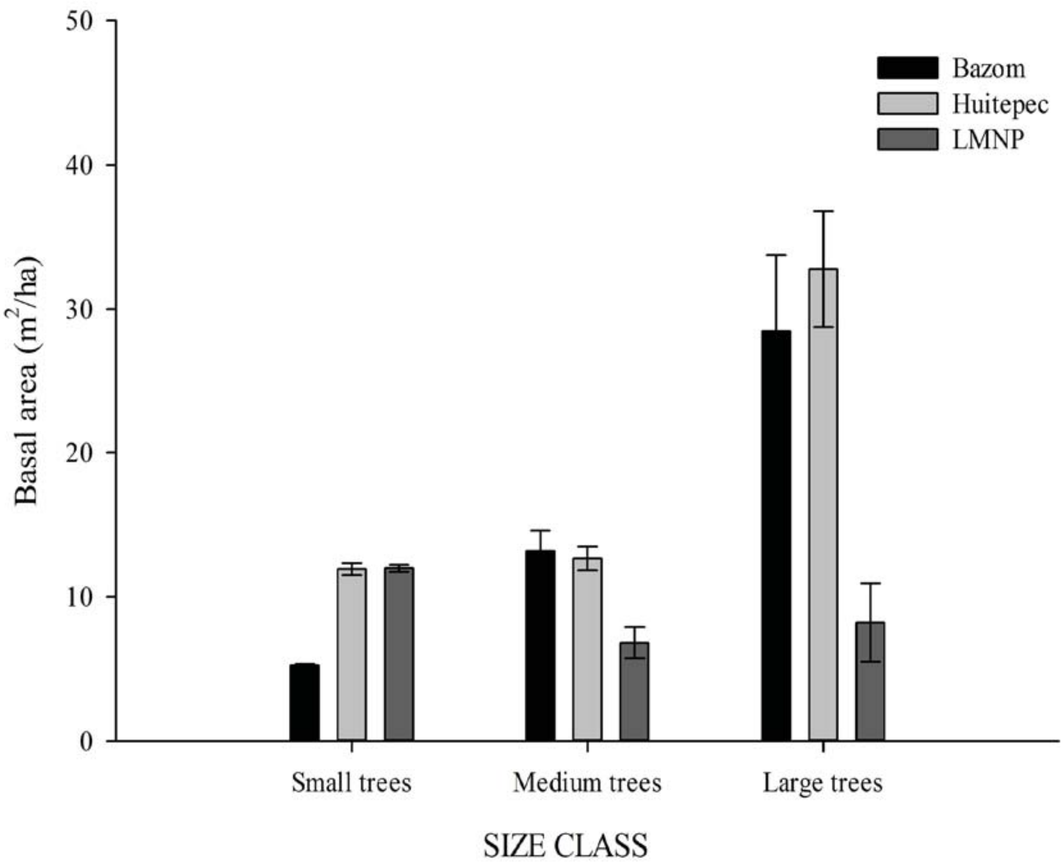

Figure 4. Mean basal area per hectare (±1 SE) by tree size class and site.

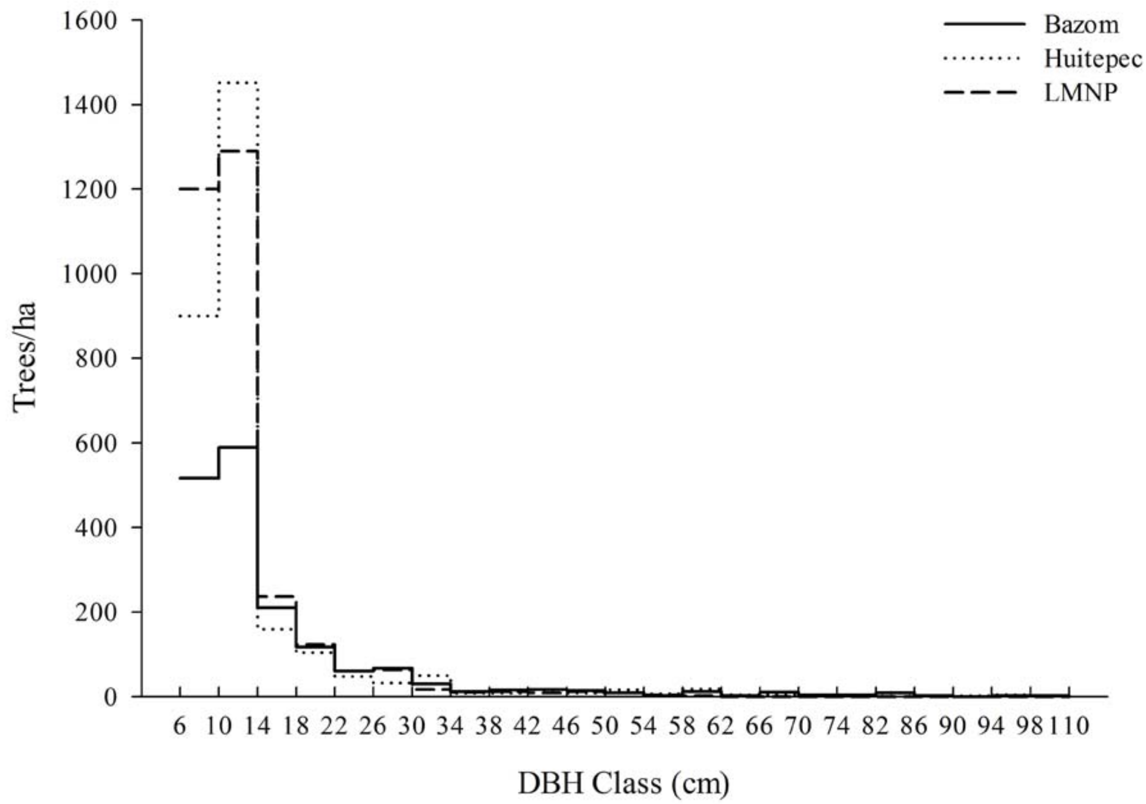

Figure 5. Trees per hectare by diameter class for each site.

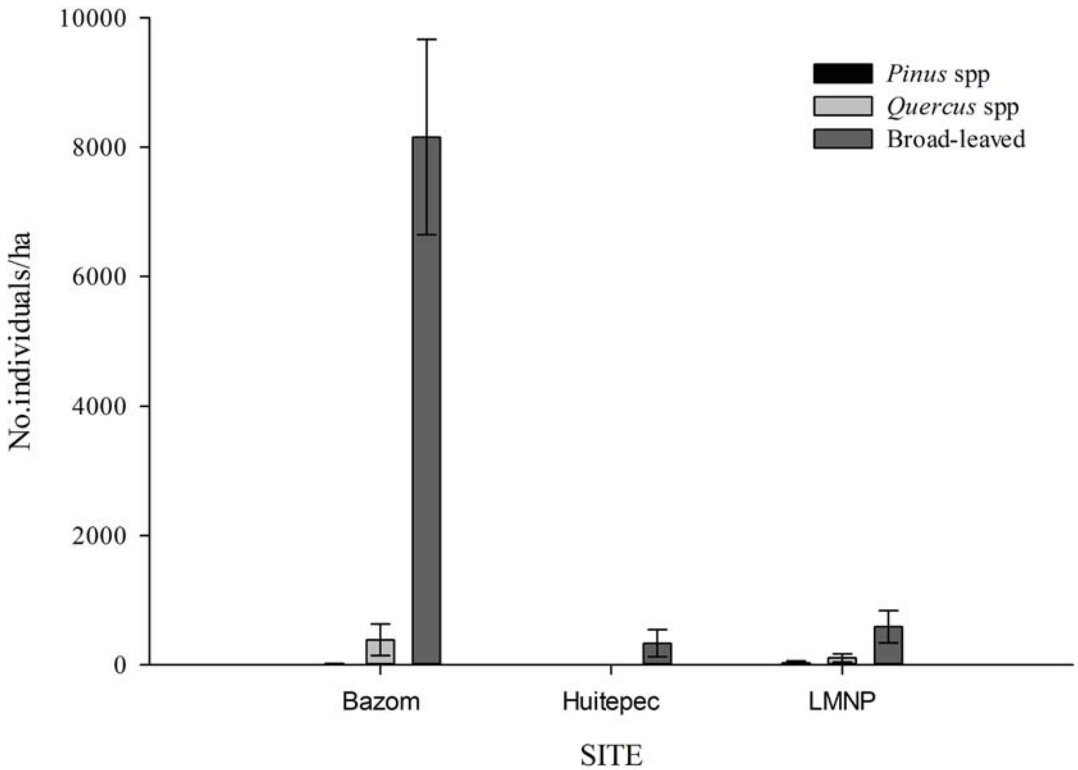

Figure 6. Number of saplings per hectare (±1 SE) of tree type by site.

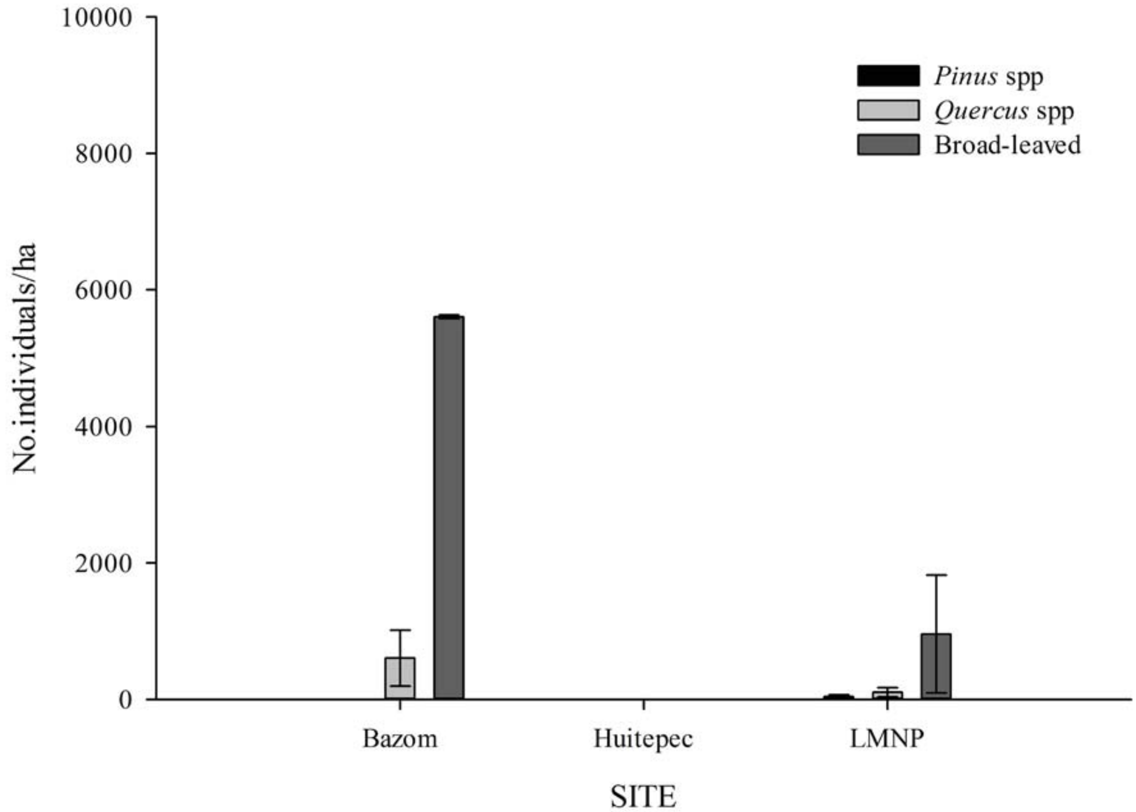

Figure 7. Number of seedlings per hectare (±1 SE) of tree type by site.

7. APPENDIX

Table A

Overstory species list and presence of each tree species at the three sites, Site 1 (Rancho Merced-Bazom), Site 2 (Cerro Huitepec Nature Reserve), and Site 3 (Lagunas de Montebello National Park). Successional status is according to the classification of Gonzalez-Espinosa et al. (2005) found in 17 plots at the Highlands, Chiapas, Mexico. E=early-successional (regeneration occurs in clearings and forest gaps); M=mid-successional (regeneration in forest edges and under open canopies); and L=late-successional (regeneration under closed canopies). p=planted.

Family	Scientific name	Successional Status	Presence		
			Site 1	Site 2	Site 3
Altingiaceae	*Liquidambar styraciflua* L.	M	Xp		Xp
Actinidiaceae	*Saurauia latipetala* Hemsl.	M	X		
Adoxaceae	*Viburnum jucundum* C.V. Morton	M		X	X
Aquifoliaceae	*Ilex vomitoria* Aiton	M			Xp
Araliaceae	*Oreopanax xalapensis* (H.B.K.) Decne. & Planchon	M		Xp	Xp
Betulaceae	*Ostrya virginiana* (Mill.) K. Koch	E		X	
Clethraceae	*Clethra chiapensis* L.M. González	L		X	X
Clethraceae	*Clethra suaveolens* Turcz	M			X

Compositae	*Eupatorium ligustrinum* DC	--		X	
Compositae	*Eupatorium nubigenum* Benth	L			X
Compositae	*Verbesina perymenioides* Sch. Bip. ex Klatt	--	X	X	
Cornaceae	*Cornus disciflora* Moc. & Sessé	M	Xp	X	X
Cupressaceae	*Cupressus lusitanica* Mill	E			X
Ericaceae	*Arbutus xalapensis* Kunth	E		X	
Fagaceae	*Quercus candicans* Née	M			X
Fagaceae	*Quercus crassifolia* Humb. & Bonpl.	M	Xp	X	
Fagaceae	*Quercus crispipilis* Trelease	E		X	
Fagaceae	*Quercus laurina* Humb. & Bonpl.	E	Xp	X	
Fagaceae	*Quercus rugosa* Née	E	Xp	X	
Fagaceae	*Quercus sapotifolia* Liebmann	E			Xp
Fagaceae	*Quercus skinneri* Benth.	E			X
Fagaceae	*Quercus* spp.	--			Xp
Garryaceae	*Garrya laurifolia* Hartw.ex Benth.	M	X	X	

Lauraceae	*Persea americana* Mill.	M	Xp	X	
Loganiaceae	*Buddleia americana* L.	E		X	
Loganiaceae	*Buddleia cordata* Kunth	--		X	
Loganiaceae	*Buddleia nitida* Benth	M		X	
Magnoliaceae	*Magnolia sharpii* Miranda	L	Xp		
Melastomataceae	*Miconia glaberrima* (Schltdl.) Naudin	M	X		
Myricaceae	*Morella cerifera* L.	E		X	Xp
Pentaphylacaceae	*Ternstroemia lineata* DC	M	X	Xp	
Pentaphylacaceae	*Cleyera theoides* (Sw.) Choisy	M	X		
Pinaceae	*Abies guatemalensis* Rehder	M		Xp	
Pinaceae	*Pinus ayacahuite* C. Ehrenb. ex Schltdl.	E		Xp	
Pinaceae	*Pinus montezumae* Lamb.	E	X		
Pinaceae	*Pinus oocarpa* var. *oocarpa* Shiede ex. Schltdl	E			X
Pinaceae	*Pinus pseudostrobus* Lindl.	E	X	Xp	
Pinaceae	*Pinus tecunumanii* Eguiluz & J.P. Perry	E	X		

Primulaceae	*Myrsine juergensenii* (Mez) Ricketson & Pipoly	M	X	Xp
Primulaceae	*Rapanea myricoides* (Schltdl.) Lundell	M	X	X
Rhamnaceae	*Rhamnus sharpii* M.C. Johnst. & L.A. Johnst.	L	X	Xp
Rosaceae	*Crataegus pubescens* C. Presl	E	X	X
Rosaceae	*Prunus rhamnoides* Koehne.	L	Xp	
Rosaceae	*Prunus serotina* Ehrenberg ssp. *capuli* (Cav.) McVaugh	E	Xp	
Rutaceae	*Zanthoxylum melanostictum* Schltdl. & Cham	L	X	
Salicaceae	*Olmediella betschleriana* (Goeppert) Loesener	L	Xp	
Styracaceae	*Styrax magnus* Lundell.	L	Xp	X
Thymelaceae	*Daphnopsis selerorum* Gilg	---	X	X
Verbenaceae	*Citharexylum donnell-smithii* Greenm	E		X

Table B

Seedlings and saplings list and presence of each species at the three sites, Site 1 (Rancho Merced-Bazom), Site 2 (Cerro Huitepec Nature Reserve), and Site 3 (Lagunas de Montebello National Park). Successional status is according to the classification of Gonzalez-Espinosa et al. (2005) found in 17 plots at the Highlands, Chiapas, Mexico. E=early-successional (regeneration occurs in clearings and forest gaps); M=mid-successional (regeneration in forest edges and under open canopies); and L=late-successional (regeneration under closed canopies). p=planted.

Family	**Scientific name**	**Successional Status**	**Presence**		
			Site 1	**Site 2**	**Site 3**
Altingiaceae	*Liquidambar styraciflua* L.	M	Xp		Xp
Actinidiaceae	*Saurauia latipetala* Hemsl.	M	X		
Adoxaceae	*Viburnum jucundum* C.V. Morton	M	X	X	
Aquifoliaceae	*Ilex vomitoria* Aiton	M			Xp
Araliaceae	*Oreopanax xalapensis* (H.B.K.) Decne. & Planchon	M	X	Xp	
Betulaceae	*Alnus acuminata* H.B.K. ssp. *arguta* (Schldl.) Furlow	E	Xp		
Clethraceae	*Clethra chiapensis* L.M. González	L	Xp		
Clethraceae	*Clethra suaveolens* Turcz	M			X
Compositae	*Eupatorium nubigenum* Benth	L	X		X
Compositae	*Senecio cristobalensis* Greenm	--	X		
Compositae	*Verbesina perymenioides* Sch. Bip. ex Klatt	--	X	X	

Cornaceae	*Cornus disciflora* Moc. & Sessé	M	Xp		X
Cornaceae	*Cornus excelsa* Kunth	E	Xp		
Cornaceae	*Nyssa sylvatica* Marshall	E			Xp
Fagaceae	*Quercus crassifolia* Humb. & Bonpl.	M	Xp		
Fagaceae	*Quercus laurina* Humb. & Bonpl.	E	Xp		
Fagaceae	*Quercus sapotifolia* Liebmann	E			Xp
Fagaceae	*Quercus* spp.	--			Xp
Garryaceae	*Garrya laurifolia* Hartw.ex Benth.	M	X		
Lauraceae	*Licaria campechiana* (Standl.) Kosterm.	--	X		
Lauraceae	*Litsea glaucescens* Kunth	M	X	X	
Lauraceae	*Persea americana* Mill.	M	Xp	X	
Magnoliaceae	*Magnolia sharpii* Miranda	L	Xp		
Melastomataceae	*Miconia glaberrima* (Schltdl.) Naudin	M	X		X
Myricaceae	*Morella cerifera* L.	E			Xp
Pentaphylacaceae	*Cleyera theoides* (Swartz) Choisy	M	X		X
Pentaphylacaceae	*Ternstroemia lineata* DC	M	Xp		
Pinaceae	*Pinus montezumae* Lamb.	E	X		
Pinaceae	*Pinus oocarpa* var. *oocarpa* Shiede ex. Schltdl	E			X

Pinaceae	*Pinus tecunumanii* Eguiluz & J.P. Perry	E	X		
Podocarpaceae	*Podocarpus matudae* Lundell	L			X
Polygalaceae	*Monnina xalapensis* Kunth	--	X		
Primulaceae	*Myrsine juergensenii* (Mez) Ricketson & Pipoly	M	X	Xp	Xp
Primulaceae	*Rapanea myricoides* (Schltdl.) Lundell	M			X
Rhamnaceae	*Rhamnus sharpii* M.C. Johnst. & L.A. Johnst.	L	X		
Rosaceae	*Photinia microcarpa* Standl.	--	Xp		
Rosaceae	*Prunus barbata* Koehne.	L	X		
Rosaceae	*Prunus rhamnoides* Koehne.		Xp		
Rosaceae	*Prunus serotina* Ehrenberg ssp. *capuli* (Cav.) McVaugh	E	Xp		
Rubiaceae	*Psychotria galeottiana* (M. Martens) C.M. Taylor & Lorence	--			X
Rutaceae	*Zanthoxylum melanostictum* Schltdl. & Cham.	L	X		
Salicaceae	*Olmediella betschleriana* (Goeppert) Loesener	L	Xp		
Solanaceae	*Cestrum guatemalense* Francey.	--	X		
Solanaceae	*Solanum nudum* Dunal.	E	X		
Staphyleaceae	*Turpinia tricornuta* Lundell.	L			Xp
Styracaceae	*Styrax magnus* Lundell.	L	Xp	X	

Symplocaceae	*Symplocos limoncillo* Bonpl.	M	X	
Thymelaceae	*Daphnopsis selerorum* Gilg.	---	X	X
Winteraceae	*Drimys granadiensis* var. *mexicana* (DC.) A.C. Sm.	L	Xp	

Table C

Non-tree species found across all three sites

Scientific name	Growth Form
Adiantum andicola Liebm.	Fern
Ageratina ligustrina (DC.) R.M. King & H. Rob.	Shrub
Ageratina mairetiana (DC.) R.M. King & H. Rob.	Shrub
Agrimonia macrocarpa (Focke) Rydb.	Forb
Alchemilla pectinata Kunth	Forb
Alchemilla pringlei (Rydb.) Fedde	Forb
Arenaria guatemalensis Standl. & Steyerm.	Forb
Arthraxon quartinianus (A. Rich.) Nash	Graminoid
Bomarea hirtella (Kunth) Herb.	Forb
Calea urticifolia (Mill.) DC.	Shrub
Cestrum guatemalense Francey	Shrub
Clematis dioica L.	Liana
Coccocypselum hirsutum Bartl. Ex DC	Forb
Crotalaria pumila Blanco	Subshrub
Cuphea cyanea DC.	Shrub
Cymbispatha commelinoides (Schult. & Schult.f.) Pichon.	Forb
Cynanchum schlechtendalii (Decne.) standl. & Steyerm.	Liana
Desmodium aparines (Link) DC.	Forb
Desmodium incanum DC.	Forb
Dichanthelium spp. (Hitchc. & Chase) Gould	Graminoid
Drymaria gracilis Schltdl. & Cham.	Forb
Epidendrum radicans Pav. Ex Lindl	Orchid
Gonolobus uniflorus Kunth.	Liana
Grass	Graminoid
Hieracium abscissum Less.	Forb
Hydrocotyle umbellata L.	Forbs/Aquatic
Hyptis urticoides Kunth.	Forb
Iostephane trilobata Hemsl.	Forb
Ipomoea anisomeres B.L. Rob. & Bartlett.	Forb
Litsea glaucenses Kunth.	Shrub
Lycianthes ciliolate (M. Martens & Galeotti).	Forb
Macroptilium spp. (Benth.) Urb	Graminoid
Metastelma schlechtendalii Decne.	Liana
Nertera granadensis (Mutis ex L.f.) Druce	Forb
Passiflora foetida L.	Liana
Passiflora membranacea Benth.	Liana
Peperomia galioides Kunth.	Forb
Perymenium chloroleucum S.F. Blake.	Forb
Platythelys maculate (Hook.) Garay	Orchid
Pseudelephantopus spicatus (Juss. Ex Aubl.) Rohr ex Gleason.	Forb

Psilochilus macrophyllus (Lindl.) Ames.	Orchid
Pteridium aquilinum (L.) Kuhn.	Fern
Ranunculus petiolaris Humb., Bonpl. & Kunth ex DC.	Forb
Roldana acutangula H. Rob. & Brettell	Forb
Rubus adenotrichos Schltdl.	Shrub/creeper
Rubus fruticosus L.	Shrub/creeper
Salvia cinnabarina M. Martens & Galeotti.	Forb
Sanicula liberta Cham. & Schltdl.	Forb
Smilax lanceolata L.	Liana
Smilax spinosa Mill.	Liana
Smilax xalapensis Kunth.	Liana
Spermacoce confusa Rendle	Forb
Stylosanthes guianensis var.*guianensis* (Aubl.) Sw.	Forb
Tagetes lucida Cav.	Forb
Tetrapteris spp cav	Forb
Tillandsia guatemalensis L.B. Sm.	Epiphyte
Tillandsia spp L.	Epiphyte
Trifolium spp L.	Forb
Triumfetta columnaris Hochr.	Shrub
Valeriana palmeri A. Gray.	Forb
Viola guatemalensis W.Becker.	Forb
Xanthoxylum foliolosum Donn. Sm.	Shrub
Xylosma chiapensis Lundell	Shrub
Zeugites americana Willd.	Graminoid
Zornia thymifolia Kunth	Forb

Table D

Structural variables measured in the overstory layer across all three sites. BA=Basal area per hectare (m^2/ha), RBA=Relative basal area (%), D=Density (ind/100m^2), RD=Relative density (%), F=Frequency, RF=Relative frequency (%), RIV= Relative importance value.

Species	No. indiv	BA	RBA	D	RD	F	RF	RIV
Abies guatemalensis	7	0.33	0.74	0.07	0.74	0.12	1.19	2.67
Arbutus xalapensis	2	0.04	0.09	0.02	0.21	0.06	0.60	0.90
Buddleia americana	3	0.14	0.30	0.03	0.32	0.12	1.19	1.81
Buddleia cordata	7	0.26	0.57	0.07	0.74	0.18	1.79	3.10
Buddleia nitida	7	0.20	0.45	0.07	0.74	0.06	0.60	1.78
Citharexylum donnell-smithii	1	0.02	0.05	0.01	0.11	0.06	0.60	0.75
Clethra chiapensis	5	0.09	0.19	0.05	0.53	0.12	1.19	1.91
Clethra suaveolens	20	0.62	1.32	0.20	2.12	0.24	2.38	5.86
Cleyera theoides	12	0.36	0.79	0.12	1.27	0.18	1.79	3.85
Cornus disciflora	24	0.87	1.92	0.24	2.54	0.41	4.17	8.62
Crataegus pubescens	4	0.73	1.61	0.04	0.42	0.18	1.79	3.82
Cupressus tusitanica	71	1.76	3.87	0.71	7.51	0.12	1.19	12.57
Daphnopsis spp	10	0.32	0.70	0.10	1.06	0.17	1.77	3.52
Eupatorium ligustrinum	1	0.03	0.07	0.01	0.11	0.06	0.60	0.77
Eupatorium nubigerum	2	0.03	0.06	0.02	0.21	0.06	0.60	0.87
Garrya laurifolia	7	0.16	0.36	0.07	0.74	0.24	2.38	3.48
Ilex vomitoria	2	0.12	0.26	0.02	0.21	0.12	1.19	1.66
Liquidambar styraciflya	25	0.79	1.73	0.25	2.65	0.35	3.57	7.65

Magnolia sharpii	21	0.54	1.20	0.21	2.22	0.29	2.98	6.39
Miconia glaberrima	3	0.05	0.10	0.03	0.32	0.12	1.19	1.61
Morella cerifera	3	0.16	0.34	0.03	0.32	0.18	1.79	2.45
Myrsine juergensenii	78	2.11	4.64	0.78	8.25	0.47	4.76	17.66
Olmediella betschleriana	1	0.06	0.13	0.01	0.11	0.06	0.60	0.83
Oreopanax xalapensis	7	0.13	0.28	0.07	0.74	0.24	2.38	3.40
Ostrya virginiana	4	0.25	0.55	0.04	0.42	0.12	1.19	2.16
Persea americana	19	0.48	1.06	0.19	2.01	0.24	2.38	5.46
Pinus ayacahuite	12	1.99	4.39	0.12	1.27	0.18	1.79	7.45
Pinus montezumae	9	1.62	3.57	0.09	0.95	0.18	1.79	6.31
Pinus oocarpa	185	7.17	15.80	1.85	19.58	0.35	3.57	38.94
Pinus pseudostrobus	9	0.93	2.04	0.09	0.95	0.24	2.38	5.37
Pinus tecunumanii	34	2.95	6.50	0.34	3.60	0.24	2.38	12.48
Prunus rhamnoides	3	0.11	0.24	0.03	0.32	0.18	1.79	2.34
Prunus serotina	2	0.09	0.20	0.02	0.21	0.12	1.19	1.60
Quercus candicans	4	0.15	0.34	0.04	0.42	0.06	0.60	1.36
Quercus crassifolia	42	4.79	10.56	0.42	4.44	0.53	5.36	20.36
Quercus crispipilis	1	0.05	0.10	0.01	0.11	0.06	0.60	0.80
Quercus laurina	111	6.44	14.19	1.11	11.75	0.65	6.55	32.48
Quercus rugosa	32	4.23	9.33	0.32	3.39	0.47	4.76	17.48
Quercus sapotifolia	2	0.92	2.02	0.32	3.39	0.24	2.38	7.79
Quercus skinneri	2	0.07	0.15	0.02	0.21	0.12	1.19	1.55
Quercus spp	2	0.04	0.09	0.02	0.21	0.06	0.60	0.89

Rapanea myricoides	2	0.06	0.14	0.02	0.21	0.12	1.19	1.54
Rhamnus sharpii	17	0.46	1.02	0.17	1.80	0.41	4.17	6.98
Saurauia latipetala	1	0.02	0.04	0.01	0.11	0.06	0.60	0.74
Styrax magnus	45	1.27	2.79	0.45	4.76	0.29	2.98	10.53
Ternostroemia lineata	25	0.59	1.29	0.25	2.65	0.29	2.98	6.92
Verbesina peryminoides	5	0.09	0.19	0.05	0.53	0.24	2.38	3.10
Viburnum jucundum	21	0.69	1.52	0.21	2.22	0.24	2.38	6.13
Zanthoxylum melanostictum	3	0.04	0.09	0.03	0.32	0.06	0.60	1.00