A survey of tree species diversity in reforested areas of the Leaves & Lizards reforestation site

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INTRODUCTION

In recent years, many reforestation projects have begun in areas of Costa Rica that were formerly used for pastureland. The purpose of these projects has been to restore forests through planting tree species that are both native and exotic to Costa Rica. Leopold *et al* (2001) show that the growth performance of native tree species and early evidences of beginning biological complexity indicate that real benefits can be achieved from the planting of mixed seeds of native species, as opposed to the planting of monocultures of exotic species, which contribute in the long term to ecosystem decline. Yet another study by Carpenter *et al* (2004) that examined the growth of native and exotic tree species planted on degraded land shows that exotic species such as *Pinus tecunumanii* grew well, along with native species such as *Vochysia guatemalensis*, *Terminalia amazonia*, and *Calophyllum brasiliense*.

While there is a significant amount of data concerning reforestation in tropical rainforests elsewhere in Costa Rica (Cusack *et al.* 2003, Butler *et al.*2007), the goal of our research was provide baseline data in a tropical wet forest. Other studies have tried to correlate the role of native species in diversity or generally assess diversity as affected by reforestation (Oosterhorn *et al.* 1999, Brandani *et al.* 1988, Behera *et al.* 2004). Our study falls in the same vein.

We collected data about importance values and diversity and attempted to relate the two. In our study we attempted to locate all the major tree species and identified these species by their distinguishing characteristics, ecological role, and economic importance. For a more focused examination of reforestation areas, we conducted quadrat sampling to establish a baseline count of data. We used these data to find the diversity in each area and the importance values of specific trees. From the study, we hoped to determine which species should be planted in order to create continual forest or more biodiversity; which, when combined with the bird study, shows sections that promote avifauna species diversity.

MATERIALS AND METHODS

Our project was undertaken between May 26 and May 31, during the beginning of Costa Rica's rainy season. We divided the property into fifteen plots, which were named Teak 1, Mixed 1, Mixed 2, Teak 2, Teak 3, Patch 1, Patch 2, Patch 3, Almendro 1, Mixed 3, Teak 4, Mixed 4, Cabins, Steve and Debbie's, and Sloth Valley. Trees in each plot were counted, and any unknown species was tagged with piece of orange tape labeled "Unknown #". There were initially seventeen unknown trees, and these were later identified with the assistance of Geovany Bogarin.

Each plot was mapped using a Trimble GeoXM handheld field computer. During mapping we recorded seven parameters to characterize each plot: (i) culture type, (ii) disturbance, (iii) distance to water, (iv) percent grass, (v) dominant tree species, (vi) dominant tree species height, and (vii) distance between trees of the dominant species. We based these parameters loosely on six parameters used in a Himalayan study to assess biological richness (Behera *et al.* 2004). To choose the parameters, we looked for quantifiable data that would give descriptive information about the state of any given area at Leaves and Lizards. Culture type could be monoculture (a single numerous species of planted tree), mixed (no single species was most numerous) or ornamental (species were planted without reforestation as a primary goal). We measured the distance between a few trees and took an average to determine the distance between our most numerous tree species.

We sampled 10m x 10m quadrats in 12 of the 15 areas (we excluded the ornamental sections and an area described as "Sloth Valley"). In each quadrat, we recorded the individuals of the species we found, their height and their circumference at hip height. From this data, we calculated frequency, relative frequency, density, relative density, dominance, relative dominance and biological importance value. We used the following formulae for these calculations (Cox 2002):

Frequency = number of plots sampled / total number of plots sampled
Relative frequency = (frequency value for a species / total frequency values for all species) x 100

Density = number of individuals sampled / area sampled
Relative density = (density for a species / total density for all species) x 100

Dominance = total of basal area / area sampled
Relative dominance = (dominance for a species / total dominance for all species) x 100

RESULTS

Based on its location and elevation, Leaves and Lizards is a tropical wet forest environment. However, within the property there are significant tracts of grass and pasture interspersed with original forest and reforested areas. These reforested areas have either been planted as a single stand of one tree species (such as teak) or planted as a mixed-species stand. We found that the diversity index of the entire property was 4.18 with an evenness of 69.4 (out of a total 100 possible for evenness). The diversity was calculated based on data from 65 species and 2605 individual trees collected by our team and by the resident expert on the property (Geovany Bogarin, pers. com.). Geovany further divided these species into either planted or original tree categories (trees originally on the property prior to any reforesting effort). We then determined that the planted species had a diversity of 3.29 and an evenness of 76.28, while the original trees had a diversity of 3.09 and an evenness of 57.23 (Figure 1).

To analyze the planting areas we divided the property into 15 different plots named: Teak 1, Mixed 1, Mixed 2, Teak 2, Teak 3, Patch 1, Patch 2, Patch 3, Almendro 1, Mixed 3, Teak 4, Mixed 4, Cabins, Steve and Debbie's, and Sloth Valley (Figure 2). The plots were defined based on indications of deliberate planting of certain tree species and delimited by fence lines and roadways. From calculating biological importance (Figure 2), we determined that the *Musa spp.* had the highest importance value (79.04). *Dalbergia retusa* and *Dalbergia glomerata* tied for smallest importance with a value of 4.11.

When we tested the relationship between diversity of each area and importance value of the most numerous tree, we found that in four of the plots, the most numerous plant did not have the highest importance value. In Patch 2, *Dipteryx panamensis* had a higher importance value than *Vochysia guatemalensis*. In Mixed 3, *Citrus aurantium* had a higher importance value than *V. guatemalensis*. In Mixed 4 and Mixed 1, *Musa spp.* had a higher importance value than *V.*

guatemalensis. This was in part due to the inclusion of dominance in the importance value calculation, which factors in the basal area of each tree. In many cases the most abundant trees were smaller in basal area because they were planted within the last year.

The plots around the Cabins and around Steve and Debbie's houses were ornamental. They should therefore be expected to have a higher diversity, as many different species of trees were deliberately planted. For the same reason, there will be no dominant tree in these areas. The Cabins plot also has a higher disturbance because it is maintained regularly and frequented by humans.

Mixed plots 1, 2 and 4 were least disturbed and showed higher diversity than other plots. The terrain of these plots was much steeper and therefore less easily accessed, meaning that they are more difficult to maintain. Compared to these plots, Teak 3, 4 and Patch 1 show a higher average tree height, greater percent grass and less diversity.

We did not take average tree height or distance between trees for the plot surrounding Steve and Debbie's house because trees planted here were on too steep a hill to be accessed. These trees had been planted as representatives of the trees that were growing on the property. Figure 8 shows an exaggerated tree height and distance between trees because this plot was pastureland. As such, there were many *Cordia alliodora*, spaced very widely apart. We did not count original trees, which would have significantly lowered the distance between trees.

CONCLUSIONS

Figure 1 shows that the planted trees had a higher diversity than original trees. This is to be expected for a number of reasons. Planted trees were chosen deliberately and in high numbers adding to the diversity. Original trees on the other hand were found left untouched and competed only against other species that would naturally grow. No artificial selection would have occurred against species such as *T. grandis* or *Vochysia spp.* that are non-native. These original trees would be working on an ecological niche and would be outcompeting similar species. Counter-examples are found in plots such as Mixed 2 and 4 and Patch 2 and 3, where the evenness was above 75. For our study, we could use our calculated diversity for the original trees, therefore, as a standard since we were unable to sample true forest.

Other studies have shown similar results. Oosterhoorn *et al.* (1999) showed that where forest edges existed, species that would not normally be seen in true forest had invaded. Our diversity for original trees (3.29) was closest to the "near-to-edge pastureland" in the Oosterhoorn *et al.* study. The Himalayan study on the other hand showed diversity indices greater than our overall diversity index (4.18). We speculate that this either means the reforestation has created an environment similar to forests in the Himalayas or that the deforestation we were encountering was similar to the deforestation seen in the Himalayas (Behera *et al.* 2004).

With this in mind we begin to look at the diversity of individual plots and find that Mixed 1 and 2 have diversities closest to those of the original trees (above 80%). Looking at out parameters, we see that these two plots are almost identical (they lack disturbance, have 40% grass, and have similar average tree heights). Each of these parameters we know are excellent conditions for reforestation (Cusack *et al.* 2003, Butler *et al.* 2007). The lack of disturbance allows natural regeneration to occur and the low percent grass means that other species of plants are beginning to colonize. Using the terrain complexity parameter from Behera *et al.* (2004) study, we see in retrospect that these plots are unique and ideal in this regard for the reforestation project. Both plots have a higher slope than other plots allowing for better drainage. Mixed 1 was also the only plot in which *Dalberghia glomerata*—a species endemic to Costa Rica—was found growing and in high quantities, with 48 of these trees counted. The presence of *D. glomerata* indicates the plot was unique.

There may be a relationship between diversity and importance value. The plots that showed a difference between tree with highest importance value and importance value for the most numerous tree also had the higher diversity. This result would make sense because there would be higher competition in these plots between trees. Our samples may have also been insufficient. By only sampling one quadrat, there is a chance that we sampled a tree with an extremely high basal area that would lend to its high importance. Our recommendation, therefore, would be to sample more than one quadrat per plot (especially in larger plots) to show a more accurate importance value.

The difference in the importance value in Patch 1 between the most numerous tree and the tree with the highest importance value should not be cause for concern because both trees, *D. panamensis* and *V. guatemalensis*, are excellent candidates for use in reforestation. However, in Mixed 1, 3 and 4, trees that are not used for reforestation had a higher importance value than other trees in the plot. Our recommendation would be to not plant more of these trees, *C. aurantium* and *Musa spp.*, because they are not ideal for reforestation. Both species, however, do have an important ecological role in providing food for birds and mammals, so we do not think it is necessary to remove them.

Throughout the study we were concerned by the amount of time spent on simple taxonomy. One major problem was in finding the scientific name for the trees at Leaves and Lizards, as with multiple common names and Spanish common names, we found that many times we were doubling work we had already finished. This problem should be alleviated in the future by our own species account and catalogue, though we have some concern that our catalogue may be in error for a few trees. Photo-documentation turned out to be a good resource for the project. It allowed for more time to be spent with the trees than we would normally have in the course of the day.

The next step in the project is to continue the monitoring, sample more quadrats, and refine the species catalogue and account. We would need to first assess the overall growth of the property and begin looking for increases in diversity. From Brandani *et al.* (1988) study we expect diversity to initially increase as the plots of land are left undisturbed. Plant species that do not grow in true forest will initially colonize each plot of land, but should eventually be out-competed by the reforested trees. As disturbance decreases and a canopy begins to form, we will begin to see a decrease in diversity that will approach the diversity found in true forests.

Sampling more quadrats in the future canl provide a truer representation of the diversity of the plots and the importance values of tree species. With smaller plots (such as Patch 2 or 3 or Mixed 4), one or two quadrats may be sufficient still, but with larger plots (especially Mixed 1 and 2 and Sloth Valley), 3 or more quadrats are needed to provide good data.Given more time, it should also be simple to refine the species catalogue. With a base already established, it is the work of future groups to make corrections to our species catalogue and update our species account.

Finally, we cannot emphasize enough the need to define a control for the project. We were unable to sample true forest because of time constraints and the danger of working in true forest. However, for our results to be truly meaningful, we need to see where the property stands in comparison to its goal. We suggest at first sampling forest along an edge or along a path. If it is ever possible in the future to sample large quadrats in true forest, we suggest that this become a priority for the project.

LITERATURE CITED

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Figure 1 Diversity measurements in reforestation areas (planted) and the original trees

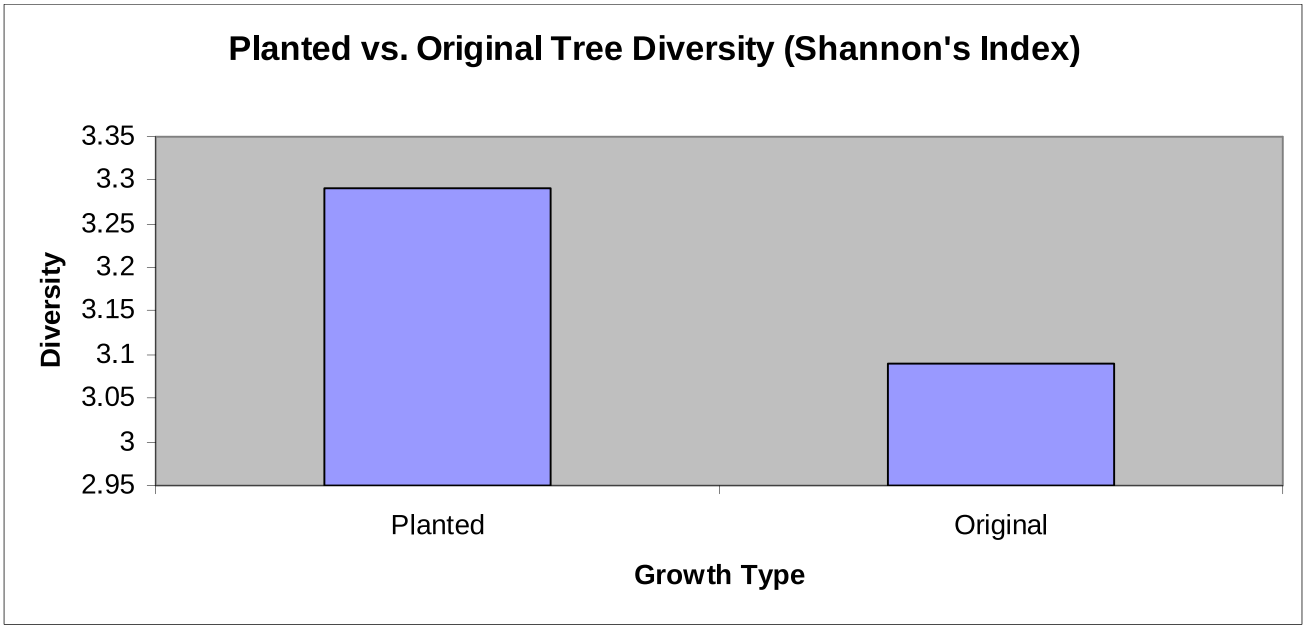

Figure 2 Map of the fifteen vegetation study areas at Leaves and Lizards

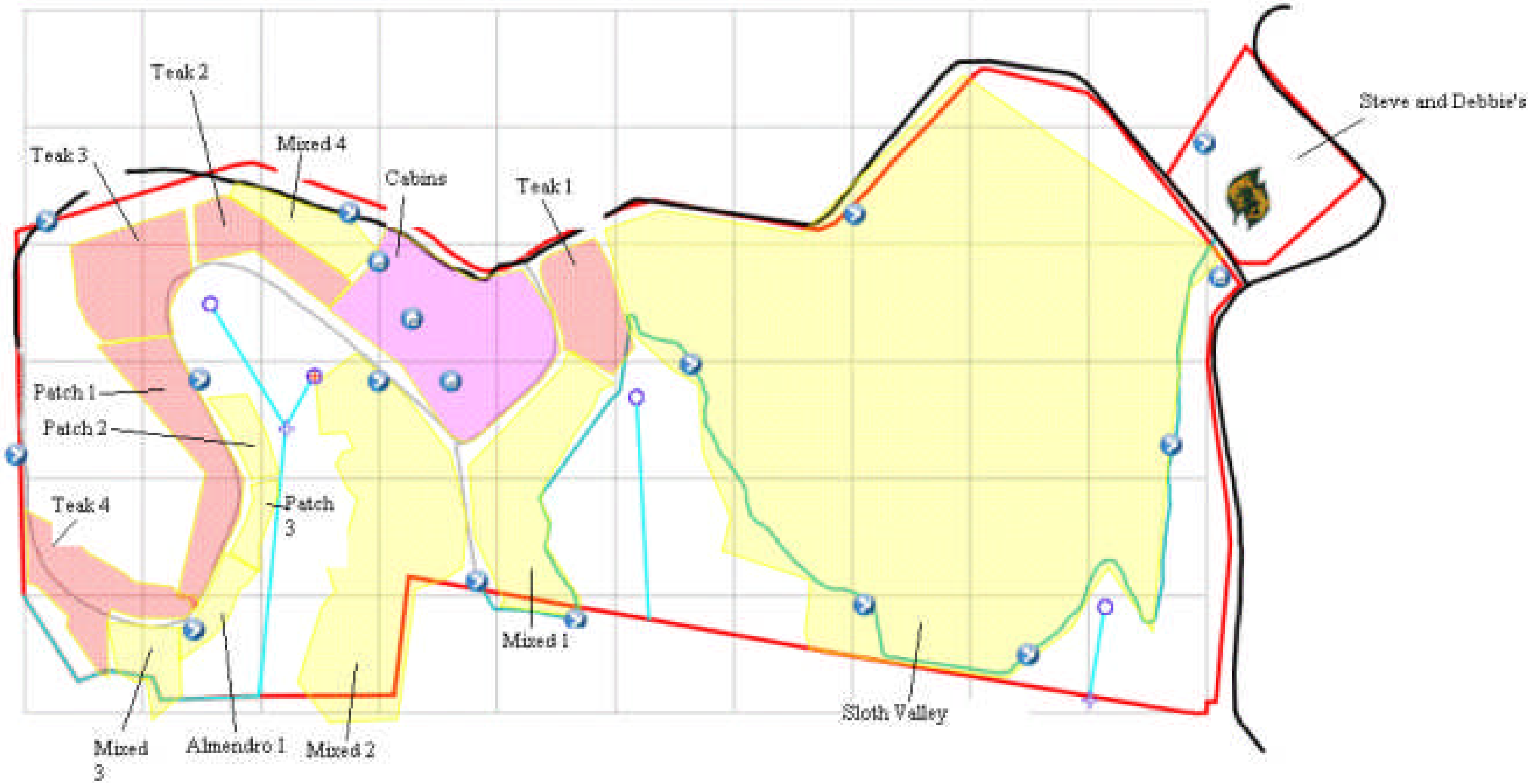

Figure 3 Biological importance values for the tree species found at Leaves and Lizards. Abbreviation codes are defined in Table 2

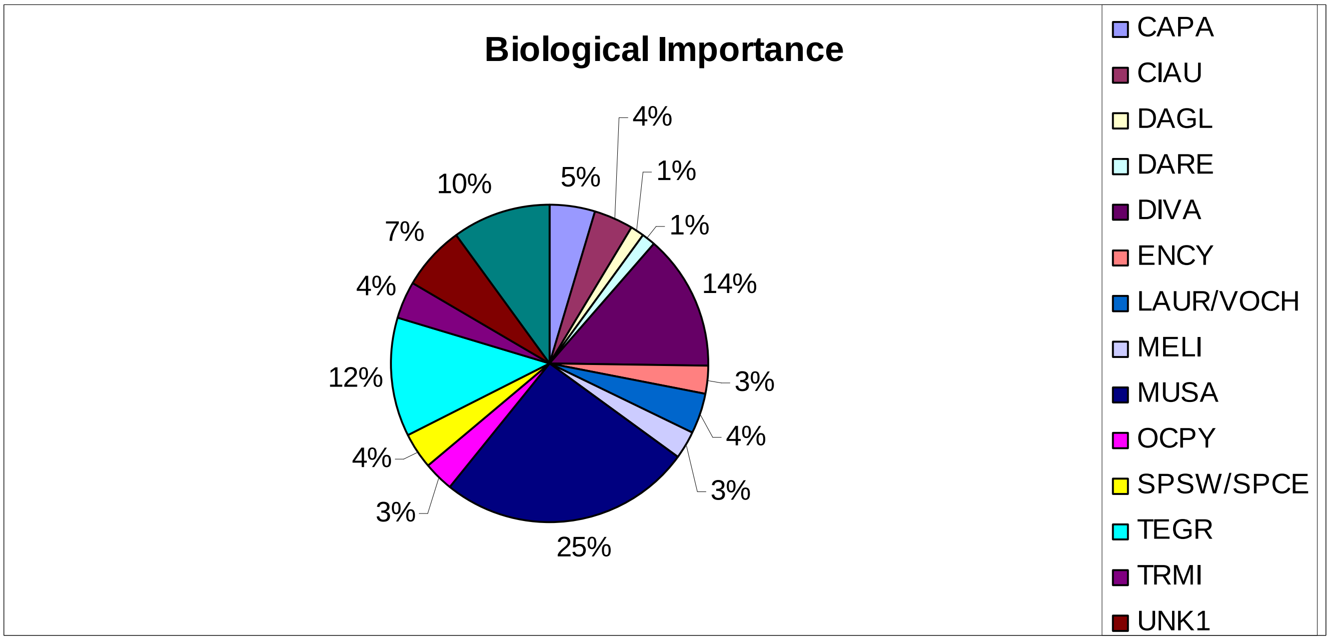

Figure 4 Evenness values for the fifteen vegetation sites at Leaves and Lizards

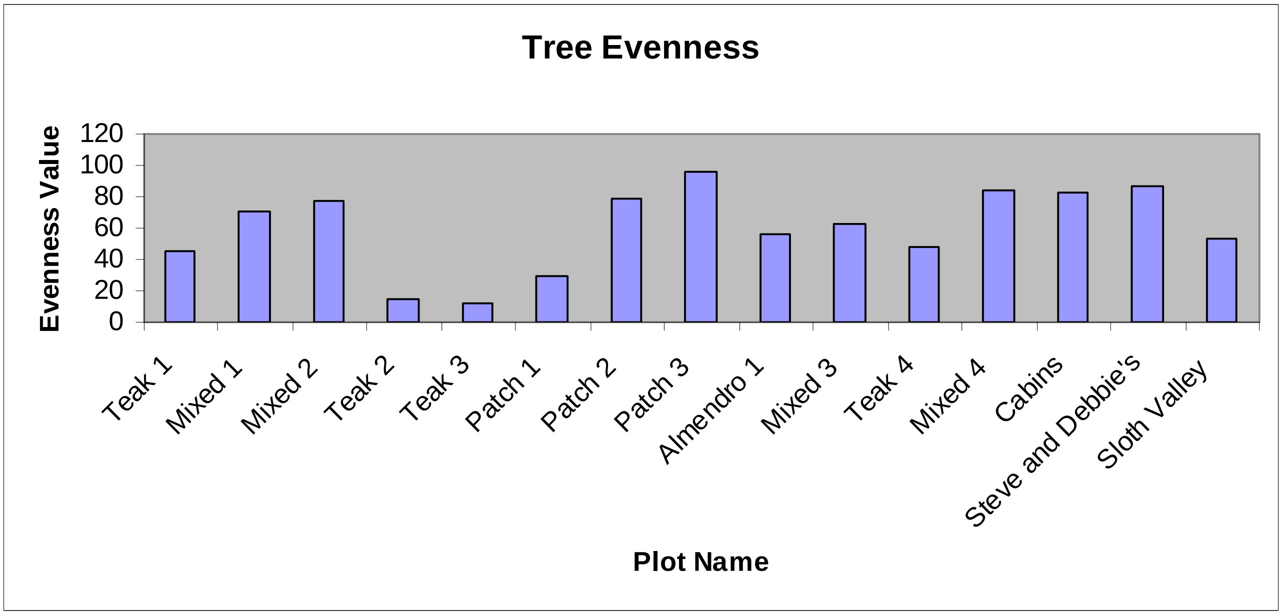

Figure 5 Shannon diversity indices for the fifteen vegetation sites at Leaves and Lizards

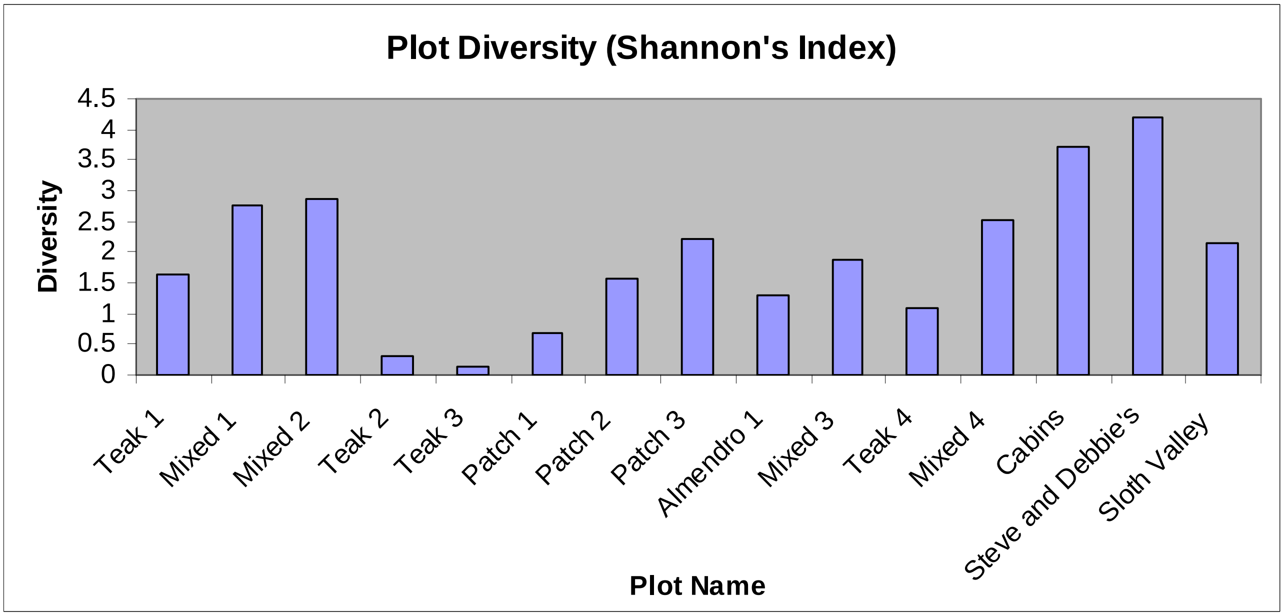

Figure 6 Tree height data for the fifteen vegetation sites at Leaves and Lizards

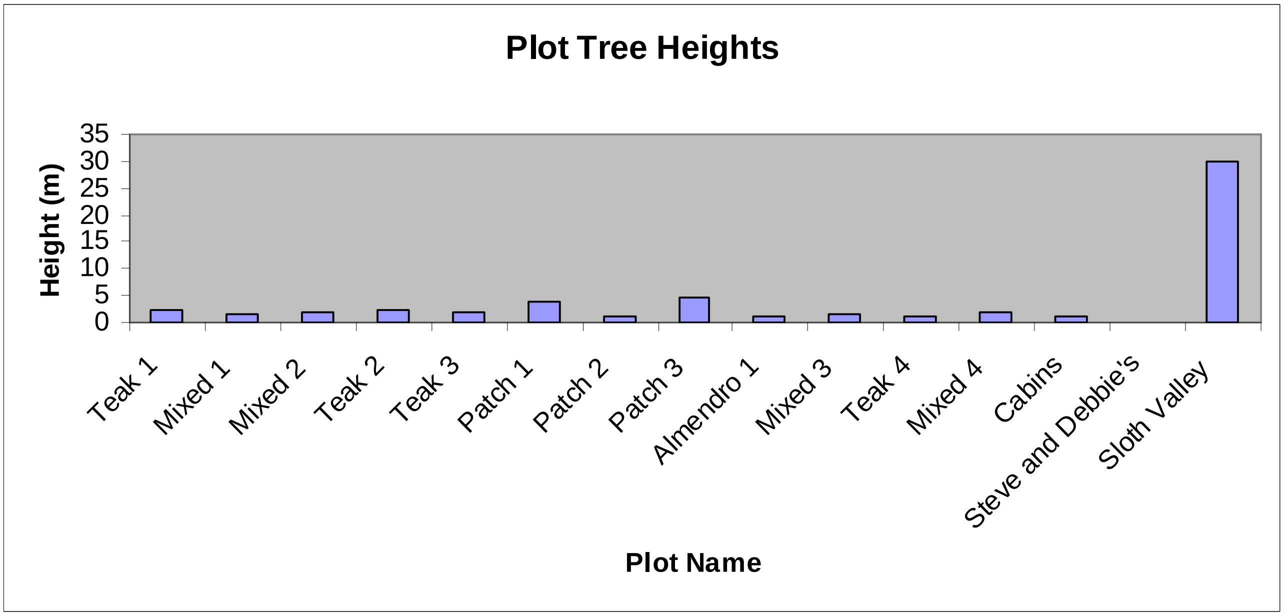

Figure 7 Distance between trees for the fifteen vegetation sites at Leaves and Lizards

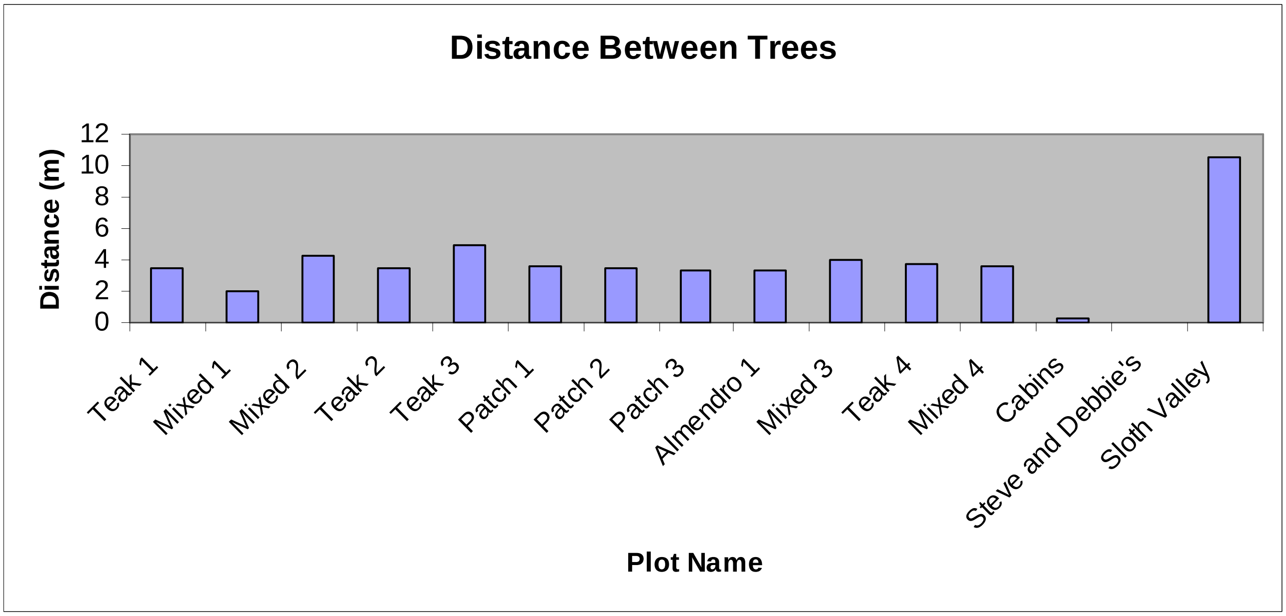

Table 1 Parameters used to characterize each of the fifteen vegetation areas at Leaves and Lizards

Plot Name	Plot Type	Disturbance	Distance to Water (m)	% Grass	Dominant Tree	Avg. Tree Height (m)	Distance btw. Trees (m)
Almendro 1	mixed	mowed	20	70%	DIVA	1	3.3
Cabins	ornamental	cabins, path	40	20%	N/A	1	0.25
Mixed 1	mixed	none	30	40%	DIVA	1.5	2
Mixed 2	mixed	none	15	40%	SPCE/SPSW	1.8	4.3
Mixed 3	mixed	mowed, path	20	70%	VOGU	1.5	4
Mixed 4	mixed	none	50	10%	VOGU	2	3.6
Patch 1	monoculture	mowed, path	30	100%	LAUR/VOCH	4	3.55
Patch 2	mixed	mowed	15	70%	VOGU	1	3.5
Patch 3	mixed	mowed	20	70%	MELI	4.5	3.3
Sloth Valley	mixed	none	51	80%	COAL	30	10.5
Steve and Debbie's	ornamental	none	---	80%	N/A	---	---
Teak 1	monoculture	none	30	25%	TEGR	2.5	3.5
Teak 2	monoculture	mowed,path	20	10%	TEGR	2.5	3.5
Teak 3	monoculture	path	15	90%	TEGR	2	4.95
Teak 4	mixed	mowed,path	30	75%	TEGR	1	3.7

Table 2 Species list for tree species found at the Leaves and Lizards site

Abbreviation	Common Name	Scientific name	Family
SPMO	Wild Plum (Jobo)	Spondias monbin	Anacardiaceae
ANMU	Soursop (Guanabana)	Annona muricata	Annonaceae
STDS	Huevos de Caballo	Stemmadenia donnell-smithii	Apocynaceae
BAGA	Peach Palm (Pejibaye)	Bactris gasipaes	Arecaceae
CONU	Cocos	Cocos nucifera	Arecaceae
UNKP	Dwarf Coconut	Cocos nucifera	Arecaceae
VEPA	Asterasia Senello (Tuete)	Vernonia patens	Asteraceae
TARO	Pink Trumpet Tree (Roble Savannah)	Tabebuia rosea	Bagnoniaceae
CEBA	Kapok Tree (Ceiba)	Ceiba pentandra	Bombacaceae
OCPY	Balsa Tree	Ochroma pyramidale	Bombacaceae
COAL	Laurel	Cordia alliodora	Boraginaceae
CAPA	Papaya (M/F)	Carica papaya	Cariciceae
CEPE	Cecropia (Guarumo)	Cecropia peltata	Cecropiaceae
SEED	Vegetable Pear (Chayote)	Sechium edule	Cucurbitaceae
SPBR		Sphaeropterix brunei	Cyatheacea
ALMA		Alcaplipha macrostachya	Euphorbiaceae
SABI		Sabium spp.	Euphorbiaceae
COJO	Angel's Hair (Lorito)	Cojoba costaricansis	Fabaceae
DIVA	Tonka Bean (Almendro)	Dipteryx panamensis	Fabaceae
ENCY	Guanacaste	Enterlobium cyclocarpum	Fabaceae
ERLA	Machete Flower (Poró)	Erythrina lanceolata	Fabaceae
UNK4	Guava	Inga spp.	Fabaceae
INGA	Guava real	Inga spp.	Fabaceae
LOCH	Lonchocarpus Velatinos	Lonchocarpus spp.	Fabaceae
UNK1	Sotacaballo	Zygia longifolia	Fabaceae
PTHA	Sangrio	Pterocarpus hayesii	Fabaceae
TEAM	Roble Coral	Terminalia amazonia	Fagaceae
UNKY	Cerillo	Casearia arguta	Flacourtiaceae
ACVE		Ocotillo veraguense	Fouquieriaceae
NERE	Guesillo	Nectandra reticulata	Lauraceae
OCTO	Aguacatillo	Ocotea tonduzii	Lauraceae
PEAM	Avocado	Persea americana	Lauraceae
BRCR	Nance	Brysonima crassifolia	Malpighiaceae
BLGR		Blakea grandiflora	Melastomataceae
COSU	Coloradillo	Conostegia subcrustulata	Melastomataceae

SWHU	Mahogony (Caoba)	Swietenia humilis	Meliaceae
SPSW/SPCE	Cedro Dulce	Cedrella tonduzii	Meliaceae
ARAL	Bread Fruit (Castanio)	Artocarpus altilis	Moraceae
Abbreviation	**Common Name**	**Scientific name**	**Family**
BRGU		Brosium guianense	Moraceae
CAEL	Rubber Tree (Hule)	Castilla elastica	Moraceae
MUSA	Banana	Musa spp.	Musaceae
VIKO		Virola koschnyi	Myristicaceae
EUDU	Gluptus (Eucalyptus)	Eucaliptus dugluptea	Myrtaceae
PSGU	Guayaba	Psidium guineense	Myrtaceae
SYMA	Malay Apple	Syzygium malaccense	Myrtaceae
AVCA	Star Fruit (Caranbola)	Averrhoa carambola	Oxalidaceae
PAND	Pandanus	Pandanus spp.	Pandanaceae
DAGL	Granadillo	Dalbergia glomerata	Papillonaceae
DARE	Cocobolo	Dalbergia retusa	Papillonaceae
UNKF	Unknown Ficus	Ficus morachia	Papillonaceae
PALI	Sweet Passion Fruit	Passiflora ligularis	Passifloraceae
BAVU	Common Bamboo	Bambusa vulgaris	Poaceae
ERJA	Japenese Plum	Eriobotrya japonica	Rosaceae
GEAM	Guaitil	Genipa americana	Rubiaceae
CIAF	Limon Dulce (Limon)	Citrus aurantifolia	Rutaceae
CIAU	Sour Orange Tree	Citrus aurantium	Rutaceae
NELA	Mamonchino	Nephelium lappaceum	Sapindaceae
MACH	Nispero Chicle (Zapote)	Manilkara chicle	Sapotaceae
QUAM	Hombre Grande	Quasilla amara	Simaroubaceae
ACAR	Guitite	Acninstus arborescens	Solanaceae
SORU	Sarillo	Solanum rugosum	Solanaceae
HELI		Heliocarpus spp.	Tiliaceae
TRMI	Trema (Capulin)	Trema micrantha	Ulnaceae
CAAC		Calicarpa acuminata	Verbenaceae
MELI	Gmelina (Molina, Paper Tree)	Gmelina arborea	Verbenaceae
TEGR	Teak	Tectona grandis	Verbenaceae
VOGU	Mayo	Vochysia guatemalensis	Vochysiaceae
LAUR/VOCH		Vochysia spp.	Vochysiaceae