Importancia de la heterogeneidad de hábitats para la biodiversidad de hormigas en los Andes de Colombia

Importance of habitat heterogeneity for ant biodiversity in the Colombian Andes

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RESUMEN

Entre marzo y octubre de 2002 se compararon los ensamblajes de hormigas que forrajean en el suelo en un sistema no manejado (reserva natural El Ciprés) y en algunas fincas vecinas. En dos transectos de 100 m se instalaron estaciones de muestreo cada 10 m con trampa de caída (pitfall) y cebo de atún epígeo durante 880 h y 92 días respectivamente. En 1471 eventos de captura se determinaron 68 especies distribuidas en 26 géneros y 8 subfamilias. En el sistema silvopastoril- guayaba y en monocultivo de granadilla (*Passiflora ligularis*) dominaron las especies de hormigas mientras que la distribución fue más equitativa en los usos del terreno con estructura vegetal más compleja (bosque, café, sucesión temprana y banco de forrajes). El sistema silvopastoril-guayaba fue el más rico en especies (31) seguido por café (30) y por el bosque y la sucesión temprana (29). El flujo de especies fue alto en bosque, café y sucesión temprana, indicando que la calidad de la matriz es factor importante para el mantenimiento de la biodiversidad.

Palabras clave: Biodiversidad; hormigas; usos de la tierra; heterogeneidad espacial; Colombia.

ABSTRACT

In order to compare the ant assemblages in the Natural Reserve of El Ciprés (Valle-Colombia) and its neighboring farms, periodical ant sampling was carried out between March and October 2002. Each site had two transects of 100m, with 10 sampling points. Each sampling point contained a pitfall trap and epigeal tuna bait established for 880 h and 92 days, respectively. In addition, the vegetation structure of each site was characterized. A total of 1471 ants were collected, representing 68 species in 26 genera and 8 subfamilies. Two agricultural systems, the guava silvo-pastoral system, and passion fruit (*Passiflora ligularis*) monoculture, typically presented dominant ant species, whereas sites with more complex vegetation structure (i.e. forest, coffee, early succession and fodder banks) had a more equitable distribution for the ant species. In terms of ant richness, the guava system was the richest (31 spp.) followed by coffee (30 spp.) and forest and early succession with 29 spp. each. The latter systems had a high turn over of species, indicating that the quality of the matrix is an important issue for the biodiversity of ant species.

Key words: Biodiversity; ants; land uses; spatial heterogeneity; Colombia.

INTRODUCTION

The Andean zone is currently the second most anthropogenically-transformed region (61.8%) in Colombia, after the Caribbean (Arango *et al*., 2003). This region represents 24.5% of the land surface of the country, and supports 70% of the human population (DANE, 1996), and 31% of the bovine population (Etter and Van Wyngaarden, 2000). As a consequence, it is one of the priority biogeographic zones for conservation management (Alexander von Humboldt Institute, 2000).

Notable management practices that maintain biodiversity in agro-ecosystems are the promotion and conservation of abundant living and decomposing biomass, the diversification of plant species (Westman, 1990), crop associations and the establishment of hedges, the conservation of soil and water, and ending burning and the use of high toxicity pesticides (Pimentel *et al*., 1992; Murgueitio and Calle, 1999).

In the last decade the El Ciprés Nature Reserve (Municipio El Dovio, Valle del Cauca) has been transformed into a mosaic of diverse matrices (pastures, polycultures, agroforestry systems, restored forests on former pastures, and patches of forest). In the locality under study, the Foundation for Research on Sustainable Farming Systems (CIPAV), trains the local farmers, and promotes and disseminates research advances in appropriate technologies amongst rural producers and sector organizations.
As 34% of the national land area is dominated by agroecosystems, and as the ants constitute an appropriate group for observing the changes in wild diversity associated with managed systems, and patterns of land use (Roth *et al*., 1994; Armbrecht *et al*., 2005), this investigation aimed to evaluate the changes in richness and composition of ant communities that forage in the soil of the El Ciprés Nature Reserve, and the neighboring farms, and to examine responses to changes in vegetation and management regimes in the productive systems.

MATERIALS AND METHODS

The El Ciprés Nature Reserve is located in the village of Bella Vista, Municipality of El Dovio, Department of Valle del Cauca (4° 31´ N; 76° 14´ O, 13 ha, 1.450 -1.850 masl, precipitation 1.515 mm, 19 °C) in a subtropical humid forest lifezone (bh- ST) (Espinal, 1977 and 1994; Calle *et al*., 1999).

Six land uses were chosen (Table 1): Two remnants of secondary forest (F), two silvopastoral systems with the star grass (*Cynodon plectostachyus*) and dominated by guava trees (*Psidium guajava*) (SPG), a forage bank (*Trichanthera gigantea*) (FB), two areas of early succession (ES), two coffee plantations (*Coffea arabica*) associated with trees of *Inga* spp. and heliconias (*Heliconia* spp.) (C), and two cultures of the granadilla crop (*Passiflora ligularis*) outside the reserve (G).

Table 1. Description of the land uses of the El Ciprés Nature Reserve, Valle del Cauca, Colombia.

Land Use	**Description**
Forest	Mature patches (between 1 and 1.5 ha, 15 and 25 m of canopy and 10 to 30 years of age), highly intervened, heterogeneous, and located on ridges and in micro-watersheds. Tended to extend into abandoned pasture, and lands destined for regeneration. Notable species: wax palm (*Ceroxylum alpinum*), balsa (*Ochroma pyramidale*), 'pategallina' (*Oreopanax* sp.), white laurel (*Nectandra lineatifolia*) and 'yarumo blanco' (*Cecropia* sp.). The under story in sparse, with an abundance of wax palms, heliconias (*Heliconia griggsiana*), anthuriums (*Anthurium* sp.), San Juanito (*Renealmia* sp.), and the low growth palms *Chamadorea* sp. and *Aiphanes* sp. (Calle *et al*., 1999).
Early Succession	Coffee plantations and pasture abandoned to natural regeneration, colonized by guava trees (*Psidium guajava*), and species of the families Myrcinaceae, Lauraceae, Asteraceae and Melastomataceae.
Guava Silvopastoral System	Located on undulating and sloping terrain, where the regeneration of trees and shrubs is appropriate. In plots of approximately 0.5 ha the dominant species are: guava (*P. guajava*), chagualo (*Myrsine guianensis*), arrayan (*Eugenia cf. florida*), ficus (*Ficus* sp.), churimo (*Inga* sp.), nigüito (*Miconia* sp.), montefrío (*Alchornea latifolia*), mestizo (*Cupania latifolia*) and scattered trees up to the 12m high arboloco (*Nectandra* sp.) and laurel (*Ocotea* sp.). The majority of the pastures are regenerated in 20 years, and 80% are composed of the association star grass (*Cynodon nlemfuensis*) - leguminosas (Espinel, 1994). Management of pastures does not include agrochemical use, nor periodic burning. Weed removal is by hand.
Coffee plantations	Traditionally of approximately 0.5 ha, adjacent to forest patches, and with shade from the guamo (*Inga* spp.); Also found in association with the (*Cordia alliodora*), chachafruto (*Erythrina edulis*), banana (*Musa paradisiaca*), heliconias and small areas of pineapple (*Annana comosus*).
Forage banks	From 1.2 ha of nacedero (*Trichanthera gigantea*), alternated with rows of 'botón de oro' (*Tithonia diversifolia*); also contains other species for animal consumption, and subsistence use, like the raspberry, ramio (*Boehmeria nivea*), chachafruto (*E. edulis*) y maíz (*Zea mays*). Has an organic soil management, (lombricompost (1t/Ha/year fresh base) and plant residues).
Granadilla (outside the reserve)	From 3 ha, planted by small or medium sized farmers from the zone that fertilize and use agrochemicals (toxicity category three) to control fungi and leaf miners, *Thrips* sp.

Between March and October of 2002 two transects of 100 m were established, with ant sampling stations every 10 m (pitfall trap for 48 hours, and epigeal tuna bait for 5 hours). For the pitfall traps plastic cups of 6 cm were buried to the soil line, and half-filled with a solution of water and detergent (modified from Jaffé *et al*., 1993). The tuna bait contained 3 – 4 grams of tuna on a piece of bond paper (22 x 8 cm).

The sampled material was preserved in 70% alcohol. The morpho-species were identified to genus using the keys of Holldobler and Wilson (1990), comparison with the Entomology Collection of the University del Valle, and also consultation with local taxonomists. The collection from the reserve was deposited in the Entomological Museum of the University del Valle (MEUV).

The vegetation volume (TVV) was estimated using the following formula:

TVV = h/10p (Mills *et al*., 1991). In which *h* is the total number of vegetation interceptions on an aluminum tube (5.4 m) at nine height intervals of the sampled points, and *p* is the number of stations.

The diversity of foliage strata (FHD) was calculated using Shannon's Index, considering intervals as species, and the number of branches and trunks registered per interval as abundances. Canopy cover was calculated using the percentage of area covered with vegetation from four readings with a spherical concave densiometer (Forestry suppliers).

The Complementarity Index between the six land uses was calculated. This index is based on the cover of the shared species (Colwell and Coddington, 1994), and is interpreted as being greater when there are fewer shared species. When the values approach one (1), the two land uses are complementary, and when it approaches zero (0), they are identical. The Complementarity Index is denoted as:

Cjk= Ujk/ Sjk

Where Sjk = Sj + Sk - Vjk
and Ujk = Sj + Sk - 2Vjk
Sj = is the observed S of the first site
Sk = is the observed S of the second site
Vjk = are the shared species

In the statistical analysis, the non-parametric richness estimator, Chao2 was used; the richness data from each site were randomized 100 times with the aim to minimize the sampling error, and the heterogeneity between the sampling units (Colwell and Coddington, 1994). Species density per sampling unit was compared using the Kruskall-Wallis test (Zar, 1996). To differentiate between sites, a multiple comparison of mean ranks was performed. To explain the variation between the land uses, the vegetation measures were submitted to principal component analysis (PCA). Non-rotated factors were used to explain the maximum variance (Stevens, 1986).

RESULTS

1471 capture events were registered and 68 ant species, distributed in 26 genera and 8 subfamilies. Station richness (density) was statistically different between land uses; the silvo-pastoral guava cultivation, coffee plantations and the forest were statistically different to early succession, granadilla and the forage bank (Table 2).

Table 2. Multiple comparison of mean ranks between the land uses in the El Ciprés Nature Reserve (El Dovio, Valle).

Land use	Rank	Groups		
Forest	88.350	I		
Guava SP	81.500	I		
Coffee	74.350	I		
Early Succession	65.025	I	I	
Granadilla	37.875		I	I
Forage Banks	15.900			I

In the six land uses, between 41 and 91% of the species were found (32 to 3 species remained to be found). It may be appreciated that the best sampled land use systems were the forest, the coffee, and the guava cultivation, while the early succession, the forage bank, and the granadilla gave a lesser estimate of richness (Table 3). Similarity between the estimated and observed numbers of species was greatest in the forest. In contrast, large differences were found in the early succession, and the forage bank, whose richness estimates with Chao2 was less certain.

Table 3. Observed and estimate values of ant richness in the sampled land uses (S obs = richness observed) in the El Ciprés Nature Reserve (El Dovio, Valle).

Land Use	S Obs	Single	Duplicated	Chao2 (%)
Guava SP	31	9	5	79
Coffee	30	8	6	86
Forest	29	6	6	91
Early Succession	29	12	4	62
Forest Banks	22	14	3	41
Granadilla	18	8	2	53
Total	**68**	**20**	**7**	**72**

The guava silvo-pastoral cultivation and the forage bank were the most complementary systems, while those adjacent to the forest (such as coffee, and early succession) had the lowest values (Table 4).

The abundances of species in the forest, coffee, early succession, and forage bank were not numerically different (Figures 1, 2). In the forest, four species dominated: *Pheidole*, *Solenopsis* sp. 1, *Gnamptogenys* sp. and *Pachycondyla impressa*; In coffee and early succession the dominant species were: *Solenopsis* sp. 1, *Pheidole* sp. 4 and sp. 5, *Paratrechina steinheili*, *Gnamptogenys* sp. and *P. impressa* (Figure 1); In granadilla the species *Solenopsis* sp. 2 dominated; and in the guava silvo-pastoral system *Ectatomma ruidum* followed by *Pheidole* sp. 3 dominated (Figure 2).

Table 4. Complementarity Index between pairs of sites in the El Ciprés NR. (El Dovio, Valle del Cauca).

	Coffee	**Guava SP**	**Early Succession**	**Forage Bank**	**Granadilla**
Forest	0.59	0.75	0.47	0.69	0.73
Coffee		0.58	0.52	0.60	0.58
Guava SP			0.66	0.76	0.63
Early Succession				0.72	0.60
Forage Bank					0.66

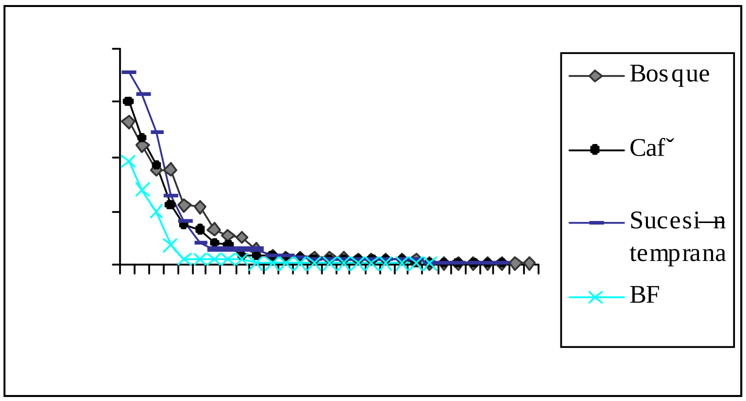

Figure 1. Curves of abundance distributions in forest, coffee, early succession, and forage bank in the El Ciprés NR, Valle del Cauca, Colombia.

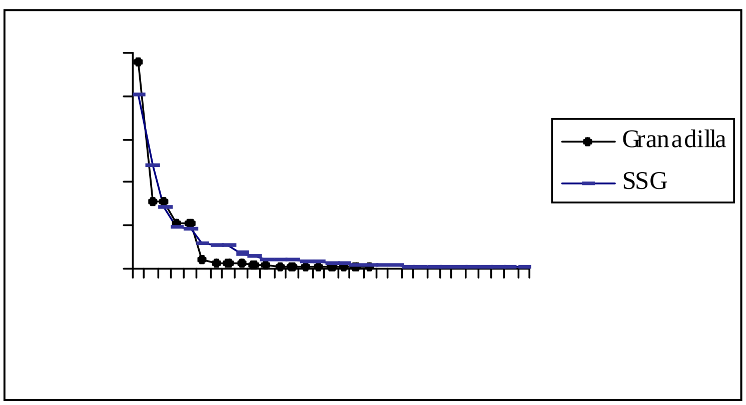

Figure 2. Curves of abundance distribution in granadilla and Guava SP in the El Ciprés NR, Valle del Cauca, Colombia.

For vegetation structure, all the variables were united in the first factor, where diversity of strata was the component that most explained the variation between land use systems (Table 5). In agreement with the PCA, the disposition of the land uses showed that, with the exception of the early succession, the replicates tended to group, and the productive systems with the simplest vegetative structure were the guava silvo-pastoral system and the granadilla (Figure 3).

Table 5. Vegetation variables for the land uses sampled in the El Ciprés NR (El Dovio, Valle del Cauca) used in the PCA.

Variable	Factor 1	Factor 2
Vegetation volume	**0.895931**	- 0.315543
Diversity of foliage strata	**0.914437**	- 0.218042
Cover	**0.792956**	- 0.607966

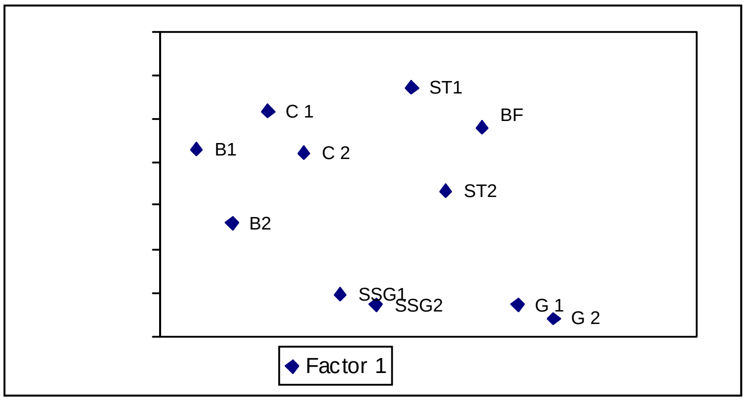

Figure 3. Location of the land uses in the El Ciprés NR (El Dovio, Valle del Cauca) according to the vegetation structure. B = Forest, C = Coffee, ST = Early Succession, SSG = Guava SP, BF = Forage Bank, G = Granadilla.

DISCUSSION

The analysis of richness showed differences between the land use systems that conformed the mosaic of uses in the reserve (silvo-pastoral guava, coffee, and forest) and the granadilla (outside the reserve). Early succession formed an intermediate group with the granadilla as a habitat in transition. The forage bank formed the last group, being a replicate (Table 2).

The saturation tendency shown by the forest is probably due to the behavior of the habitat in transition to primary forest, where the number of species is reduced, giving way to the actual forest species. In contrast, the difference between singles and duplicates reflects particular histories and intrinsic dynamics in the early succession, and the forage bank.

The areas of early succession adjacent to the forest fragments, whose aim was to increase the size of the forests, constitute ecotones, which could function as corridors for the flow of tourist species that cross the land uses, offering food and nesting resources.

As the forage bank is an intensive system for production of vegetable biomass (with harvests every three or four months), this management system generates drastic changes in physical and structural conditions in the vegetation, and in ant displacement and recolonization processes. Ramírez (2006) found that the harvests create patches of forage of different ages, and offer micro-habitats to which the ants can migrate when facing the hostile conditions of the harvest. In addition, massive and rapid migration may occur towards the neighboring lands, although, when the foliage has recuperated, the ants will recolonize once again (Ramírez *et al*., 2007).

The complementarity values between forest, coffee and early succession indicate a considerable flow of species, or survival of similar assemblages of ants. This demonstrates the importance of the matrix quality for maintaining a constant flow, and for the exchange of species between forest and neighboring sites. When they compared forest fragments and Andean pastures, Jiménez and Lozano (2003) found that small habitats, such as the ditches, presented a large biological potential, functioning as connectors between different landscape elements.

In México, Perfecto and Vandermeer (2002) reported that the exchange of species between forest fragments and well-conserved coffee plantations was greater than between fragments and intensified coffee plantations. They proposed as an alternative, or complementary solution, to invest energy in attempting to fragment habitats with matrices of high quality, rather than promoting biological corridors.

The high complementarity between guava silvopastoral systems and the forage bank, both intensive systems with the same aim (cattle fodder), could be due to the adaptation of ants to the physical and management characteristics of each system.

In the land uses, the community structure of ants is hierarchical (Kolasa, 1989), and generalist species are dominant. According to abundance curves, and principal component analysis in and outside the reserve, the species distribution seems to be related with the vegetation structure (Figure 3). The guava silvopastoral and granadilla systems, which showed a marked difference between dominant species and those that cohabit with them (i.e. a marked dominance of the species that are adapted to disturbed and open zones, the context in which they are found, and the management that they receive), determined differences in the structure and the composition of the ant communities. The high use of agrochemicals and the removal of the organic soil layer in the granadilla system was manifest in the relative poverty of subfamilies and species.

As the silvopastoral system received different management to the pastures neighboring the Reserve (controlled regeneration of guava trees), it created micro-habitats with non-grass vegetation, and harboring different fauna, thus promoting the arrival of other species of ant (Esquivel, 2001).

CONCLUSIONS

The community composition and structure of the ant assemblages varied in the mosaic of land uses.

The land uses with the more complex vegetation structure presented a more balanced distribution of ant species.

Landscape features such as shade coffee plantations, regeneration areas and forage banks harbored, promoted and stimulated the flow of species with forest patches.

From ecological and landscape planning perspectives, the conservation of species in heterogeneous matrices is more favorable than having fragmented areas of forest where survival and ecological processes could be severely affected.

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