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**RECOVERY OF DISTURBED ECOSYSTEMS AS MONITORED BY ANT AND VEGETATION
DIVERSITY IN FORESTS AND SURROUNDING SAVANNAS OF VENEZUELA**

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Running Head: Ecosystem recovery in the Hylean highlands

ABSTRACT

The recovery of ecosystems after disturbance in the tropics is of interest for future programs of sustainable development. The dynamics of ecosystem recovery in 26 sites in Venezuela was evaluated using various methods. The ant and plant biodiversity of disturbed forest and surrounding savanna sites at different stages of recovery were compared with those for nearby primary vegetation. We estimated the species composition for ants, the number of species and equitability for ants and plants, and the plant coverage at each site. Of these indices, percentage of plant cover showed the most rapid return to pre-disturbance values. In a few cases, full return of all indices to pre-disturbance values occurred after around 25 years in both savanna and forest. A multiple factorial analysis of ant composition showed that species structure in old recovered sites converged sometimes, but not always, to that in surrounding natural habitats. Our results suggest that ant diversity indices provide for quantitative estimates of ecosystem recovery. They also suggest that even small scale human intervention may have irreversible effects on neotropical habitats. The estimated time constant for forest recovery could serve to estimate human carrying capacity of forest sites for eventual sustainable use of these ecosystems in the neotropics.

Keywords: Ants, diversity, recovery, ecosystem disturbance, forest, neotropical, Venezuela.

INTRODUCTION

Sustainable use of a natural ecosystem implies that recovery of a given ecosystem, after controlled and limited human intervention, is possible. Sustainable development has been extensively promoted worldwide, especially in the Neotropics (IUCN, PNUMA & WWF, 1991; WWF, 1991; WRI, IUCN & PNUMA, 1992; Jaffe & Sanchez, 1992). It is well known that tropical ecosystems possess high biodiversity but are fragile (Nilsson & Grelsson, 1995) and their recuperation after human intervention may be slow and even impossible (Engelhardt & Fittkau, 1984; Uhl & Jordan, 1984; Uhl, 1987), depending on the magnitude and characteristics of the impact (Folster, 1994). To our knowledge no quantitative evidence exists of neotropical ecosystems recovering after specific types of disturbance. A common type of intervention in these forests, which may be less drastic than mining or lumbering, is farming. The traditional farming method in tropical forests, practiced by Indians in the New World, is the "slash and burn" technique, known locally in Venezuela as "conuco" farming. Here, small areas of tropical forest are cut down, burnt, and then cultivated until the yield of the crops diminishes strongly, at which point the site is abandoned and allowed to recover. This farming technique has been considered as the least destructive way of farming tropical forests (Engelhardt & Fittkau, 1984; Uhl, 1987), and is promoted as a technology for sustainable agriculture in the Neotropics and elsewhere (Jaffe & Sanchez, 1992).

The aim of this study was to evaluate the usefulness of different diversity indices, and to estimate the rate of recovery of plant and ant diversity in three different tropical ecosystems that have been subject to "mild" human intervention. We selected ants for the evaluation of the faunal diversity for several reasons: they are extremely abundant, there is a relatively high species richness, there are many specialist species, they occupy different trophic levels, they are easily sampled, they are responsive to changing environmental conditions and ant species richness reflects that of other taxa in a site (Majer, 1977, 1978). Ants have been previously used as bio-indicators (Oliver and Beattie, 1993). For example, Weir (1978) used *Iridomyrmex purpureus* as an indicator for contamination with pesticides, Majer (1983) used ant communities as indicators for land use and degree of recovery after open mining and Andersen (1991) assessed the effect of fire on ant communities.

MATERIALS AND METHODS

Study sites :

This study was conducted in 26 different sites in three areas in Venezuela: two in forest and one in savanna. The forests studied were a Humid premontane forest in the Guyana highland, described in detail by Huber (1986); and a "Morichal" or gallery forest lining rivers crossing the savannas (Dry tropical forest), described by Gonzalez (1987). Both sites had been partially subjected to slash and burn farming in the recent past. We examined various abandoned "conucos" at different stages of recovery, evaluating plant and ant species diversity. These included 8 sites in the forests surrounding San Ignacio de Yuruani (Bolívar state, 5° 2' N; 60° 57' W; 975 m above sea level), and 10 sites in the gallery forest or "Morichal" of the Uracoa river (El Merey, Monagas state, 8° 45' N; 62° 47' W; 70 m.a.s.l.). Pemón indians and other subsistence farmers of these regions provided us with information on the age of the abandoned "conucos". We studied only those conucos for which at least two independent reports on their age were available and for which reports on their age were congruent. In the forest surrounding San Ignacio de Yuruani we used "conucos" abandoned for either 8, 13, 23, 30 or 45 years, and in the Morichal (the transitional forest of El Merey) we used "conucos" abandoned for either 10, 12, 20 or 25 years. Each conuco covered an area between one and five ha.

To contrast data from these two types of forest we also studied a savanna described in detail elsewhere (Huber, 1986; Gonzalez, 1987; Tamayo, 1961). The savannas of the Guayana shield in Venezuela are especially fragile and their recuperation, if it occurs, is very slow, principally because of the characteristics of the soils of this region (Grime, 1977). In the savanna, we chose sites with old dirt tracks no longer in use at different stages of recovery, and evaluated plant and ant species diversity. We used dirt tracks abandoned for either 5, 7, 8, 13 or 20 years at 7 sites in the savanna surrounding Canaima camp (Bolívar state, 5° 55' N; 61° 06' W; 400 m.a.s.l.).

The sites in all areas were surrounded by what we considered to be undisturbed pristine habitat. These habitats provided us with the undisturbed control sites, chosen close to the experimental sites (less than 500 m away), giving 3 control sites for San Ignacio and Canaima and 6 for El Merey.

Sampling :

At the center of each site we obtained ant samples using a transect split into three consecutive 60 m sections. We placed a pitfall trap every 10 m along the transect (total of 18 traps with 250 ml volume each). The traps were baited with a mixture based on results by Romero & Jaffe (1989) containing tinned tuna, pulverized ham, crushed biscuits and honey, placed in the traps above the liquid, out of the reach of ants. The bottom of the trap contained 50 ml of 3% formalin solution (Romero & Jaffe, 1989). We placed a plastic sheet (20 cm²) approximately 5 cm over the container, holding it aloft using small branches to protect the trap from rain. On the third and fifth day after setting the traps we collected the trapped insects and preserved them in 70% alcohol. Once in the laboratory, we separated the ants from the other insects and with the help of a stereo microscope identified the ants to genus, and then to morpho-species, noting the number of morpho-species present in each sample. Results for each site are given with 3 replicates each representing the collections from a 60 m transect.

To obtain estimates of vegetation diversity and of the percentage of plant cover, we arbitrarily chose two (or in the case of control sites, three) sample areas (10m x 1m) at each site. For each sample area we estimated the number of plant morpho-species based on leaf morphology (Vareschi, 1980) and estimated their abundance as the frequency they were encountered. Percentage of plant cover was estimated using the "line intercept method" (Andersen & McCormick, 1962), where the degree of canopy cover is expressed as a percentage of all the canopy layers. For the savanna, the vegetation was sampled using two sample areas of 50 x 50 cm² surfaces in each studied area. Within each surface, we sampled the plant morpho-species and estimated percentage ground cover (Feinsinger et al., 1981). Preliminary experiments showed that increasing the area sampled in those sites did not change the correlation between the various diversity indices used. Thus, we maximized the number of sample areas in each site. The exact number of replicates, i.e. total number of sample areas for each area are given as N in Table I.

Data Analysis :

We assessed plant and ant diversity by studying the two basic components of diversity separately. Both species richness and equitability were calculated to provide more insight into ecosystem dynamics than can be gained when global diversity indices are used (Majer, 1983). Species

richness was assessed as the number of species collected in each site, and the equitability was measured by the Proportional Similarity Index of Czekanowsky (Feinsinger et al., 1981). For the myrmecofauna, the indices were calculated based on frequency of occurrence (proportion of traps capturing a given species) rather than number of individuals. This is because the gregarious nature of social insects means that the number of individuals collected is a less reliable indicator of species abundance than frequency of occurrence (Romero & Jaffe, 1989). We defined a hierarchy of most common ant species by classifying in increasing order the five species most frequently collected in the traps. A value of 1 indicated the most common ant species and 5 the least common among the 5 most common. Many species showed equal frequency of falling in the pitfall traps, and were assigned the same number in the hierarchy of abundance. Therefore, more than one species may be classified at the same hierarchical level. For the multi-factorial analysis, dummy values of 10, 8, 6, 4 and 2 were assigned to frequency of occurrence of species at the hierarchical level from 1 to 5, and values of 0 for species occurring at frequencies lower than hierarchical level 5. Samples for some data points were lost due to accidents in the field, and thus the number of replicates reported in the tables is sometimes lower than the total described here.

RESULTS

Table I shows the results of the statistical analysis evaluating the sensitivity of the various indices used. Here we correlated each index with time of recovery using non-parametric statistics. Different sites correlated differently with the various indices. At San Ignacio, and to a lesser degree at Canaima, plants, but not ants, seemed to be reliable indicators for recovery. At El Merey the opposite seemed to hold.

At San Ignacio and Canaima, ant diversity varied without a clearly discernible pattern. This may suggest that ants moved freely from the surrounding habitats to the cleared sites. In fact, when the ant species composition at the different sites was analyzed (Table II to IV) we observed that 40% of the dominant ant species occurred in both, control sites and intervened sites at San Ignacio, 29% at El

Meroy and 35% at Canaima. At El Meroy, undisturbed sites showed a more distinct ant species composition compared to intervened ones. Direct observations suggested that soil erosion was taking place in some of the old sites at El Meroy and Canaima.

The comparison of ant species composition at each site (Table II to IV) suggests ant species that were present in most sites included the generalist or potential tramp species, such as species in the genera *Solenopsis*, *Pheidole*, *Wasmannia*, *Crematogaster*, and *Odontomachus*. For example, *O. chelifera* was dominant in all sites at the Morichal, whereas *O. bauri* was dominant in San Ignacio. Other species were dominant soon after abandonment of the conucos, including *Wasmannia*, *Tapinoma*, *Paratrechina* and *Pheidole* spp. A principal component analysis, using the five most frequently captured ant species at each site (Figure 1), shows that some, but not all, of the oldest sites which had suffered human intervention converged to the patterns of control sites.

We estimated the time needed for the indices of a given disturbed ecosystem to recover to values similar to that of nearby control sites by assuming as a first approximation a linear speed of recovery. Plots of the raw data seemed to justify this approximation (not shown). In Table V we indicate the relevant constants and statistics of the linear regression for the values of each index as they relate to time of recovery, at each study area. The mean value for each index at the control sites is also given. We used the following criterion for estimating the time of recovery of a site: the minimum value of the variable time which, when introduced into the linear regression of a given index, gave values which were equal to or greater than the mean values of their nearby control sites. This recovery time was similar in all three areas, i.e. 26, 23 and 27 years for San Ignacio, El Meroy and Canaima respectively, for those indices which showed the most statistically significant regression coefficient.

DISCUSSION

The most sensitive index seems to be the percentage of plant cover, as it gave consistently the highest significant correlation value with recovery time. Plant cover however does not tell us about plant

diversity, thus other indices were used. Different sites correlated differently with the various indices. At San Ignacio, and to a lesser degree at Canaima, plants, but not ants, seemed to be reliable indicators for recovery. At El Meray the opposite seemed to hold.

At San Ignacio and Canaima, ant diversity varied without a clearly discernible pattern. This may suggest that ants moved freely from the surrounding habitats to the cleared sites. In fact, when the ant species composition at the different sites was analyzed (Table II to IV) we observed that several dominant ant species occurred in both, control sites and intervened sites and undisturbed sites showed a more distinct ant species composition compared to intervened ones. This can be explained by the fact that the gallery forest fauna is very distinct from that of the surrounding savanna. Thus, intervening gallery forests introduces ants from the surrounding savanna, which happens less when conucos are cut inside forests like in San Ignacio.

Comparison of our results from the different sites regarding physical aspects such as soil and drainage conditions seems to confirm that recovery of disturbed patches is sensitive to the geometry and size of the disturbance, as well as the nature of the disturbance. Direct observations suggested that soil erosion was taking place in some of the old sites at El Meray and Canaima. During the first years after abandonment of the sites, the low ant diversity may reflect the low plant diversity and biomass as reported for other ecosystems (Greenslade & Greenslade, 1977; Caldas & Moutinho, 1993; Gadagkar et al., 1993; Verhaagh, 1991). Later on, the reduction in plant and ant diversity in some sites may reflect the savannisation of the site. Gonzalez (1987) suggested that perturbations such as changes in river dynamics, fire and agricultural practices may stop or even revert successional processes. The gallery forests or Morichales are susceptible to changes in water levels caused by human activity which affects water movement in the ecosystem. In the case of dirt tracks in savannas, plant cover and plant species richness may never reach values of pristine savanna. Direct observations confirmed that plant cover could be very badly affected in some sites, showing evident signs of erosion by rain water. This fragility of the savannas in the Hylean shield has been attributed to poor soils, slow vegetational growth and strong erosion. The myrmecofauna present in these sites though, does not seem to be much affected by the erosion, possibly because of the short distance to undisturbed savanna. This result may be attributed to the fact that the area affected by human activity was not large

enough to stop ants from surrounding undisturbed habitats migrating to the disturbed area.

The comparison of ant species composition at each site (Table II to IV) suggests that disturbance affects the ant communities. Ant species that were present in most sites included the generalist or potential tramp species, such as species in the genera *Solenopsis*, *Pheidole*, *Wasmannia* and *Crematogaster*, confirming previous studies on the ant fauna in conucos in Mexico (Mackay et al., 1991).

We estimated the time needed for the indices of a given disturbed ecosystem to recover to values similar to that of nearby control sites which was similar in all three areas, i.e. 26, 23 and 27 years for San Ignacio, El Meray and Canaima respectively, for those indices which showed the most statistically significant regression coefficient. This rate of recovery was faster than that of a similar forest recovery reported for slash and burning farming sites in the Peruvian Amazon forest (Denevan & Padoch, 1990). These authors reported the disappearance of planted trees 35 years after humans left the site, which they equated with the recovery of the original floral composition of the "purna" forest. Our results for the speed of recovery may be overestimated as the speed of recovery may slow down near the maximal values of recovery. Our results also showed that not all sites recover after human intervention. Soil erosion may affect a site irreversibly making a recovery to the original status impossible.

CONCLUSIONS

Slash and burn farming allows recovery of the plant cover and ant diversity of the affected site after approximately 25 years. This recovery is possible only if the size of the intervention is reduced and if erosion by rain is not important. Savannas seem to be more fragile than forest sites in that recovery after human intervention is more unlikely. This new time constant for forest recovery could serve to estimate human carrying capacity of forest sites for eventual sustainable use of these ecosystems in the neotropics.

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REFERENCES

- Andersen A N (1991) : Response of ground-foraging ant communities to three experimental fire regimes in a savanna forest of tropical Australia. *Biotropica* **23** : 575-585.
- Andersen J W, McCormick J (1962) : An evaluation of devices for estimation of tree cover. *Broteria Serie Trimestral de Ciencias Naturales* **31** : 15-30.
- Caldas A, Moutinho P R S (1993) : Composição e diversidade da fauna de formigas (Hymenoptera, Formicidae) em áreas sob remoção experimental de árvores na reserva florestal de Linhares, ES, Brasil. *Rev Brasil Entomol*, **37** : 299-304
- Denevan W, Padoch C (1990) : *Agroforesteria Tradicional en la Amazonia Peruana*. N.Y. Bot. Garden and Centro de Investigacion y Promocion Amazonica, Lima`.
- Engelhardt W, Fittkau E J (1984) : Tropische Regenwälder - eine globale Herausforderung. *Spixiana*, Supplement 10 : 159-160
- Feinsinger P, Spears E E, Poole W (1981) : A simple measure of evenness. *Oikos*, **56** : 319 -323.
- Folster H (1994) : Stability of forest ecosystems in the humid tropics. *Interciencia*, **19** : 291-296
- Gadagkar R, Nair P, Chandrashekara K, Bhat D M (1993) : Ant species richness and diversity in some selected localities in Western Ghats. India. *Hexapoda*, **5** : 79-94.
- Gonzalez V (1987) : *Los morichales de los llanos orientales*. Ediciones Corpoven, Caracas.
- Greenslade P J M, Greenslade P (1977) : Some effects of vegetation cover and abundance on a tropical ant fauna. *Insectes Sociaux*, **24** : 163-182
- Grime J P (1977) : Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *American Naturalist*, **111** : 1169-1194.
- Huber O (1986) : La vegetacion de la cuenca del río Caroní. *Interciencia*, **11** : 301-310.
- IUCN, PNUMA, WWF (1991) : *Caring for the Earth: a strategy for sustainable Living*. IUCN, Gland, Switzerland.
- Jaffe K, Sanchez P (eds.) (1992) : *Tecnologías alternativas para el uso y conservacion de bosques tropicales*. Universidad Simón Bolívar, Caracas.
- Mackay W P, Rebeles A, Arredondo H C, Rodriguez A D, Gonzales D A, Vinson S B (1991) : Impact

- of the slashing and burning of a tropical rain forest on the native ant fauna (Hymenoptera: Formicidae).
Sociobiology, **18** : 257-268.
- Majer J D (1977) : Preliminary survey of the epigaeic invertebrate fauna with particular reference to ants, in areas of different land use at Dwellingup, Western Australia. *Forest Ecology and Management*, **1** : 327-334.
- Majer J D (1978) : The importance of invertebrates in successful land reclamation with particular reference to bauxite mine rehabilitation. *Rehabilitation of mined lands in Western Australia workshop proceedings* (ed. J.E.D. Fox), pp. 47-61. Perth, Australia.
- Majer J D (1983) : Ants: bio-indicators of minesite rehabilitation, land use, and land conservation. *Environmental Management*, **7** : 375-383.
- Nilsson C, Grelsson G (1995) : The fragility of ecosystems: a review. *Journal of Applied Ecology*, **32** : 677-692.
- Oliver I, Beattie A J (1993) : A possible method for the rapid assessment of biodiversity. *Conserv. Biol.* **7** : 562-568.
- Romero H, Jaffe K (1989) : A comparison of methods for sampling ants (Hymenoptera: Formicidae) in savannas. *Biotropica*, **21** : 348-352.
- Tamayo F : (1961) : Las sabanas tropofilas. *GEA*, **1** : 30-44.
- Uhl C (1987) : Factors controlling succession following slash-and-burn agriculture in Amazonia. *Journal of Ecology* , **75** : 377-407.
- Uhl C, Jordan C F (1984) : Succession and nutrient dynamics following forest cutting and burning in Amazonia. *Ecology*, **65** : 1476-1490.
- Vareschi V (1980) : Vegetationsoekologie der Tropen. Ulmer Verlag. Stuttgart 293 pp.
- Verhaagh M (1991) : Clearing a tropical rain forest - effects on the ant fauna. *Proceedings of the International Interdisciplinary Symposium of Tropical Ecosystems* (eds. W. Erdelen, N. Ishwaran & P. Muller), pp 59-68. Margraf Scientific Books, Weikersheim, Germany.
- Weir J S (1978) : *The ant Iridomyrmex, as a biological indicator of pesticide contamination*. N.S.W. State Pollution Control Comm.
- WRI, IUCN, PNUMA (1992) : *Estrategia Global para la biodiversidad*. Gland, Switzerland

WWF (1991) : *La Conservación de los Bosques Tropicales*. Gland, Switzerland.

Table I: Spearman correlation coefficients (rs) of comparisons between diversity indices of the sites and the time of recovery (Controls were assigned a dummy value of 50 years).

Index	rs	N	p
San Ignacio de Yuruani			
Plant cover	.806	12	<.01
Plant richness	.522	23	<.01
Plant equitability	.581	13	<.05
Ant richness	-.085	23	ns
Ant equitability	-.146	23	ns
El Merey			
Plant cover	.739	10	<.05
Plant richness	-.044	27	ns
Plant equitability	.241	11	ns
Ant richness	.451	27	<.01
Ant equitability	.624	27	<.01
Canaima			
Plant cover	.903	16	<.01
Plant richness	.850	16	<.01
Plant equitability	-.230	16	ns
Ant richness	.193	24	ns
Ant equitability	.188	24	ns

Table II: The five most common ant species found on abandoned conucos and undisturbed control sites in the forests around San Ignacio de Yuruani.

Ant species	Years of recovery					Control site		
	8	13	23	30	45	1	2	3
<i>Camponotus</i> sp.6					5	3		
<i>Solenopsis</i> sp.12							5	
<i>Solenopsis</i> sp.13								1
<i>Odontomachus chelifer</i>	1	3	1	3	2	4	2	
<i>Solenopsis</i> sp.7	2	1	2			2	1	4
<i>Pheidole</i> sp.1	4		1		5	2	1	3
<i>Pachycondyla</i> sp.1	5	5			1	4	5	
<i>Ectatoma lugens</i>	5	1				1	5	2
<i>Pheidole</i> sp.16			4			5	2	
<i>Solenopsis</i> sp.1			5	2	2	4		
<i>Paratrechina</i> sp.2			4				4	
<i>Tapinoma</i> sp.1	4							
<i>Wasmannia</i> sp.1	3	5						
<i>Pachycondyla obscuricornis</i>	3	2	3					
<i>Pheidole</i> sp.2	5	4			4			
<i>Pheidole</i> sp.4				4	5			
<i>Pheidole</i> sp.3				1	1			
<i>Gnamptogenys</i> sp.1				5				
<i>Iridomyrmex</i> sp.1				2				
<i>Solenopsis</i> sp.5					3			

Table III: The five most common ant species found on abandoned conucos and undisturbed control sites in the Morichal at El Meray.

Ant species	Years of recovery				Control site					
	10	12	20	25	1	2	3	4	5	6
<i>Paratrechina</i> sp.1					1	1	1		5	
<i>Pheidole</i> sp.13					4	5		5		
<i>Pachycondyla</i> sp.2						2	3			
<i>Solenopsis</i> sp.2					3				4	4
<i>Trachymyrmex</i> sp.1					5					
<i>Acromyrmex</i> sp.1					5					
<i>Solenopsis</i> sp.11						4				
<i>Pheidole</i> sp.18						5				
<i>Camponotus</i> sp.7						5				
<i>Ectatoma</i> sp.3	4	4								3
<i>Pheidole</i> sp.8	1				2	3		4		
<i>Odontomachus bauri</i>	4	3	5	5		4	4	3	4	5
<i>Solenopsis</i> sp.1	3				3	2	5	2	3	2
<i>Pheidole</i> sp.7				1	2	5	5	1	1	4
<i>Pheidole</i> sp.2	2			5				4	4	1
<i>Camponotus</i> sp.1		3	1	1					2	2
<i>Camponotus</i> sp.2			2	2					4	3
<i>Solenopsis</i> sp.5				4						4
<i>Wasmannia</i> sp.2			3		4	2	2			
<i>Pheidole</i> sp.14	5									
<i>Pheidole</i> sp.15	5									
<i>Paratrechina</i> sp.4	1									
<i>Pheidole</i> sp.9	1									
<i>Brachymyrmex</i> sp.1		5								
<i>Pheidole</i> sp.19		1								
<i>Pheidole</i> sp.10		2								
<i>Crematogaster</i> sp.1		2								
<i>Conomyrma</i> sp.2		3								
<i>Solenopsis</i> sp.4		3								
<i>Solenopsis</i> sp.3		3								
<i>Solenopsis</i> sp.6			4	3						
<i>Pseudomyrmex termitarius</i>			3							
<i>Paratrechina</i> sp.2			3							
<i>Pheidole</i> sp.12			4							

Table IV: The five most common ant species found on abandoned roadways and undisturbed control sites in the savanna around Canaima.

Ant species	Years of recovery					Control site		
	5	7	8	13	20	1	2	3
<i>Pheidole</i> sp.2							4	4
<i>Pheidole</i> sp.17							5	
<i>Camponotus</i> sp.4						5		
<i>Solenopsis</i> sp.8						4		
<i>Creomyrgaster</i> sp.1	2	3	5			2	4	5
<i>Leptothorax</i> sp.3	3	2	1	5	2	1	2	2
<i>Pheidole</i> sp.5	4	1	2		1		2	4
<i>Paratrechina</i> sp.5		1		1	4	3	3	
<i>Pseudomyrmex termitarius</i>		4			3	3	1	
<i>Pheidole</i> sp.6				5	4			
<i>Conomyrma</i> sp.1	1		1					1
<i>Ectatoma</i> sp.2	2		1					3
<i>Solenopsis</i> sp.9	2		3					5
<i>Atta laevigata</i>	5							
<i>Ectatoma</i> sp.1		3						
<i>Conomyrma</i> sp.3		5						
<i>Solenopsis</i> sp.6		4		3				
<i>Leptothorax</i> sp.1				2				
<i>Leptothorax</i> sp.2				4				
<i>Oxyopocus</i> sp.1				5				
<i>Ponera</i> sp.1				5				
<i>Camponotus</i> sp.5				5				
<i>Camponotus</i> sp.1			4	5	4			
<i>Camponotus</i> sp.3				5	3			
<i>Crematogaster</i> sp.2					2			
<i>Conomyrma</i> sp.3					4			

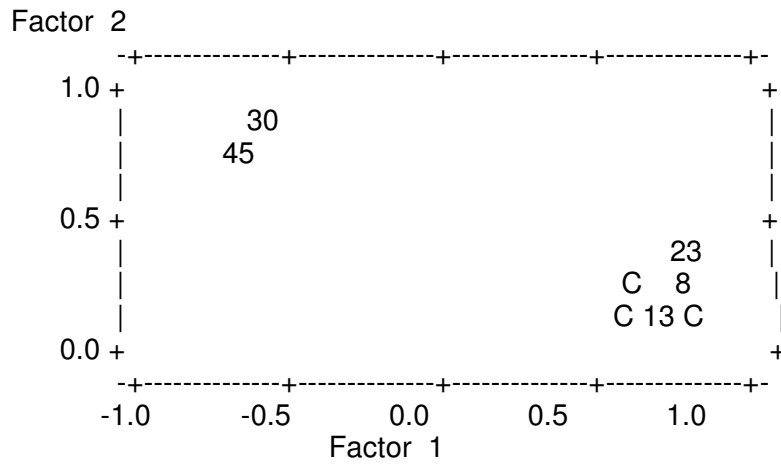
Table V:

Speed of recovery of different ecosystems as given by: Regression coefficient (r), t-statistics (t) and probability (p) for the linear regression calculated with the values of each index vs. the time of recovery. The time value of the intercept between a linear regression of an index and the mean value of that index as calculated from nearby undisturbed sites (controls).

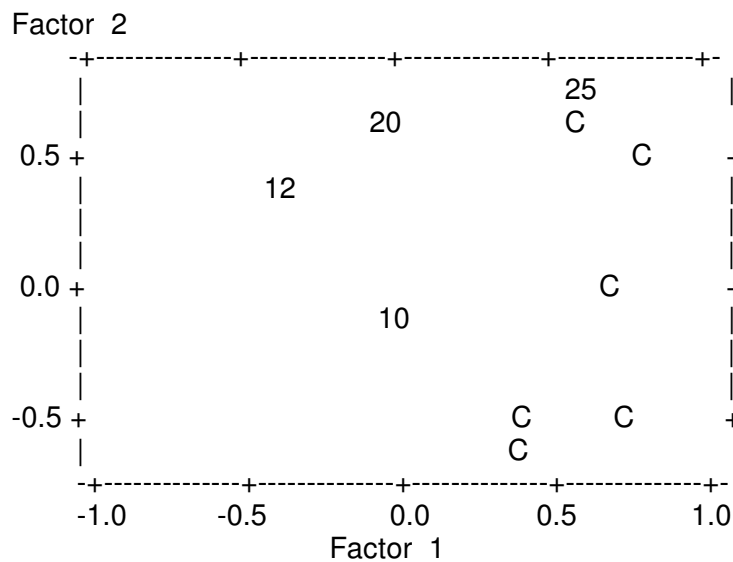
Index	r	t	p	Intercept (years)	Controls (mean)
San Ignacio de Yuruany					
Plant cover	0.800	3.77	.005	31.1	328.0
Plant richness	0.833	4.25	.003	26.0	35.5
Plant equitability	0.531	1.77	.115	ns	0.600
Ant richness	0.012	0.05	.958	ns	43.8
Ant equitability	0.218	-1.02	.318	ns	0.704
Mean				28.6	
El Merey					
Plant cover	0.676	2.25	.066	31.8	256.0
Plant richness	0.042	0.19	.847	ns	19.3
Plant equitability	0.238	0.73	.482	ns	0.569
Ant richness	0.586	2.29	.045	19.8	31.0
Ant equitability	0.870	5.57	.000	22.8	0.726
Mean				24.8	
Canaima					
Plant cover	0.591	2.07	.072	16.9	88.3
Plant richness	0.807	3.87	.005	26.7	11.0
Plant equitability	0.262	1.02	.326	ns	0.669
Ant richness	0.077	0.36	.721	ns	19.6
Ant equitability	0.200	0.96	.349	ns	0.729
Mean				26.8	

Figure 1: Principal component (factor) plot for dominant ant species composition at the different habitats studied. C indicate controls and numbers indicate sites with that age of recovery.

A. Factor loading for San Ignacio: 67.5 % of total variance explained by Factors 1 and 2



B. Factor loading for El Meray: 54.1 % of total variance explained by Factor 1 and 2



C. Factor loading for Canaima: 69.4 % of total variance explained by Factors 1 and 2



