Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA
Vinculada ao Ministério da Agricultura
Centro de Pesquisa Agropecuária do Trópico Úmido - CPATU
Belém, PA

1º Simpósio do Trópico Úmido

1st Symposium on the Humid Tropics

1er Simpósio del Trópico Húmedo

ANAIS
PROCEEDINGS
ANALES

Volume VI

Temas Multidisciplin

Multidisciplinary Themes

Temas Multidisciplinarias

ento de Difusão de Tecnologia
Brasília, DF
1986

ISSN 0101–2835

Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA
Vinculada ao Ministério da Agricultura
Centro de Pesquisa Agropecuária do Trópico Úmido - CPATU
Belém, PA

1º Simpósio do Trópico Úmido

1st Symposium on the Humid Tropics

1er Simpósio del Trópico Húmedo

ANAIS
PROCEEDINGS
ANALES

Belém, PA, 12 a 17 de novembro de 1984

Volume VI

Temas Multidisciplinares

Multidisciplinary Themes

Temas Multidisciplinarias

Departamento de Difusão de Tecnologia
Brasília, DF
1986

EMBRAPA-CPATU. Documentos, 36

Exemplares desta publicação podem ser solicitados à
EMBRAPA-CPATU
Trav. Dr. Enéas Pinheiro s/n
Telefone: 226-6622
Telex (091) 1210
Caixa Postal 48
66000 Belém, PA - Brasil

Tiragem: 1.000 exemplares

Observação

Os trabalhos publicados nestes anais não foram revisados pelo Comitê de Publicações do CPATU, como normalmente se procede para as publicações regulares. Assim sendo, todos os conceitos e opiniões emitidos são de inteira responsabilidade dos autores.

Simpósio do Trópico Úmido, 1., Belém, 1984.
Anais. Belém, EMBRAPA-CPATU, 1986.
6v. (EMBRAPA-CPATU. Documentos, 36)

1. Agricultura - Congresso - Trópico. I. Empresa Brasileira de Pesquisa Agropecuária. Centro de Pesquisa Agropecuária do Trópico Úmido, Belém, PA. II. Título. III. Série.

CDD 630.601

FOREST DEVELOPMENT FOLLOWING PASTURE USE IN THE NORTH OF PARÁ, BRAZIL

Robert Buschbacher[1], Christopher Uhl[2] and Emanuel Adilson Souza Serrão[3]

ABSTRACT - Over the past 20 years, large areas of the Amazon Basin have been converted to pasture. Normally, after four to eight years of use, Amazon pastures are abandoned because of problems with weed competition, insect attack, and nutrient availability (particulary phosphorus). At present the amount of abandoned pasture land probably exceeds the amount of land in active use and there is much debate about the residual productive capacity of these abandoned lands. We sought to determine the rate at which these abandoned Amazon pasture lands return to rainforest through a study of vegetation biomass, structure, and composition on 17 abandoned pastures in the environs of Paragominas, Pará. This report provides a comparison of forest regrowth on three of those sites. The sites chosen for comparison were all abandoned eight years before but differed markedly in land use history: one had poor grass establishment from the beginning and was only used lightly; the second was periodically burned and weeded before abandonment; the third was repeatedly burned and weeded and then bulldozed before being eventually abandoned. These different land-use historics had drastic effects on biomass accumulation and species diversity. Total biomass accumulation after eight years was 81 t/ha in the low-use site, 42 t/ha in the medium-use site, and 7 t/ha in the intensive use site. Accordingly, the Shannon-Weiner species diversity index (H') also declined with increasing use-intensity from 0.94 (low-use) to 0.33 (high-use). The overall conclusion to be drawn from this study is that rainforest clearing for pasture development does not necessarily preclude the possibility of rapid rainforest regeneration after abandonment, but that the rate of recovery will be inversely proportional to the intensity of pasture use.

Index terms: Amazon, rainforest, degraded pastures, rate of regeneration.

DESENVOLVIMENTO FLORESTAL APÓS FORMAÇÃO E UTILIZAÇÃO DE PASTAGEM NO NORTE DO PARÁ, BRASIL

RESUMO - Nos últimos 20 anos, grandes áreas de floresta da Bacia Amazônica têm sido convertidas em pastagens. Normalmente, após quatro a oito anos de utilização, muitas pastagens são abandonadas devido a problemas de plantas invasoras, ataque de insetos e disponibilidade de nutrientes (principalmente fósforo). Atualmente, a quantidade de áreas de pastagens abandonadas provavelmente excede a quantidade de terra em uso ativo e existe muita controvérsia quanto a capacidade produtiva residual destas áreas abandonadas. Procurou-se determinar a taxa com a qual essas áreas retornam a floresta através de um estudo de biomassa da vegetação, estrutura e composição èm 17 áreas de pastos abandonados na região de Paragominas, Estado do Pará. O trabalho apresenta uma comparação entre três dessas áreas. As três áreas eram todas pastagens abandonadas a oito anos atrás mas diferiam bastante em seu histórico de utilização: uma teve um fraco estabelecimento da gramínea; e só foi pouco utilizada antes de ser abandonada (pouco uso); a segunda foi queimada e submetida a limpezas de invasoras periodicamente (médio uso); a terceira foi queimada e submetida a limpezas de invasoras repetidas vezes e mecanicamente preparada antes de ser eventualmente abandonada (uso intensivo). Estes diferentes tipos de uso resultaram em drásticos efeitos no acúmulo de biomassa e diversidade de espécies. O acúmulo de biomassa total depois de oito anos foi

[1] Ecologist, , Ph.D., University of Georgia. Institute of Ecology. Athens, Georgia, 30602, USA.

[2] Ecologist, Ph.D., Pennsylvania State University. Department of Biology. University Park, PA 16802, USA.

[3] Eng. - Agr., Ph.D., EMBRAPA-CPATU. Caixa Postal 48. CEP 66000 Belém, PA.

de 81 t/ha na área de pouco uso, 42 t/ha na área de médio uso e 7 t/ha na área de uso intensivo. Da mesma forma, o índice de diversidade de espécies de Shannon-Weiner (H') também diminuiu com o aumento da intensidade de uso de 0,94 (pouco uso) a 0,33 (uso intensivo). Como conclusão deste estudo, pode-se dizer que a derrubada da floresta para o desenvolvimento de pastagem não elimina a possibilidade de uma rápida regeneração da floresta após o abandono. Entretanto, a taxa de recuperação será inversamente proporcional à intensidade de uso da pastagem.

Termos para indexação: Amazônia, floresta tropical úmida, pastagens degradadas, taxa de regeneração.

INTRODUCTION

Until recently the massive watershed of the Amazon river – covering some 7.6 million square kilometers – was little affected by man. However, within the last century and particularly within the last twenty years, large areas of the Amazon Basin have been cleared by man as part of development activities. Much forest land is being directly converted to pasture. Toledo & Serrão (1981) estimated that about 6 million hectares of Amazonian land are in pasture. Since then, the amount has, no doubt, increased even more. Planners had hoped that Amazon pastures would have sustained yield, but, generally, these cleared lands have only been productive for 4-8 years before they have had to be abandoned. Hence, there are now millions of acres of abandoned pasture in Amazonia, and it is not known how much time will be required for these abandoned lands to regenerate to forest. Some scientists believe that hundreds of years will be required for recovery, while others believe that regeneration to forest will be rapid.

The goal of our study was to determine the rate of secondary succession and the floristic characteristics of colonizing vegetation on abandoned pastures. We centered our study in the municipality of Paragominas in the North of Pará because this is the principle ranching center in the eastern Amazon.

The native vegetation at Paragominas is lowland evergreen rainforest; annual rainfall is generally between 1800-2500 mm; soils are latosols (high clay content on hills and slopes; sandier in texture in valleys).

DEFINITION OF THE PROBLEM

Pasture formation and maintenance practices vary widely in the region Paragominas, Pará. Because pasture-use history could greatly influence natural succession following abandonment, we felt it was critical to carefully define the types of pasture management common to the region. We found that most abandoned pastures were managed in one of the following three ways prior to abandonement:

1. **Low use**: Following forest cutting and burning, the area is seeded to pasture grasses but these do not establish well[4]. The area is never weeded or burned. Grazing is very light. Abandonment occurs within four years of pasture formation. Approximately 10-15% of the abandoned pastures in the Paragominas region fit this description.

2. **Medium-use**: Following forest cutting and burning, the area is seeded to pasture grasses which establish well. The area is cut (weeded) by hand and burned every one to two years. Grazing pressure is intermediate (± 1 animal/ha). Abandonment occurs 6-8 years after pasture formation. Some 60% of the abandoned pastures in the region fit this description.

3. **High use**: Following forest cutting and burning, the area is seeded to pasture grasses which establish well. After several cutting and burning treatments to control weeds, the areas are mechanically cleared. This entails removing all residual woody biomass (in the form of logs and standing trunks) from the site. Subsequently, sites are mechanically mowed and burned each year. Grazing pressure is heavy (> 2 animals/ha). Abandonment occurs after

[4] Poor grass establishment predestines these areas to early abandonment. Grass may not establish well because of low-viability of seeds, dry conditions or competitive exclusion by native plants.

10 or more years of use. Sites subjected to such heavy use are relatively rare, representing, perhaps, only 5% of abandoned pastures in the region.

Based on interviews with ranch owners and managers, we located 17 abandoned pasture sites with well documented management histories. These ranged from sites which had been poorly established, lightly grazed, and never weeded, at the low-intensity end of the disturbance gradient, to sites which had been heavily grazed, burned and weeded several times, and later bulldozed to remove woody residue, at the severe end of the disturbance-intensity gradient.

Each of these 17 sites representes a unique combination of the factors which determine the "intensity" of pasture use, and multivariate regression analysis will enable us to determine which of the factors has the greatest effect on the rate of post-abandonment forest regeneration. However, for this preliminary analysis we chose to focus on 3 sites which we feel are representative of low, moderate, and high intensity pasture use.

As shown in Table 1, all 3 sites were last burned or weeded 8 years previously, and this was chosen as the point at which forest regeneration is said to begin. Although grazing by cattle did occur for some time after this point, we feel that this has a much less severe effect in terms of setting back succession than either burning or weeding.

The low use-intensity site was seeded by airplane after the initial rainforest cut-and-burn, but due to poor seed germination, there was poor establishment by the grass, and after 4 years of light grazing, the site was abandoned without weeding or reburning. We found many abandoned pasture sites in the region with this general history of poor establishment and very light use.

The medium use-intensity site was used for about 7 years after pasture establishment and during that time was heavily grazed, with approximately bi-annual weeding and burning. This pattern of use is by far the most common in the region, being typical for "well-established and well-managed" sites.

The high-intensity use site was also a well-established pasture, used for 8 years with bi-annual weeding and burning. However, after 8 years this site was cleared of all vegetation and woody residue by a tracked tractor and replanted with *Panicum maximum*. It was then used for 3 more years prior to abandonment. This site was atypical of the abandoned pasture sites we observed, both in the intensity of its use and in the poor development of secondary vegetation. However, we chose to include it as indicative of the extreme case in the

TABLE 1. Management history of three abandoned pasture sites considered to have low, moderate, and high intensity of use.

Management history	Low-use intensity	Moderate-use intensity	High-use intensity
Age since final burning or weeding (yrs)	8	8	8
Number of years of active use (i.e., number of years between formation and final burning or weeding)	0	7	11
Grass cover after initial seeding	Poor	Good	Good
Number of times weeded	0	4	6
Number of times reburned since grass established	0	2	2
Grazing intensity†	Low-moderate	Moderate-high	High
Use of bulldozer	No	No	Yes††

† Less than 1 adult animal per hectare is considered low; 1-2 animals per hectare is considered moderate and more than 2 animals per hectare is considered high.

†† All vegetation and woody residue were cleared by a tracked bulldozer, 8 years after pasture formation.

gradient of pasture use intensity, both to illustrate the potential for ecosystem degradation that can occur with extreme perturbation, and because the treatment of woody residue removal by bulldozing is becoming increasingly common in the region.

METHODS

Site history was determined by interviewing both ranch managers and owners. In most cases we were able to question two individuals who were familiar with the entire time period of site use.

All sites selected for study were located on the heavy yellow-red latosols typical of the hill-sides and hill-tops of the region.

Vegetation of each site was sampled in 8 to 10 plots located at 50 to 100 meter intervals along a transect with a random starting point. Each plot consisted of a set of nested quadrats, 10 x 10 meters, 3 x 3 meters, and 1 x 1 meter.

All trees > 2 meters tall in the 10 x 10 meter plot were identified, height and diameter were measured, and the extent of vine infestation was noted (i.e., whether vines were present on the tree, and if so, whether the tree was leaning over as a result). For each tree, biomass was calculated from height and diameter, using a series of regression equations that were developed by harvesting a total of 85 trees in the region. Separate regression equations were developed for the 5 most common species, and a sixth equation was used for all other species (a full list of the regression equations will be included in a later publication).

All tree saplings 25-200 cm tall, and all tree seedlings 5-25 cm tall were counted in 3 x 3 meter and 1 x 1 meter plots, respectively, and total weights were determined by harvesting. All vines greater than 2 meters long, and all herbs or shrubs greater than 1 meter tall occurring within the 3 x 3 meter plot were counted, and the weight of each life form was measured by harvesting. The same procedure was followed for vines less than 2 meters long, herbs or shrubs under 1 meter tall, and all grasses in the 1 x 1 meter plot. Grasses were subdivided as either species native to the region or species that are introduced cultivars.

Fine root biomass was determined by harvesting all roots less than 2 mm in diameter from 8 cm diameter cores. For each site, 15 cores were taken from the top 15 cm of soil, 5 cores from 15 to 30 cm, and 3 cores from 30 to 50 cm. The average root mass from each depth was then summed to determine total fine root biomass. Coarse root biomass was determined by harvesting all roots greater than 2 mm in diameter in 50 x 50 cm pits located in the center of several of the 10 x 10 m survey plots. Five samples were taken from both 0-15 and 15-30 cm, plus 3 samples from 30-50 cm.

RESULTS

Total biomass accumulation 8 years after abandonment was 81,000 kg/ha for the lightly disturbed site, 42,000 kg/ha for the moderately disturbed site, and 5,700 kg/ha for the intensively disturbed site (Table 2).

Compared to the low use-intensity site, the moderate use-intensity site has a greater percent of biomass in the vine, shrub, and grass life forms, and a greater proportion of biomass below-ground (Fig. 1). Almost all the above-ground biomass in the high use-intensity site is in the form of herbs and shrubs, with some native grasses. This site also has the highest proportion of total biomass in fine roots.

The large difference in tree biomass between the low and moderate use-intensity sites is not due to the number of trees, but rather to the average tree size (Table 3). An analysis of the size distribution shows that the smallest 50% of the trees on each site do not differ markedly in stature (i.e., the median height and diameter for the 2 sites are similar), but the trees from the larger end of the size spectrum are much larger in the low use-intensity compared to the moderate use-intensity site. The largest tree on the low use-intensity site is 4.3 meters taller, and

TABLE 2. Above and below-ground biomass, by life form, 8 years after abandonment of 3 pasture sites having low, moderate, and high use intensity (kg . ha^{-1}, with number of observations & standard error in parentheses).

Biomass	Low use-intensity	Moderate use-intensity	High use-intensity
Trees: > 2 m tall	72,987 (8; 6,241)	25,092 (10; 6,222)	< 100
25 - 200 cm	83 (8; 19.8)	175 (10; 65)	30 (10; 15.8)
5 - 25 cm	0	14 (10; 7.7)	0
Vines: > 2 m	1,678 (8; 416)	5,742 (10; 1,801)	143 (10; 52)
< 2 m	8 (8; 6.4)	121 (10; 86)	186 (10; 128)
Herbs and shrubs: > 1 m	51 (8; 51)	1,366 (10; 1,229)	261 (10; 57)
< 1 m	0	50 (10; 25)	3,238 (10; 653)
Grass: cultivated species	0	412 (10; 333)	1 (10; 1)
native species	0	119 (10; 85)	527 (10; 172)
Total above-ground biomass	74,807	33,091	4,486
Roots: < 2 mm diameter	1,080	2,010	883
> 2 mm diameter	5,203	6,932	309
Total below-ground biomass	6,283	8,942	1,192
Total live biomass	81,090	42,033	5,678

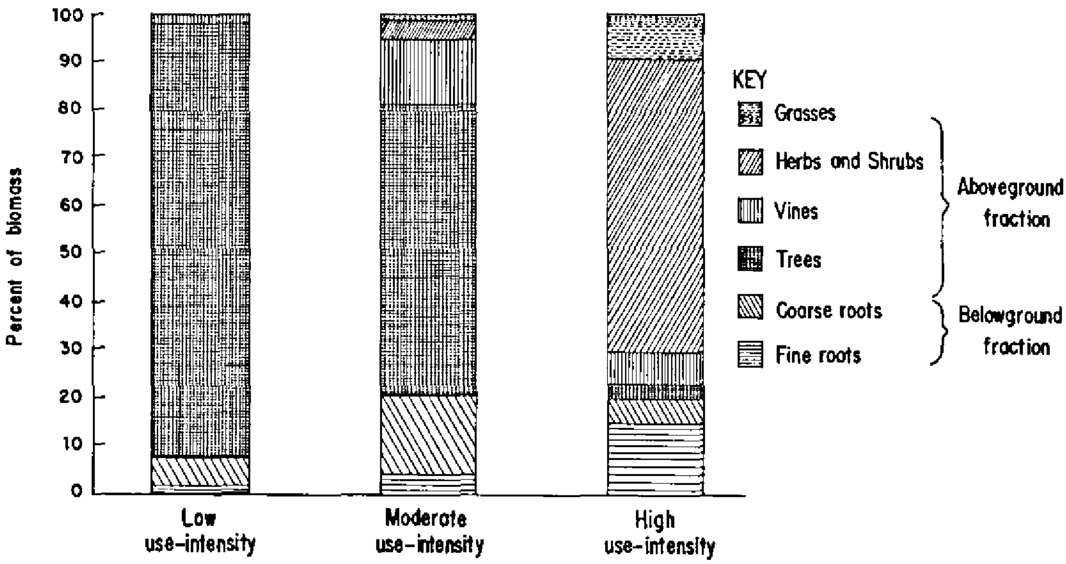

FIG. 1. The relative distribution of biomass above and below ground, with above-ground biomass subdivided by life form, 8 years after abandonment of pastures, having low, moderate, and high use-intensity.

6.6 centimeters thicker, than the largest tree on the moderate use-intensity site (Table 3).

The three successional sites differ dramatically in the relative importance of the different short-lived species which have colonized them (Table 4). The single most important genus in the low use-intensity site is *Cecropia*. By contrast, the moderate use-intensity site is dominated by *Vismia guaianensis* and *Banara guaianensis*, and almost all of the plants on the high use-intensity site are *Solanum grandiflora*.

The difference in the degree of dominance by these short-lived successional species is reflected in the diversity indices for each community. Species diversity, using either the Simpson or Shannon-Weiner index, is negatively correlated with the intensity with which the site was used as a pasture (Table 5). Because short-lived species are more dominant in terms of numbers than in terms of basal area or biomass, the diversity

TABLE 3. Number and size distribution of trees greater than 2 meters tall 7 years after abandonment of pastures with low, moderate and high use intensity (height in meters and diameter in centimeters).

Variable	Low use-intensity	Moderate use-intensity	High use-intensity
Number of trees > 2 m tall (per hectare)	7,050	6,920	60
Lower quartile* diameter and height	1.8/3.8	1.6/3.4	3.0/3.0
Median diameter and height	2.9/5.9	2.4/4.5	3.2/3.2
Upper quartile** diameter and height	5.6/8.9	3.7/5.8	3.6/4.6
Maximum diameter and height	19.4/17	12.8/12.7	6.0/4.3

* 25% of trees are smaller and 75% are larger.
** 25% of trees are larger and 75% are smaller.

TABLE 4. Relative density and importance value of the most common short lived successional tree species, 8 years after abandonment of pastures with low, moderate, and high use-intensity.

Species	Low use-intensity			Moderate use-intensity			High use-intensity		
	Relative Density*	Importance Value 1**	Importance Value 2+	Relative Density	Importance Value 1	Importance Value 2	Relative Density	Importance Value 1	Importance Value 2
Vismia guianensis	0.2	0.2	0.2	42.9	28.8	25.1	0	0	0
Banara guianensis	0	0	0	14.6	10.2	10.8	0	0	0
Cecropia spp.	18.0	22.3	16.8	2.3	5.0	3.2	16.7	19.6	-
Solanum grandiflora	0	0	0	0.1	0.3	0.3	83.3	80.4	-
other short-lived species	2.0	1.5	2.0	1.9	2.1	2.2	0	0	0
Total	20.2	24.0	19.0	61.8	46.4	41.6	100	100	

* Number of individuals in that species, divided by total number of trees, and converted to a scale of 100%
** Importance Value 1 is based on frequency, density, and basal area, converted to a scale of 100%
\+ Importance Value 2 is based on frequency, density, and biomass, converted to a scale of 100%

TABLE 5. Diversity indices for trees > 2 m tall 8 years after abandonment of pastures with low, moderate, and high use intensity.

Indices	Low use-intensity	Moderate use-intensity	High use-intensity
Simpson's Diversity Index - D_s	.94	.79	.33
Shannon-Weiner Diversity Index - H'			
- based on numbers	1.51	1.11	.20
- based on numbers, frequency & basal area	1.51	1.38	.21
- based on numbers, frequency & biomass	1.54	1.41	-

index for the moderate use-intensity site increases if these factors are taken into account when calculating the importance of each species (Table 5).

The number of tree saplings (25-200 cm tall) was highest in the low use-intensity site, intermediate in the moderate use-intensity site, and very low in the high use-intensity site (Table 6). The proportion of these saplings that are short-lived successional species is 3%, 20%, and 75%, respectively.

There was a high degree of vine infestation in all three sites. Larger woody climbers predominated in the tree communities; herbaceous scandent forms were most common in the open high use site. Larger vines (> 2 m long) were somewhat more numerous in the moderate use-intensity site as compared to the low use-intensity site (Table 7). While the number of trees affected was about the same in the 2 sites, more

TABLE 6. Number of juvenile trees per hectare and the relative proportion of short-lived successional species 8 years after abandonment of pastures with low, moderate, and high use intensity (number of observations and standard error in parentheses).

	Low use-intensity	Moderate use-intensity	High use
Trees 25 - 200 cm	9,861 (8; 2684)	5,667 (10; 1448)	444 (10; 246)
% of trees 25 - 200 cm that are short-lived successional species	3%	20%	75%

TABLE 7. Relative importance of vines 8 years after abandonment of pastures with low, medium, and high use intensity. (Values in parentheses are number of observations and standard error).

Presence of vines	Low use-intensity	Moderate use-intensity	High use-intensity
Percent of tree stems > 2 m tall affected by vines			
- no vines	43% (8; 4.3)	45% (6; 6.8)	75% (3; 25)
- vines present, tree straight	46% (8; 4.0)	28% (6; 3.9)	17% (3; 17)
- vines present, tree bent over	12% (8; 2.6)	27% (6; 6.2)	8% (3; 8)
Number of vines present per hectare			
- vines ≥ 2 m long	6,806 (8; 1712)	10,222 (10; 1813)	3,889 (10; 997)
- vines < 2 m long	2.500 (8; 1637)	33,000 (10; 9444)	40,000 (10; 19777)

trees in the moderate use-intensity sites were severely affected (i.e., they were leaning over because of the vines).

DISCUSSION AND CONCLUSIONS

The large difference in biomass among the sites is a good indication of the rate of forest regeneration after pasture abandonment. The low use-intensity site, which was merely cut, burned, and lightly grazed, can be taken as indicative of the baseline potential for regeneration following a clearing of this spatial magnitude. The fact that total biomass is reduced by 50% when recovery of the moderate use-intensity site is compared to this low use baseline, indicates that repeated burning and weeding significantly reduce the rate of post-abandonment biomass accumulation.

Comparison of these sites with the high use-intensity site, which was bulldozed, shows a dramatic additional reduction in biomass. Of added significance is the fact that on this high use site, over 75% of the above-ground biomass is composed of herbs and shrubs with very few trees. This community lacks much potential for further biomass aggregation in the short term, since most of the plants have already reached their maximum size. In the long term, stress tolerant trees may gradually colonize and form a forest again, but 100's of years will be required for this to occur.

The species composition of the trees colonizing the low and moderate use-intensity sites is indicative of the relative site quality. *Vismia guianensis*, the strongly dominant species on the moderately disturbed site, is adapted to inhabit nutrient imporverished soils on sites that are intolerable to most species. In contrast, the low disturbance intensity site was less dominated by any one species, and had a higher proportion of mature-forest species present. The most important genus on this site, *Cecropia*, is adapted to rapid colonization of lightly disturbed sites such as tree fall gaps and slash and burn agricultural clearings, and we take it as an indicator of relatively favorable site conditions (Uhl & Jordan 1984).

The overall conclusion to be drawn from this study is that rainforest clearing for pasture development does not necessarily preclude the possibility of rapid rainforest regeneration after abandonment, but that the rate of recovery will be inversely proportional to the intensity of pasture use. In the most severe case we observed, following the use of bulldozers to remove all above-ground organic material from the site, tree colonization after 8 years was virtually nil.

REFERENCES

TOLEDO, A.T. & SERRÃO, E.A.S. Pasture and animal production in Amazonia. In: HECHT, S.B. & NONES, G.A. eds. **Land use and agricultural research in the Amazon Basin.** Cali, Colombia, CIAT, 1981.

UHL, C. & JORDAN, C.F. Succession and nutrient dynamics following forest cutting and burning in Amazonia. **Ecology**, 65:1476-90, 1984.