PLANT COMMUNITY DIVERSITY RELATIVE TO HUMAN LAND USES IN AN AMAZON FOREST COLONY*

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ABSTRACT

Numbers of plant species and individuals were examined relative to land use in an agricultural settlement in the Brasilian Amazon. Land uses were forest, cropped after forest, fallows, cropped after fallow, and pasture. These uses corresponded roughly to farmers' land use changes over time. As expected, species diversity was high in forest. Diversity was also high, however, in fallows of 3-5 years--as a result of both survival/reestablishment of forest species and appearance of plants not found in forest. Lands cropped using slash-and-burn maintained moderate numbers of species--both forest and non-forest. Not considering pastures, lands cropped for a third year after forest and the first year after fallows had the highest plant density, reflecting weed invasions. Useful (e.g., for construction, food, and medicines) forest plants decreased with land conversion; although new species also appeared. The least number of useful plants and the greatest losses of the forest species were encountered in pastures. Conversion to pasture rather than slash-and-burn agriculture *per se* was the main contributor to biodiversity loss.

INTRODUCTION

More than 10% of the 4 million km^2 of Brasil's Amazon tropical forest was cleared by 1991, with 70% of the clearing by medium or large ranchers and 30% by small farmers (Fearnside 1993). These human uses of forest resources lead to changes in plant community composition, decreases in biodiversity, and changes in forest structure and function (Bormann and Likens 1979, Nepstad *et al* 1992, Nepstad *et al* 1991, Uhl *et al* 1988). Even less extensive forest uses such as extractive reserves result in substantial changes (Browder 1992).

To describe such losses in biodiversity and changes in plant communities, we took plant samples from plots representing different land uses in a government-organized colony, Pedro Peixoto, in the Brasilian Amazonian state of Acre. Plant communities were sampled in forest, cropped fields at different time periods after forest clearing and burning, fallows of different lengths, cropped fields after fallow, and pastures. These land uses approximated the series of consecutive human land uses after forest clearing in the colony; such that the plant communities described also represent an approximate progression over time.

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RESULTS

Mean number of plant species and individuals by land use transects. The mean numbers of species found per different land use transects (not including pastures) showed the expected highest diversity in forest (78 species) followed by fallows (62-69), and cropped fields after both forest and fallow (43-55). Mean numbers of individuals counted in the transects was lowest in the first cropping after forest (319) and highest in the third year of cropping after forest (990) and in the first year of cropping after fallow (883). Mean numbers of individials per transect were similar in forest (523) and fallow (547-642).

Total numbers of plant species by land use. In terms of total numbers (by aggregating transects), 507 plant species were distinguished: 46% (233 species) were encountered in forest; 28% were in areas cropped both after forest and after fallow clearing; 28-43% were found in the fallows; and 16% were located in pastures (Table 1). Comparing uses, the number of families (67 or 74% of the total number encountered) was highest in the forest. The most abundant families (and number of respective species) were: *Arecaceae* (13 species), *Caesalpiniaceae* (13), *Mimosaceae* (11), *Euphorbiaceae* (9), *Fabaceae* (9), *Rubiaceae* (8), and *Bignoniaceae* (8).

Divided by plant type relative to land use, numbers of tree species declined successively from a high of 142 (61% of forest species) in the forest with each cropping period, increased to near-forest levels in the fallows of 3-5 years (115 species), and declined to a low of 22 species in the pastures. Relative to forest (22 species), herbaceous plants increased over the cropping periods (to 48) and decreased over time in fallows (to 20), returning to forest levels; but then increased to remain high in the pastures (34 species). Numbers of shrubs were lowest in forest (7), but increased with successive cropping (15 species in the second year) and in early fallows (18). The diversity of palms--like trees--was highest in the forest (14) and lowest in pastures (1). The highest diversity of vines was found in medium-aged fallows (45), but remained high (27-38) in all other treatments except for pasture (11; Figure 1).

Total numbers of species by land use were similar in the forest (234) and in fallows of 3-5 years (219) and lowest in the pastures (80). Fallows of greater than five years: a) contained fewer species--and fewer tree species--than early or intermediate fallows, and b) were similar to the cropped periods after forest and after fallow in terms of numbers of species per plant type.

proportion dropping to 16% (23 species) by the third year. During the fallow, 35% of the forest trees were found in the 1-2 year fallows, a high of 46% (66 species) were found in the 3-5 year fallows; and 31% were in the fallows of more than 5 years. In cropped fields after fallow only 22-26% of the forest trees could be found. Finally, only 3-8% of the forest tree species were encountered in pasture lands.

Trees most sensitive to slash-and-burn agriculture included the families *Anacardiaceae, Burseraceae, Hippocrateaceae, Lauraceae, Meliaceae*, and *Sapotaceae*; as well as the palm *Arecaceae*. Five families, each represented by only one species, were also found **only** in forest: *Myristicaceae, Olacaceae, Opiliaceae, Quiinaceae*, and *Strychnaceae*. The species encountered belonging to these families were generally represented by few individuals.

A substantial number of forest trees put out new shoots and stems after felling and burning; but the numbers of species so surviving decreased with years of cropping: 40 species after initial forest clearing and burning, 33 species for fields cropped after forest for a second year, but only 7 species after a third year. Plant families present in the forest and more successful in surviving slash-and-burn agriculture were those having seeds dispersed largely by birds and bats (*Annonaceae, Euphorbiaceae, Lauraceae, Meliaceae*, and *Sapotaceae*) and those having wind-dispersed seed (*Apocynaceae, Bignoniaceae, Bombacaceae, Boraginaceae, Rubiaceae*, and *Vochysiaceae*).

"New" species also appeared in the land uses after forest conversion. In total for the non-forest land uses, 107 new tree species, 74 herbaceaous plants, 48 vines, 29 shrubs, 2 palms, one *Musa* sp, and 17 "other" plant species which did not appear in the forest samples were counted in the cropped lands, fallows, and pastures (Figure 3, the second paired bar for each land use). Considering only trees again, 42 species "appeared" in the lands cropped after forest; 82 were found in the fallows; 38 were encountered in the fields cropped after fallow; and 8 tree species not found in the forest were counted in the pastures (totals are more than the 107 "new" trees because of species found in more than one land use). Several trees found in cropped lands but not in forest were "forest" trees that had been missed in the sampling: 8 tree species were among those which survived initial forest felling and burning by sending up new branches and had clearly been among forest trees.

By land uses, "new" trees appeared most in fallows (82 species), but also in the cropped periods (38-42). Only 8 non-forest trees were found in the pastures. Both non-forest herbaceous plants (53) and shrubs (19) were of the species were identified as "undetermined" in terms of human uses, loss of species of potential utility may be quite high, especially as land is converted to pasture.

DISCUSSION

Colonists' land use in Pedro Peixoto followed an approximate sequence comprised of forest, cropping, fallow, cropping, and finally pasture. Many forest species were "lost" in the process. Cropping reduced the number of forest tree species by up to 84%, while pastures represented a 92% reduction in tree species. Palm trees, vines, and shrubs were similarly lost in the conversion from forest to other uses. Species lost were generally those represented in the forest by few individuals, those producing fleshy fruit with large seeds which are difficult to disperse, and/or species requiring more shade and higher soil moisture.

With cultivation and fallow, "new" species more adapted to disturbed, more open conditions emerged to replace some of the forest species such that 3-5 year fallows were nearly as diverse as forest in total numbers of species (although numbers of species again dropped as fallows aged and conditions again became more forest-like). Species diversity similarly increased until about seven years when total numbers tended to stabilize due to competitive elimination in a study of tropical forest succession after shifting cultivation in southwestern Nigeria [illegible] 1981).

[illegible]ioneer species and species most able to continue through the land use conversions were generally: a) [illegible] amounts of small seed capable of being dispersed by wind, birds, and bats; b) competitive in [illegible]ment; and c) fast growing, with a single main vertical trunk, with either simple [illegible] Such charac[illegible]istics mean that these would be the species most likely [illegible] and yearly burning were discontinued) depending on the [illegible]ing, seed stocks in the [illegible] from [illegible] of the species were identified as "undetermined" in terms of human uses, loss of species of potential utility may be quite high, especially as land is converted to pasture.

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The pioneer species and species most able to continue through the land use conversions were generally: a) those producing large amounts of small seed capable of being dispersed by wind, birds, and bats; b) competitive in more open, less shaded environments; and c) fast growing, with a single main vertical trunk, with either simple deciduous or large composite or lobed leaves. Such characteristics mean that these would be the species most likely to recolonize abandoned pastures (i.e., where grazing and yearly burning were discontinued) depending on the presence of nearby forests.

Other studies of succession have shown the importance of seed survival after burning, seed stocks in the soil, and of bat- and bird-dispersed seed. In the southern Venezuelan Amazon, grasses and forbs established from large seed banks to dominate fallows after cultivation or pasture, seneced by one year, and where followed by led to decreases in subsidized ranch formation, road building, and colonization projects. Deforestation rates in the Amazon dropped, although rates are still substantial (Fujisaka *et al* 1995). The decrease in absolute rates of deforestation, however, can only help to maintain plant diversity.

Agroforestry research has sought to enhance fallow regeneration in terms of more rapid biomass production (ICRAF 1994). A complementary goal would be to enhance fallow diversity; and indigenous forest management may hold useful clues as to how. The forest canopy of unmanaged fallows in the upper Ecuadorian Amazon were dominated by *Cecropia* spp and were much less diverse than fallows managed by the indigenous population (Irvine 1989); and a study from the eastern Amazon showed greater aggregate species diversity for indigenously managed forest succession in which different vegetational zones were exploited or managed (Balee and Gely 1989). The data from Pedro Peixoto show relative species richness in fallow recolonization--a process that should be sustainable as long as sufficient forest areas remain in the greater area.

Again, most species losses occurred when land was converted to pasture. Land in Pedro Peixoto was converted to pasture largely because of increased values assigned to such lands (Fujisaka *et al* 1995). Policies related to land tenure and credit would have to be changed to reduce this incentive. Unfortunately, a planned road to be built between Acre and the coast of Peru, giving Brazil access to the Pacific, will greatly increase land speculation and incentives to continue conversion to pasture.

Sanford, RL, J Saldarriaga, KE Clark, C Uhl, & R Herrera. 1985. Amazon rainforest fires. *Science* 227:53-55

Uhl, C, R Buschbacher, & EAS Serrao. 1988. Abandoned pastures in eastern Amazonia. I. Patterns of plant succession. *Journal of Ecology* 76:663-681

Uhl, C, H Clark, & K Clark. 1982. Successional patterns with slash-and-burn agriculture in the upper Rio Negro region of the Amazon Basin. *Biotropica* 14:4:249-254

Uhl, C, H Clark, & P Maquirino. 1982. Successional pattern associated with slash-and-burn agriculture in the upper Rio Negro region of the Amazon Basin. *Biotropica* 14:249-254

Uhl, C, K Clark, H Clark, and P Murphy. 1981. Early plant succession after cutting and burning in the upper Rio Negro region of the Amazon Basin. *Journal of Ecology* 69:631-649

Uhl, C and K Clark. 1983. Seed ecology of selected Amazon Basin successional species. *Botanical Gazette* 144:3:419-425

Table 3. Plants sampled which provide building materials (mostly commercial timber), Pedro Peixoto, 1995.

Genus species	Family	Local name
Astronium lecointei	Anadiaceae	*Aruera*
Spondias lutea	Anacardiaceae	*Caja*
Tapirira guianensis	Anacardiaceae	*Pau pombo*
Guatteria poeppigiana	Annonaceae	*Envira caju*
Aspidoperma sp	Apocynaceae	*Amarelin pereiro*
Aspidoperma vargasii	Apocynaceae	*Amarelao*
Didymopanax morototonii	Araliaceae	*Morototo*
Tababuia serratifolia	Bignoniaceae	*Pau d'arco amarelo*
Ceiba pentandra	Bombacaceae	*Samauma preta*
Chorisia speciosa	Bombacaceae	*Samauma barriguda*
Ochroma sp	Bombacaceae	*Algodoeiro bravo*
Cordia alliodoro	Boraginaceae	*Freijo*
Cordia guediana	Boraginaceae	*Freijo preto*
Protium apiculatum	Burseraceae	*Breau vermelho*
Protium divaricarum	Burseraceae	*Breau manga*
Apuleia molaris	Caesalpiniaceae	*Cumaru Cetim*
Cassia cf. lucens	Caesalpiniaceae	*Sao joao*
Copaifera sp	Caesalpiniaceae	*Guaribeiro*
Hymenaea courbaril	Caesalpiniaceae	*Jatoba*
Martiodendron elatum	Caesalpiniaceae	*Pororoca*
Sclerobium sp	Caesalpiniaceae	*Tachi vermelho*
Tachigalia myrmecophyla	Caesalpiniaceae	*Tachi preto*
Rheedia macrophylla	Clusiaceae	*Bacuri liso*
Terminalia sp	Combretaceae	*Imbirindiba amarela*
Alchorneopsis floribunda	Euphorbiaceae	*Farinha seca*
Alchorneopsis sp	Euphorbiaceae	*Pintadinho*
Dipterix odorata	Fabaceae	*Cumaru ferro*
Hymenolobium excelsum	Fabaceae	*Favela preta*
Myroxilum peruiferum	Fabaceae	*Balsamo*
Pterocarpus sp	Fabaceae	*Macucu sangue*
Vatairea sericea	Fabaceae	*Sucupira amarela*
Casearia cf. sylvestris	Flacourtiaceae	*Caferana*
Casearia risinifera	Flacourtiaceae	*Sernambi de indio*
Casearia sp	Flacourtiaceae	*Laranjinha*
Casearia sp	Flacourtiaceae	*Cabelo de cotia*
Mezilaurus itauba	Lauraceae	*Itauba*
Nectandra membranacea	Lauraceae	*Louro preto*
n.d.	Lauraceae	*Louro embauba*
Bertholletia excelsa	Lecythidaceae	*Castanheira*
Cedrela odorata	Meliaceae	*Cedro*
Guarea costulata	Meliaceae	*Jito preto*
Guarea purusana	Meliaceae	*Jito da tierra firme*
Guarea trichiliodes	Meliaceae	*Jito branco*

Table 4. Plants sampled which provide food, Pedro Peixoto, 1995

Genus species	Family	Local name
Spondias lutea	Anacardiaceae	*Caja*
Anona sp	Annonaceae	*Atinha*
Guatteria poeppigiana	Annonaceae	*Envira cajo*
Tabernaemontana heterophyllum	Apocynaceae	*Grao de galo*
Rauwolfia sp	Apocynaceae	*Marfim fedorento*
n.d.	Araceae	*n.d.*
Euterpe precatoria	Arecaceae	*Asahi / Azai*
Oenocarpus bacaba	Arecaceae	*Bacaba*
Phytelephas macrocarpa	Arecaceae	*Jarina*
Astrocarium murmuru	Arecaceae	*Murmuru*
Jessenia batava	Arecaceae	*Pataua*
Astrocaryum tucuma	Arecaceae	*Tucuma*
Scheelea martiana	Arecaceae	*Uricuri*
Arrabidea sp	Bignoniaceae	*Cipo cruz*
Protium apiculatum	Burseraceae	*Breu vermelho*
Hymenaea courbaril	Caesalpiniaceae	*Jatoba*
Cassia tora	Caesalpiniaceae	*Matapasto*
Jaracatia spinosa	Caricaceae	*Jaracatia*
Rheedia brasiliensis	Clusiaceae	*Bacuri de espino*
Rheedia macrophylla	Clusiaceae	*Bacuri liso*
Costus sp	Costaceae	*Orelha de danta*
Cucurbita sp	Cucurbitaceae	*Cipo melancinha*
Alchorneopsis floribunda	Euphorbiaceae	*Farinha seca*
n.d.	Fabaceae	*Feijao bravo*
Bertholletia excelsa	Lecythidacaea	*Castanheiro*
n.d.	Mimosaceae	*Angelca vermelha*
Inga cf. neisseriana	Mimosaceae	*Inga peluda*
Inga cf. thibaudina	Mimosaceae	*Inga vermelha*
Albizzia sp	Mimosaceae	*Timbauba*
Clarisia racemosa	Moraceae	*Guariuba amarelha*
Brosimum alicastrum	Moraceae	*Inhare*
Brosimum guianensis	Moraceae	*Inhare mole*
Sorocea sp	Moraceae	*Jaca brava*
Brosimum uleanum	Moraceae	*Manite*
Helicostylis sp	Moraceae	*Paima caucho*
Pseudolmedia laevis	Moraceae	*Paima preta*
Psidium araca	Myrtaceae	*Araza bravo*
Eugenia sp	Myrtaceae	*Arazazinho*
Eugenia sp	Myrtaceae	*Goibinha*
Neea sp	Nyctaginaceae	*Joao mole*
n.d.	n.d.	*Fruta jacu*

Table 5. Plants sampled which provide medicines, Pedro Peixoto, 1995

Genus species	Family	Local name
Adianthum sp	Adianthaceae	*Barba de paca*
Himathantus sucuuba	Apocynaceae	*Janaguba*
Geissospermum sp	Apocynaceae	*Quina quina branca*
n.d.	Araceae	*n.d.*
Euterpe precatoria	Arecaceae	*Asahi / Azai*
n.d.	Asteraceae	*Quebra panela*
Copaifera multijuga	Caesalpiniaceae	*Copaiba*
Cassia tora	Caesalpiniaceae	*Matapasto*
n.d.	Caesalpiniaceae	*Moroso branco*
Cecropia sp	Cecropiaceae	*Embauba branca*
Cecropia sp	Cecropiaceae	*Embauba de capoeira*
Vismia guianensis	Clusiaceae	*Lacre*
Costus guianensis	Costaceae	*Cana de macaco*
Cucurbita sp	Cucurbitaceae	*Cipo melancihna*
n.d.	Cucurbitaceae	*Melancihna*
Phyllanthus sp	Euphorbiaceae	*Quebra pedra*
Myroxilum peruiferum	Fabaceae	*Balsamo*
Bahunia macrostachya	Fabaceae	*Cipo de jaboti*
Salacia sp	Hippocrateaceae	*Cipo xixua*
Humirianthera sp	Icacinaceae	*Surucuina*
Maranthus sp	Maranthaceae	*Pacavira*
Cedrela odorata	Meliaceae	*Cedro*
Guarea trichiliodes	Meliaceae	*Jito branco*
Siparuna cf. cervicornia	Monimiaceae	*Capitiu macumbeiro*
Bagassa guianensis	Moraceae	*Tajajuba*
Psidium araca	Myrtaceae	*Araza bravo*
Potomorphe peltata	Piperaceae	*Capeba*
Piper sp	Piperaceae	*Pimenta brava*
Digitaria insularis	Poaceae	*Capim rabo de burro*
Andropogon bicornis	Poaceae	*Capim rabo de raposa*
Imperata brasiliensis	Poaceae	*Sape*
n.d.	Rubiaceae	*Quina-quina*
Manilkara sp	Sapotaceae	*Massaranduba*
Physalis angulata	Solanaceae	*Canapum / saco de bode*
Solanum jurubeba	Solanaceae	*Jurubeba*
Brunfelsia guianensis	Solanaceae	*Manaca*
Guazuma ulmifolia	Sterculiaceae	*Mutamba preta*
Tremma micrantha	Ulmaceae	*Periquiteira*
Lantana cf. lilacina	Verbenaceae	*Chumbinho*
Vitex triflora	Verbenaceae	*Taruma*