SOIL PHYSICAL AND CHEMICAL PROPERTIES OF CULTIVATED PASTURE ON FOREST LAND, RORAIMA, BRAZIL.

Michael J. Eden (*)
Duncan F. M. McGregor (*)
Nelson A. Q. Vieira (**)

SUMMARY

Soil conditions under pasture were examined in a range of sites representing the seuqence of conversion of forest to pasture at two locations in the vicinity of Ilha de Maracã, Roraima. Comparisons were made with adjacent savanna. Soil bulk densities are shown to increase after forest clearance, and soil chemical data indicate that the initial beneficial effects on nutrient supply of burning forest debris are rather short-lived. Very low levels of available phosphorus prevail in areas of savanna and cultivated pasture of all ages. Variations in the status of older cultivated pastures are mainly attributable to different grazing levels.

INTRODUCTION

Forest clearance for pasture development has occurred widely in Amazonia in recent decades. It has at times been assumed that such pastures, when well-managed, will maintain themselves in good condition for many years (Falesi, 1976). This view has previously led to official encouragement of large-scale pasture establishment in Brazilian Amazonia (Feranside, 1980). The shortcomings of such development have latterly been elaborated (Serrão **et al.**, 1979; Fearnside, 1979, 1980; Dantas, 1980; Hect, 1981, 1985; Buschcacher, 1986; Buschbacher **et al.**, 1986), but the process of cutting and burning of forest for pasture continues in many areas.

Several environmental problems arise when forest land is cleared for pasture in Amazonia. In many cases, pasture productivity is high foran initial 4 to 5 years, but hereafter pastures generally deteriorate. According to Serrão **et al.** (1979) a critical

(*) Centre for Developing Areas Research, Department of Geography Royal Holloway and Bedford New College (University of London), Egham, Surrey TW20 OEX, U. K.

(**) Departamento de Sociologia e Antropologia, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.

constraint on productivity in eastern Amazonia is the availability of soil phosphorus. Phosphorus levels are relatively high immediately after forest clearance and burning, but availability of the nutrient declines to minimal levels over time. Soil physical conditions also deteriorate as pasture age. This is apparent in the increasing of pasture topsoils, which suffer reduced infiltration rates and increased sheetwash erosion (Hecht, 1981).

Weed invasion is also a serious problem in areas of cultivated pasture. Woody weeds rapidly invade pasture land, especially when introduced forage grasses lose their initial vigour, and time-consuming and expensive manual weed control becomes necessary (Dantas and Rodrigues 1980; Hecht 1981). Burning of weed pastures is often practised, but, although disposing of existing weed material, it does little to arrest general decline in pasture quality. The status of the pasture is also aggravated by overgrazing which helps accelerate soil deterioration and weed invasion. In spite of its damaging impact, overgrazing is often an attractive economic option, since cleared, albeit degraded, land can readily be sold at a profit and the proceeds re-invested in further clearance of forest land (Fearnside 1980; Hecht 1981).

This paper examines soil conditions under pasture on recently-cleared forest land in Roraima, Brazil. The study area lies in semi-evergreen seasonal forest along the western margin of the Rio Branco-Rupununi savanna. At present, forest clearance in the area is only occuring on a small scale, but rates of clearance are increasing, and, as elsewhere in Amazonia, the potential for deforestation is considerable. In these circumstances, it is desirable to investigate the nature and impact of local pasture development, so that appropriate long-term management strategies can be formulated. Fieldwork for the study was undertaken as part of the Royal Geographical Society Maracá Rainforest Project (1987-88).

STUDY AREA

The study area is located to the south and southwest of Maracá Ecological Station (c. 3°30'N, 61°30'W) and lies approximately 130 km northwest of Boa Vista, the capital of Roraima (Figure 1). The local climate is of seasonal tropical type, with mean monthly temperatures in the range 26-29°C. Annual rainfall is approximately 1900-2000 mm, most of which falls during the months April to August.

The study area lies on the southern flank of the Guiana Shield. The local landscape is gently to moderately dissected in charater, with soils developed over weathered Shield rocks, mainly micaceous schists. Both residual and colluvial parent materials are encountered. Soils are mostly fine-textured, and commoly dystrophic Red-yellow Podzols (Ultisols), with local occurrence of eutrophic Red-yellow Podzols (Alfisols).

A representative forest profile is as follows (Table 1):

Site Nº.:	74
Location:	c. 3 km north of Fazenda Patchuli
Vegetation:	mature, closed-canopy semi-evergreen seasonal forest
Relief:	mid-slope of 8-9º
Parent material:	schist
Soil:	dystrophic Red-yellow Podzol
0 - 25 cm	Red (2.5YR4/6) sandy clay loam, with few fine pisolithic gravels.
25 - 50 cm	Red (2.5YR4/6) sandy clay, with few fine pisolithic gravels
50 - 75 cm	Red (2.5YR4/6) sandy clay, with few to common, fine to medium pisolithic gravels
75 -100 cm	Red (2.5YR4/6) clay, with few common, fine to medium pisolithic gravels.

Dense forest of hylaean type is characteristic of the study area. The taller trees are 30-35 m in height, with occasional emergents reaching 40 m or so; the largest trees attain approximately 100 cm DBH. The majority are evergreen, but some species such as **Tabebuia uleana** (Kraenzl.) Gentry and **Lueheopsis duckeana** Bussett lose their leaves during the dry season (Eden **et al.**, 1990a).

Savanna in the study area consists mainly of a bunch-grass community with a sparse of low trees and shrubs, corresponding to the **campo sujo** category in central Brazilian terminology; in places, **campo coberto** is present. Woody species in the savanna include **Curatella americana** L., **Bowdichia virgilioides** Kunth, **Erythroxylum suberosum** St. Hil., **Xylopia grandiflora** St. Hil. and **Siparuna guianensis** Aubl. The ground layer consists mainly of **Trachypogon** sp., various panicoid grasses, and the sedge **Bulbostylis paradoxa** (Eden **et al.** 1990a).

Cattle were first introduced to the Rio Branco-Rupununi savanna in the late 18th century, when they rapidly across the area, but it has only been in recent decades that there have been any significant attempts to extend ranching onto adjacent forest land. One area where this has occurred is to the south of Maracá, where several small ranches (1000-2000 ha) have been established, including Fazenda Patchuli and Fazenda Pau Roxo. The area first became accessible in the early 1950s when a dirt road was constructed from Boa Vista and local clearance began. However, most of the derived pasture is more recent, having been developed over the last 15 years. This has largely been a response to construction of the Manaus-Boa Vista road and the enhanced marketing opportunities that this provides for local cattle producers.

METHODS

The present results relate to clearance at two sites near the Maracá Ecological Station, namely, Fazenda Patchuli located 9 km to the south and Fazenda Pau Roxo located

13 km to the southwest (Figure 1). The results from Fazenda Patchuli are based on soil and other data collected from a transect, approximately 2 km in length, extending from undisturbed forest, through cultivated pasture of various ages, into natural savanna. At Fazenda Pau Roxo, the data are derived from forest, cultivated pasture and savanna sites within a radius of approximately 1 km of the ranch house.

Soil profiles were examined, and topsoil samples were collected in representative forest, cultivated pasture and savanna sites. Four topsoil samples (0-10 cm) were collected at each site for laboratory analysis, together with three core samples (c. 115 cm^3) from which bulk density determinations were made. The samples were individually collected at randomly-selected points within an area of approximately 30 x 30 m in the central part of each site. All samples were obtained at the end of the rainy season (August-September 1987), some six months or so after the annual cutting and burning period in the area.

Laboratory analyses have been undertaken as follows: organic carbon was determined by the Walkley-Black method; Exchangeable Ca, Mg, Na, H and Al were extracted with 1 M KCl and exchangeable K with 0.02 M HCl, and measured by atomic absorption spectrophotometer or flame photometer; available phosphorus was determined using the Bray 1 method; total N was determined using a micro-Kjeldahl procedure; pH was measured in a 1:2.5 suspension in H_2O and dilute $CaCl_2$ (Black **et al**. 1965).

No attempt was made to obtain quantitative data on pasture composition or plant biomass, but general information on plant conditions was collected at all sites. Dominant species were recorded in pasture and savanna sites, with specimens collected for identification as necessary.

RESULTS

Forest clearance for pasture

Pasture establishment in the study area follows a relatively uniform pattern. Trees are generally cut by axe or chainsaw during the dry season from September to March, and after partially drying out, are fired. Foliage and small branches are mostly consumed, but larger branches and trunks generally survive the initial burn with only superficial charring. Ash and fine charcoal debris are unevenly distributed over the newly-exposed topsoil.

Initially, the cleared land is devoted to subsistence crops, which benefit from the enhanced nutrient supply provide by the burn. The main crops, which are normally planted with the initial rains in April and May, are maize and rice, with a range of subsidiary crops like beans, banana, manioc and water melon. Grass cuttings are also usually planted amid the food crops. Initially, **colonião** (**Panicum maximum** Jacq.) was the commest pasture grass in use, together with **jaraguá** (**Hyparrhenia rufa** (Ness) Stapf),

but since about 1980 **quicuio da Amazônia** (**Brachiaria humidicola** (Rendle) Schweik.) has been widely adopted. The latter is now established at Fazenda Patchuli, although planting of **colonião** still continues at Fazenda Pau Roxo.

During the initial cropping phase, hand weeding is often undertaken, but as time passes increasing shrubby invasion occurs. In the subsequent dry season, the wood weeds are generally cut by hand and the site reburned. The burn disposes of the weed debris and depletes the remaining timber debris. After the burn, the grass cuttings re-establish themselves and an initial pasture is created. This is normally achieved in the second rainy season after clearance, although in places food cropping may be continued for a second, or even third, year and pasture establishment delayed accordingly.

Once established, introduced forage grasses such as **colonião** and **quicuio da Amazônia** develop a more or less continuous ground cover. New growth of **quicuio da Amazônia** provides a thicker ground layer, but the taller colonião creates a dense stand that similarly discourages weedy growth. Nevertheless, some woody weeds establish themselves in the pasture, and, given time, would readily dominate the community.

Among commoner invading wood plants are the palms **Maximiliana maripa** (Correa) Drude and **Astrocaryum aculeatum** G. F. W. Meyer, leguminous shrubs like **Mimosa** spp. (M. **scharankioides** Benth, **M. pudica** L.) and **Chamaecrista nictitans** (L) Moench., and others such as **Vitex schomburgkiana** Schauer and **Solanum** sp. In the face of persisting wood regrowth, periodic hand cutting of weeds necessarily continues in most pastures, although ranchers also resort to the biocide Tordon for removing persistent weeds such as **jurubeba** (**Solanum** sp.). In most areas, pastures are also burned each dry season in order to dispose of weed debris and renew the grass cover.

Although this initial pasture sequence after forest clearance recurs throughout the area, there is considerable variation apparent in the condition of older pastures. In places, pastures originally planted to **colonião** were still well-established on land tha has been cleared 10 years or more ago, with relatively few weeds present. Elsewhere, **colonião** pastures of similar age were completely over-run with woody weeds, or, in a few cases, seemingly so degraded that they could only support a low cover of native grasses and herbaceous and shrubby weeds. Most older pastures, however, contained a misture of grasses and wood weeds, and no evidence was apparent of any general, early deflection of cleared forest land to open bunch-grass savanna. In places, a few isolated examples of **Curatella americana** occurred in older weedy pastures, but the characteristics **Trachypogon-Curatella** association of the savanna was not generally extending onto cleared forest land.

Since the pastures in question were all examined at the end of the rainy season (August-September 1987), and had in no cases recently been burned, it was assumed that their variable status was primarily a response to differential soil conditions and/or recent stocking levels. In order to illustrate the pasture sequence and associated soil changes, data are presented from Fazenda Patchuli and Fazenda Pau Roxo.

Fazenda Patchuli

Fazenda Patchuli is located near the savanna-forest boundary some 9 km south of the Maracá Ecological Station. Summit areas in the vicinity of the ranch are at approximatelly 140 m above sea level, but considerable local dissection of the landscape has occurred, giving rise to undulating convexo-concave relief. Slopes of 6-10° are characteristic, with an amplitude of relief of 25-35 m. Soil parent material are schistose, giving sandy loam to sandy clay loam topsoils over sandy clay to clay at depth. The soils are provisionally classed as dystrophic Red-yellow Podzols (Ultisols). Land currently in use on the ranch is reported to comprise approximately 250 ha of cultivated pasture established on cleared forest land in recent years and some 100 ha of savanna grazing. The sites examined at Fazenda Patchuli in August 1987 are as follows:

(a) Mature forest located to the north of the cleared zone.

(b) Cleared forest land (1st year). The area was cut and burned in late 1986/early 1987, and at the time of the time of the survey was being cropped for maize, rice and other food plants. Most of the area was also planted with cuttings of **quicuio da Amazônia**. Abundant timber debris remained on the ground, but after recent weeding there were few weedy plants in the field.

(c) Cleared forest land (2nd year). The site was cut and burned in late 1985/early 1986, and subsequently cultivated for food plants. In the following dry season (late 1986/early 1987), weedy regrouwth was cut and burned, following which the pasture established itself. At the time of survey, **quicuio da Amazônia** and scattered **colonião** were present. A very well-developed cover of **quicuio da Amazônia** existed, forming a ground layer 40-50 cm in height. Scattered low woody shrubs and palms were present. Abundant timber debris remained on the ground.

(d) Cleared forest land (3rd year). The site received similar early treatment to the above. It has been burned each dry season since forest was cleared, and, at the time of the survey, was under **quicuio da Amazônia** with some **colonião**. The grass and woody weeds were similar to site (c) above. Abundant timber remained on the ground.

(e) Cleared forest land (4th year). The site received similar initial treatment to the above. It has been burned each dry season since forest clearance, and, at the time of the survey, was under **quicuio da Amazônia** with some **colonião**. A well-developed grass cover existed, with a ground layer 25-30 cm in height. Common low palms and woody shrubs to 1.0-1.5 m in height were present. Considerable timber debris remained.

(f) Cleared forest land (6th year). The site received similar initial treatment to the above, except that **colonião, quicuio da Amazônia** and **jaraguá** grasses were originally planted in adjoining strips. The grasses have persisted, especially **quicuio da Amazônia**, but form part of a mixed herbaceous community that also contains numerous native grasses. The herbaceous layer is relativelly sparse, with only 70 percent ground cover,

and is mostly of low stature (<30 cm). Little timber debris remains although scatterd standing trunks are present. The site has been burned in recent years.

(g) Cleared forest land (12th year). After initial cutting, burning and cultivation, the area was established under **colonião**. Periodic dry season burning took place to control weed growth, but, in 1980/81, the site was ploughed and re-seeded with **colonião**. The **colonião** has now been displaced by a mixed herbaceous community, which includes many native grasses. At the time of survey, the herbaceous layer provided an 80 percent ground cover, but was mostly of low stature (<25 cm)>. Common low wood weeds (30-50cm in height and also a few palms (<100 cm in height) were present. No timber debris remained, although a few standing trunks existed. The site has been burned in recent years.

(h) Savanna. This is a natural, bunch grass savanna, dominated by **Trachypogon** sp. with a few low scattered trees, mostly **Curatella americana**. The herbaceous cover is 25 percent. The site is burned each dry season.

The above pastures, including savanna, are generally grazed on a rotational basis. At the time of survey, 340 cattle were reported to be on the ranch. They were mostly zebu steers, of mixed Nellore/Indo-Brasil breeds, that had been bought in for fattening from adjacent savanna ranches. On the cultivated pastures, stocking levels of 1-2 animals/ha were usually maintained.

Fazenda Pau Roxo

Fazenda Pau Roxo is located near the savanna-forest boundary some 13 southwest of the Maracá Ecological Station. The ranch is an outstaion of the larger Fazenda Canadá, although it operates autonomously in terms of pasture development. Summit heights in the area are at about 140 m above sea level; general topographic characteristics are similar to those found at Fazenda Patchuli, although at Pau Roxo occasional outcrops of schistose and granitic rocks are encountered on summits, their flanks, and at stream level. Topsoils are mainly sandy loam, grading through sandy clay loam to clay loam to clay loam at depth, and are provisionally classed as eutrophic Red-yellow Podzols (Alfisols). Land currently in use on the ranch comprises approximately 500 ha of cultivated pasture established on cleared forest land and about 200 ha of savanna grazing. The sites examined at Fazenda Pau Roxo in August-September 1987 are as follows:

(a) Mature forest, comprising three sites located east and southeast of cleared zone.

(b) Cleared forest land (1st year). The area was cut and burned in late 1986, and at the time of survey was being cropped for maize and rice, with a few bananas and pineapples. Abundant timer debris remained on the ground.

(c) Cleared forest land (2nd year). The site received similar early treatment to the above. After cultivation, weedy growth was cut and burned in the 1986/87 dry season. following which **colonião** was planted except for one small area of banana. A dense,

mixed herbaceous and shrubby cover 2-3 m in height and containing a few emergent regenerating palms, was present at the time of survey. Timber debris was common.

(d) Cleared forest land (3rd year). The site received similar treatment to the above, including initial maize cultivation. **Colonião** was subsequently planted. The area has been burned each dry season since clearance. A continuous mixed herbaceous and shrubby cover (1 m in height) with scattered shrub and palm emergents to 2-3 m was present at the time of survey. Abundant timber debris lay on the ground; common standing trunks were also present.

(e) Cleared forest land (7th year field). The site received similar treatment to the above, including initial maize cultivation. **Colonião** was subsequently planted. The site is reported to have been burned each dry season since clearance, with the **colonião** subsequently regenerating. At the time of survey, a dense **colonião** cover (75-80 percent) to 2 m in height, containing common shrubby weeds, was present. A few emergent palms (4-5 m in height) existed, together with occasional woody savanna species (**Curatella americana**). Timber debris was scarce.

(f) Cleared forest land (c. 12th year field). The site received similar treatment to the above, including initial maize cultivation and subsequent planting of **colonião**. The site is reported to have been regularly burned during dry seasons, with the **colonião** subsequently regenerating. At the time of survey, a dense stand of **colonião** (85-90 percent cover) to 2.5 m in height was present, interspersed with abundant wood shrubs. Common emergent palms were present, together with occasional **Curatella americana** to 2m in height. Timber debris was scarce. The site was fenced, and intermittently grazed.

(g) Savanna. This is a natural, bunch grass savanna, dominated by Trachypogon sp., with a scattered tree cover of mainly **Curatella americana**. Herbaceous cover is approximately 65 percent.

At time of survey, only 400 cattle were reported to be on the ranch, after recent sale of some 250-300 animals. There was no immediate need for establishment of additional pasture, and re-cultivation of recently-cleared areas for a second, or even third, year was taking place. It was reported that cattle on the ranch, mainly of Guzerat and Indo-Brasil breeds, preferred the **colonião** pasture to **quicuio da Amazônia**, which was previously planted on a small scale. Natural savanna, including some more favourable **campo de baixadas**, was being used for general grazing purposes, with **colonião** mainly in use for fattening cattle. On **colonião**, stocking levels of less than 1 animal/ha prevailed at the time of survey.

Soil and Pasture Conditions

Marked differences exist between Fazenda Patchuli and Fazenda Pau Roxo in respect of pasture conditions. In younger pastures (less than 5 years old), there is a lower density of wood weeds in sites planted to **quicuio da Amazônia** at Patchuli than in sites

under **colonião** at Pau Roxo. In older pastures (more than 5 years), there is a greatly reduced herbaceous and wood biomass at Patchuli by comparisson with Pau Roxo where substancial herbaceous and wood biomass persists.

Since neither of the above areas had been burned since the preceding dry season (i.e. at least 6 months prior to the time of survey), burning is not considered to be a significant factor in the observed differences.

In younger pastures, the grass species signficantly influences pasture status. **Quicuio da Amazônia**, with its well-developed ground cover, is clearly more effective at suppressing weed competition than **colonião**. This seems to be the main explanation for early contrasts in pasture status. In older pastures, where a significant contrast exists in plant biomass, both herbaceous and woody, between the two areas, other factors are clearly involved. It is postulated that such contrast is related to soil conditions and/or grazing levels.

In respect of soil conditions, the present study indicates the impact of clearance on the natural soils of the area. The main soil physical change observed over time is in topsoil bulk density (0-10 cm). As elsewhere in Amazonia, bulk density increases relatively rapidly following conversion of forest to pasture (Table 2). Three determinations were taken at each site. Values under forest average 1.1 to 1.2 g/cm^3. These increase in the early years after clearance, and subsequently attain values of 1.3 to 1.6 g/cm^3. The latter values approximate those in adjacent savanna sites.

Exposure and compaction by trampling contribute significantly to the pattern of bulk density change after forest clearance. Such change generally leads to increased rates of soil erosion, especially sheetwash. Although the broad trend of bulk density change is similar at both Pau Roxo and Patchuli, the degree of compaction is somewhat lower in the pastures at Pau Roxo. This accords with the lower intensity of grazing reported there.

Soil chemical data for the study sites are given in Table 3. The data indicate that, although natural soil conditions under forest at Patchuli and Pau Roxo differ somewhat, notably in respect of organic carbon, pH and exchangeable cations, some measurable effects of clearance and burning are evident in both areas. This is particularly so in respect of pH which shows a substantial increase in both areas in first-year cultivation sites (i.e. sites sampled 7-8 months after initial clearance and burning). Subsequently, the pH values decline. Even older derived pastures, however, show pH values that are higher than those of adjacent savannas.

In respect of exchanged bases, notable increases in calcium and magnesium occur as a result of initial forest clearance and burning at Patchuli. At Pau Roxo, where higher levels of exchangeable calcium and magnesium are present under natural forest, no comparable increase in these elements is recorded under first-year cultivation, although the calcium and magnesium levels are at this stage similar in both areas. Since sampling of the cultivated sites occurred six months or more after initial clearance and burning, it is assumed that the original post-burn nutrient boosts were at this

stage already somewhat diminished. In comparison, there is a reduction in both exchangeable calcium and magnesium in sites under pasture, although this is less pronouced at Pau Roxo than at Patchuli. In neither area, however, is there a consistent or progressive decline in exchangeable bases as pastures age; in several cases, older pastures contain higher levels of bases than younger ones. In general, this accords with conditions reported in eastern Amazonia (Falesi, 1976), and reflects continuing nutrient release through decomposition of residual timber debris as well as relatively efficient nutrient re-cycling in older weedy pastures (Eden **et al.**, 1990b). It is also noted that exchangeable bases are higher in cultivated pastures than in adjacent savanna where soils have become relatively degraded over time.

Available phosphorus values are similar under forest in both areas. At Patchuli, higher values are recorded under first-year cultivation, but not at Pau Roxo. There is gradual subsequent decline in values in both areas. In all sites, however, available phosphorus levels are very low and below that regarded as adequate for most crops (London, 1984). As Fearnside (1980) and others indicate, phosphorus is usually the most limiting factor to pasture performance in Amazonia, resulting in poor-quality growth irrespective of other fertility indicators. This is presumably also the case in the present study area, where very low available phosphorus levels prevail in all pastures, both cultivated and natural.

Topsoil organic matter, which is normally considered to decline as a result of forest clearance (Detwilwer & Hall, 1988), does not display a simple trend. Compared with forest, slightly lower values are recorded after initial clearance and burning at both sites, but thereafter conditions are variable.

In spite of some soil contrasts between the two areas, it is not evident that the former account for observed differences in pastures status. Some soil advantages exist at Pau Roxo, but available phosphorus is very low in both areas and presumably most limiting. In general, it seems more likely that cattle densities are the critical variable, particularly under existing pasture management. At Patchuli, rotational grazing occurs at moderate cattle densities by Amazonian standards (1-2 animals/ha), resulting in low-quality grazing in older pastures. Pau Roxo has carried fewer animals in recent times (<1 animal/ha), and its older pastures appear to have been conserved as a result of low levels of rotational grazing; under such conditions, the pasture status does not appear to decline over time (Eden **et al.**, 1990b).

CONCLUSION

The present data generally confirm the findings reported elsewhere in cultivated Amazonian pastures, both in respect of soil physical and chemical conditions and of weed invasion (Falesi, 1976; Serrão **et al.**, 1979; Fearnside, 1980; Hecht, 1981; Cochrane & Sanchez, 1982). Initial pasture quality is generally favourable in the study area,

with woody weeds effectively controled by regular burning. In later years, however, pasture conditions are rather variable. At Fazenda Patchuli, older pastures are in a degraded condition, having been invaded by savanna grasses and herbaceous weeds, while, at Fazenda Pau Roxo, older pastures support common to abundant woody weeds, but also a dense cover of **colonião**. Although there are some inherent soil contrasts between the two areas, the status of older cultivated pastures seems mainly to reflect differing grazing levels. At Fazenda Pau Roxo, these levels are particularly low, and unlikely to generate a significant economic return on land use.

ACKNOWLEDGEMENTS

Grant assistance was received from the Ford Foundation/Royal Geographical Society (MJE/DFMM/NAQV), the Carnegie Trust for the Universities of Scotland (DFMM), and the Central Research Fund of the University of London (MJE). Grateful acknowledgements is made of logistical and other assistance by the Royal Geographical Society Maracá Rainforest Project and by Brazilian government agencies, notably the **Secretaria Especial do Meio Ambiente**, the **Instituto Nacional de Pesquisas da Amazônia**, and the **Empresa Brasileira de Pesquisa Agropecuária**. Laboratory analyses were undertaken by M. Onwu and cartography by E. Milwain. Plant identifications were made by Dr. J. A. Ratter, Dr. G. P. Lewis and W. Milliken.

Table 1. Analytical results for forest soil profile near Fazenda Patchuli, Roraima.

	Texture Sand (%)	Silt	Clay	Organic carbo (%)	pH	Exchangeable (meq/100 g) Ca	Mg	Na	K	Al	H	Total N (%)	Available P (ppm)
0 - 25 cm	55	12	33	0.40	4.3	0.10	0.08	0.06	0.06	0.03	0.93	0.08	2.2
25 - 50 cm	50	12	38	0.35	4.3	0.06	0.08	0.06	0.04	0.03	0.70	0.06	2.1
50 - 75 cm	45	14	41	0.43	4.2	0.06	0.08	0.07	0.05	0.04	0.58	0.06	1.5
75 - 100cm	36	16	48	0.35	4.3	0.10	0.10	0.08	0.05	0.04	0.58	0.07	0

Table 2. Topsoil bulk density (g/cm^3) at Fazenda Patchuli and Fazenda Pau-roxo, Roraima.

No. of samples	Patchuli	Pau-roxo	No. of Samples	
Forest	6	1.12	1.11	6	Forest
Year 1 (cultivation)	6	1.27	1.31	3	Year 1 (cultivation)
Young pasture (years 2, 3 & 4)	9	1.42	1.31	6	Young pasture (years 2, 3 & 4)
Old pasture (years 6 & 12)	6	1.58	1.44	6	Old pasture (years 7 & 12)
Savanna	6	1.48	1.52	3	Savanna

Table 3. Analytical results for topsoil samples (0-10 cm) at Fazenda Patchuli and Fazenda Pau-roxo, Roraima.

	Number of samples	Organic carbon (%)	pH (H_2O)	pH ($CaCl_2$)	Ca	Mg	Exchangeable Na (meq/100 g)	Exchangeable K (meq/100 g)	Al	H	Total N (%)	Available P (ppm)
Fazenda Patchuli												
Forest	8	1.58	4.6	4.0	0.81	0.86	tr	0.11	0.36	0.97	0.13	3.6
Cleared forest												
Year 1 cultivation	8	1.22	6.4	5.7	3.78	2.28	0.01	0.17	0.30	0.20	0.12	6.1
Young pasture (years 2, 3 & 4)	12	1.92	5.5	4.7	1.51	0.62	tr	0.21	0.10	0.36	0.12	4.5
Old pasture (years 6 & 12)	8	1.89	5.6	4.8	2.24	0.41	0	0.15	0.05	0.27	0.12	4.2
Savanna	8	1.09	4.9	4.1	0.22	0.08	tr	0.07	0.48	0.36	0.15	3.1
Fazenda Pau-roxo												
Forest	12	0.74	6.1	5.6	5.13	2.87	0.01	0.17	0	0.18	0.19	3.3
Cleared forest												
year 1 cultivation	6	0.70	7.1	6.5	4.47	2.12	0.01	0.11	0	0.11	0.14	3.2
young pasture (years 2 & 3)	8	0.59	6.2	5.5	3.90	0.75	0.01	0.23	0	0.16	0.16	2.5
Old pasture (years 7 & 12)	8	0.56	5.9	5.2	4.21	1.24	0.01	0.21	0	0.16	0.16	1.5
Savanna	4	1.25	5.4	4.5	1.04	0.46	tr	0.12	0.10	0.59	0.07	2.8

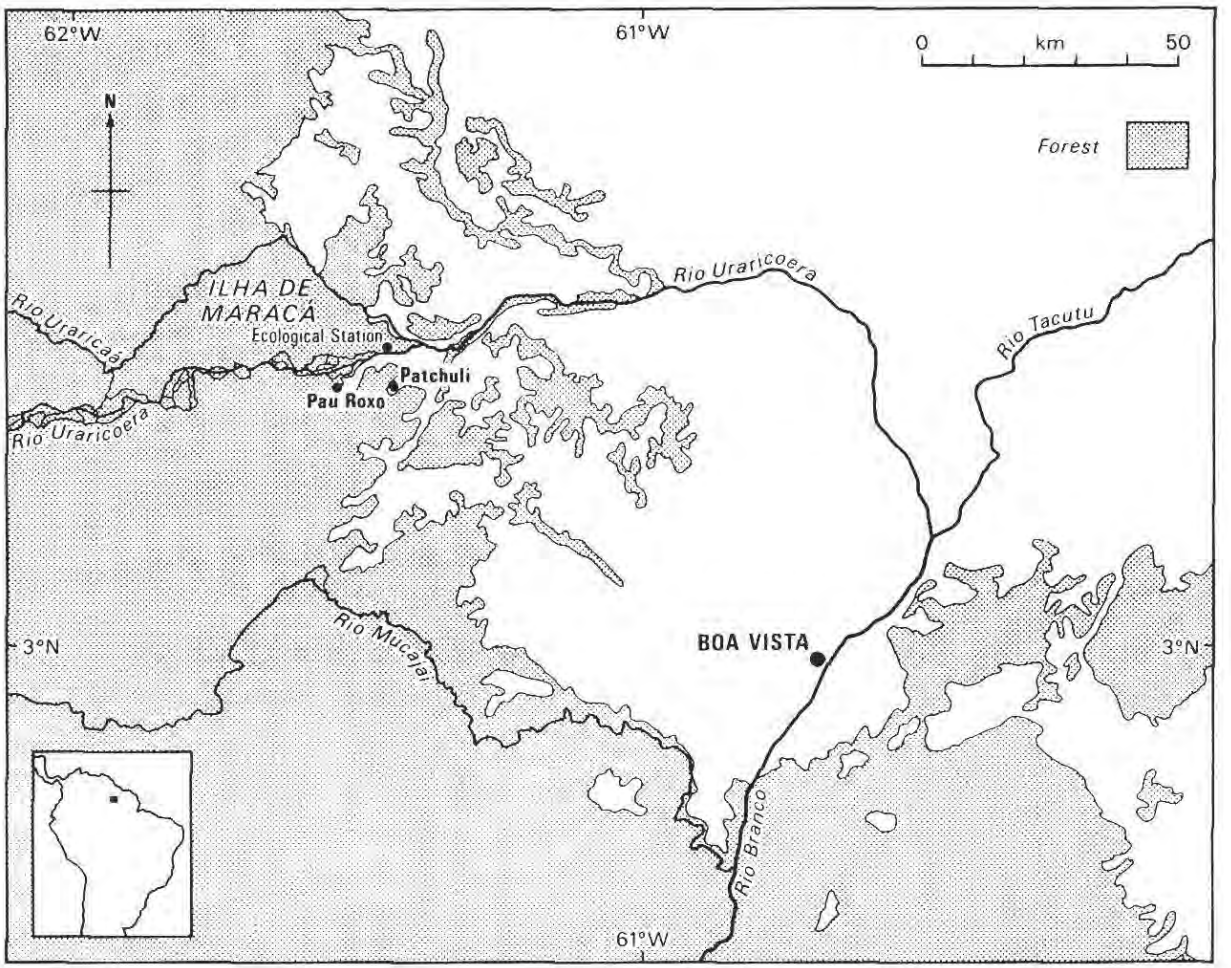

Fig. 1. Location map - Maracá Island and field sites.

References

Black, C. A.; Evans, D. D.; White, J. L.; Ensminger, L. E.; Clark, F. E. - 1965. **Methods of Soil Analysis**. American Society of Agronomy, Madison.

Buschbacher, R. J. - 1986. Tropical deforestation and pasture development. **BioScience**, 36:22-28.

Buschbacher, R. J.; Uhl, C.; Serrão, E. A. S. - 1986. Pasture management and environmental effects near Paragominas, Pará. **In**: Jordan, C. F. (ed.). **Amazonian Rain Forests. Ecosystem Disturbance and Recovery**.New York, Springer-Verlag. pp. 90-99.

Cochrane, T. T. & Sanchez, P. A. - 1982. Land resources, soils and their management in the Amazon. **In**: Hecht, S. B. (ed.). **Amazonia, Agriculture and Land Use Research**. Centro Internacional de Agricultura, Cali. pp. 137-209.

Dantas, M. - 1980. Ecossistema de pastagens cultivadas. Algumas alterações ecológicas. **EMBRAPA Miscelânea** (Belém), 1:1-19.

Dantas, M. & Rodrigues, I. A. - 1980. Plantas invasoras de pastagens cultivadas na Amazônia. **EMBRAPA Boletim de Pesquisa** (Belém), 1:1-23.

Detwiler, R. P. & Hall, C. A. S. - 1988. Tropical forests and the global carbon cycle. **Science**, 239:42-47.

Eden, M. J.; Furley, P. A.; McGregor, D. F. M.; Milliken, W.; Ratter, J. A. - 1990a. Effect of forest clearence and burning on soil properties in northern Roraima, Brazil. **Forest Ecology and Management**, 38 (in press).

Eden, M. J.; McGregor, D. F. M.; Vieira, N. A. Q. - 1990b. Pasture development on cleared forest land in northern Amazonia. **Geographical Journal**, 156:283-296.

Falesi, I. C. - 1976. Ecossistema de pastagem cultivada na Amazonia Brasileira.**EMBRAPA Boletim Técnico** (Belém), 1:1-193.

Fearnside, P. M. - 1979. Cattle yield prediction for the Transamazon highway of Brazil. **Interciencia**, 4:220-225.

---- - 1980. The effects of cattle pasture on soil fertility in the Brazilian Amazon: consequences for beef production sustainable. **Tropical Ecology**, 21:125-137.

Hecht, S. B. - 1981. Deforestation in the Amazon basin: magnitude, dynamics and soil resource effects. **Studies in Third World Societies**, 13:61-108.

---- - 1985. Environment, development and politcs : capital accumulation and the livestock sector in eastern Amazonia. **World Development**, 13:663-684.

Landon, J. R. (ed.) - 1984. **Booker Tropical Soil Manual**. Longman, Harlow.

Sanchez, P. A. - 1976. **Properties and Management of Soils in the Tropics**. New York, Wiley.

Serrão, E. A. S.; Falesi, I. C.; de Veiga, J. B.; Neto, J. F. T. - 1979. Productivity of cultivated pastures on low fertility soils in the Amazon of Brazil. **In**: Sanchez, P. A. and Tergas, L. E. (eds.). **Pasture Production in Acid Soils in the Tropics**. Centro Internacional de Agricultura Tropical, Cali.

(Aceito para publicação em 04.03.91)