SOIL CHEMICAL PROPERTIES AND PASTURE DEGRADATION IN THE AMAZON REGION: A CASE STUDY.

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Cumulative deforested area in Brazilian Amazon was estimated to have reached 470.000 km^2 in 1994. From this total, actively grazed pastures occupied about 45%, secondary forest derived from degraded pastures amounted 28%, and 2% was degraded pasture (Fearnside & Barbosa, 1998). Numbers show that ≅ 75% of the total cleared area was used for pasture, and that 30% was not in use anymore because of pasture degradation, what leads to more deforestation. The present study examines the relationship between soil chemical properties and pasture degradation. The study area (Jacundá - 4°30' S; 49°05' W) is close to the city of Marabá, Pará State, eastern Amazon. Climate type at Marabá's region is Awi (Köppen), with mean annual temperature of 31.8°C, and mean annual rainfall of 2000 mm. The expression "pasture degradation" is used here to refer to a decrease in forage production, with a decrease in livestock feeding capacity. Different levels of pasture degradation were visually perceived by primary grass production, weed invasion and soil covering. Five situations, three of them in an increasing degradation sequence (p1-p2-p3), were chosen for the study and evaluated in June of 1996, end of the rainy season, when the phytomass of the pasture is believed to be maximal:

- **pn** – primary forest, which served as reference of soil characteristics before forest clearance;
- **p1** – *Panicum maximum* pasture of 11 years, planted after 2 years of manioc after forest clearance;
- **p2** – *P. maximum* pasture of 16 years, planted after 1 year of rice crop after forest clearance;
- **p3** – an herbaceous fallow of 2 years, succeeding a *P. maximum* pasture of 6 years, which was preceded by 8 years of alternate manioc crop and fallow, after forest clearance;
- **p4** – *Andropogon gayanus* pasture of 2 years, which is an attempt to recover an herbaceous fallow of 3 years, succeeding a *Panicum maximum* pasture of 11 years after forest clearance.

The pastures have never received fertilizers, and they were all kept from grazing for some weeks before evaluations. The soil at study sites was classified as a Red-Yellow Podzolic Soil (Ultisol), sandy loam texture. Trenches were dug on each site to study the root system and/or to collect soil samples. Roots of 4 clumps of the cultivated grass were counted per site, using a 50 x 50 cm board (grid of 5 x 5 cm). A ten sample set was collected per site to represent soil fertility at depths of 0-5, 5-10 and 10-20 cm. Laboratory analysis consisted of: pH determined in water; Al^{3+}, H^+, Ca^{2+} e Mg^{2+} extracted by KCl 1N; K^+ and P extracted by Mehlich (HCl 0.05 N + H_2SO_4 0.025 N). Aboveground phytomass data were obtained from a single representative 2 x 2 m plot within each site, positioned close to the trenches. As it was not possible to replicate this evaluation, these data were not statistically treated. At each plot, all vegetal material was collected and partioned in: cultivated grass, other herbaceous plants and lignous plants. For each mentioned part the phytomass was separated into living parts (aboveground biomass) and dead parts (plant necromass).

Aboveground phytomass data (Table 1) show clear differences between pastures, reflecting degradation levels initially observed. Grass biomass decreased sharply from p1→p2 (526→216 g m^{-2}) and disappeared at p3, the same occurring for grass necromass (315→170 g m^{-2}). An inverse trend was observed for other herbaceous phytomass (bio + necro), which have increased greatly from p1→p3. Pasture recovering with *A. gayanus* seems very successful, achieving grass bio and necromass values (respect. 976 and 521 g m^{-2}) higher than p1. Comparing total aboveground phytomass (TAGP) values, p2 and p3 had a decrease of 31.5 and 33 %, respect., in relation to p1, and p4 had an increase of 78% in relation to p1. Although there is almost no difference between p2 and p3 TAGP values, the percentage of grass phytomass on TAGP of p2 was almost 57%, while on p3 it was 0%. For p1 and p4 these percentage was almost the same, near 85%. Soil covering by litter was also different between plots. Litter dry matter decreased from p1→p3 (141→21 g m^{-2}) and increased in p4 (204 g m^{-2}).

Results of soil chemical analysis are shown in Table 2. Numbers represent the average of 7-10 samples per site. As a reference of soil original status, carbon (C) and nitrogen (N) contents decreased with increasing soil depth under forest, and were relatively low, although they can be considered normal for the soil texture (sandy loam). Pasture plots showed higher variability of C contents for the superficial layer (0-5 cm) than the forest plot, what may be due to the cespitous habit of the grass species. Even though, we can see that pasture plots have slightly (not significantly) higher C concentrations (16.1 – 21.6 g kg^{-1}) than the forest (16.1 kg^{-1}). At sub superficial layers these trend is inverted, and the forest has higher C contents than the pastures. The same occurred for N. No differences were observed in the superficial layer, but N contents were significantly higher at forest than at p1 and p4 in the subsuperficial layers. The C/N ratios were slightly lower on forest (13.1 – 13.5) than on pastures (13.8 – 16.3). One important thing here is that there is no significant difference between pasture plots for C and N contents, and that forest clearance and conversion to pasture did not provoque important differences on C and N contents for the surface horizons after almost 2 decades.

Soil acidity proved to be naturally high, what is very common for oxisols and ultisols of the Amazon Region (Sánchez, 1981). Forest pH values showed almost no changed from 0-5→10-20 cm layer (4.0→4.1), while pastures always had significantly higher pH values (4.7-5.8) for the three layers, except p2 in the 10-20 cm layer. There was no clear relationship between pasture aging or degradation and soil pH, since p3 always showed high pH values. However, we can see that p1 always had the highest pH values and p2 always had the lowest ones. Exchangeable aluminium (Al^{3+}) contents increased with increasing soil depth, and pastures showed significantly lower Al^{3+} concentrations (0.6-5.7 $mmol_c$ dm^{-3}) than forest (11.1-14.6 $mmol_c$ dm^{-3}) for all layers, except for p3 at both subsuperficial layers. Figure 2 shows that aluminium saturation values ($Al^{3+}/_{ef}CEC$) were as high as 70 % on subsuperficial layers of the forest plot, decreasing significantly on the pastures. Aluminium saturation values increased in the sequence p1-p2-p3 for all layers, and in p4 these values decreased.

Under forest, contents of potassium (0.3-0.3 $mmol_c$ dm^{-3}), calcium (6.7-3.1 $mmol_c$ dm^{-3}) and magnesium (2.8-1.5 $mmol_c$ dm^{-3}) were low, and decreased with increasing depth for calcium and magnesium. Values of sum of bases (S) were significantly lower on the forest for all layers, except for p4 on 10-20 cm layer, and also decreased in subsuperficial layers (9.8→4.9 $mmol_c$ dm^{-3}). No significant difference between pasture plots were observed for S. The saturation of bases (S/CEC) was very low under forest condition, and decreased with increasing soil depth (14→9%). No significant difference was observed between pastures for S/CEC, but values were always significantly higher than on forest, and tended to be higher in the 0-5 cm layer. These results show that forest clearance and burning of the phytomass enriched the soil with bases, and that after almost 2 decades pasture plots maintained soil fertility levels significantly higher than the original levels. Another important observation is that there is no significant difference between pastures for sum of bases, and probably this is not the cause for pasture degradation.

Mehlich phosphorus contents (Figure 1) decreased significantly from the superficial layer to layers bellow (5.3→3.7→2.6 mg dm^{-3}) under forest. On pastures, phosphorus contents also decreased with increasing depth, and they were still lower than on forest, with significant difference between forest and p1 and p2 on 5-10 cm layer. These phosphorus contents seem to be very low when compared with literature data. FONSECA et al. (1997) found critical levels of phosphorus on the soil in the range of 23-34 mg dm^{-3} for *P. maximum* in a soil of low fertility level. Data variability for P, K, Ca and Mg on pasture plots was somewhat expected, taking into account that the forest clearing at these sites, like in many other sites used for the same purpose by small ranchers in the Amazon Region, used only hand work and fire after timber removal. Also the effect of the cespitous (clumpy) habit of the grass species should be considered here.

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TABLE 1: Aboveground phytomass of 4 pasture plots in Jacundá-PA.

Aboveground composition		**p1** *Panicum maximum*		**p2** *Panicum maximum*		**p3** herbaceous fallow		**p4** *Andropogon gayanus*	
		g/m2	%	g/m2	%	g/m2	%	g/m2	%
AGB[1]	**Cultivated grass**	526.00	53.12	216.45	31.89	0.00	0.00	976.13	55.48
AGB[1]	**Other herbaceous**	2.55	0.26	97.58	14.38	373.58	56.39	34.30	1.95
AGB[1]	**Lignous**	0.00	0.00	0.00	0.00	0.83	0.12	0.00	0.00
PN[2]	**Cultivated grass**	315.48	31.86	169.18	24.93	0.00	0.00	521.28	29.63
PN[2]	**Other herbaceous**	4.65	0.47	65.30	9.62	266.68	40.25	23.23	1.32
PN[2]	**Lignous**	0.00	0.00	2.68	0.39	0.00	0.00	0.00	0.00
Litter		141.50	14.29	127.53	18.79	21.45	3.24	204.65	11.63
AGB+PN **cultivated grass**		**841.48**	**84.98**	**385.63**	**56.82**	**0.00**	**0.00**	**1497.40**	**85.10**
TAGP[3]		**990.18**	**100.00**	**678.70**	**100.00**	**662.53**	**100.00**	**1759.58**	**100.00**

[1]AGB→Aboveground biomass: aerial parts, living parts of the plants. [2]PN→Plant necromass: part of the plants which are entirely dry, but still linked to the plant. [3]TAGP→Total aboveground phytomass: sum of all the living and dead parts of the plants plus litter.

TABLE 2: Mean analytical values of soil samples of forest and four pasture plots in Jacundá-PA*.

Land cover	**C**	**N**	**C/N**	**pH**	**Al^{3+}**	**H+Al**	**S**	**CEC**	**S/CEC**
	g Kg^{-1}			**H_2O**	**$mmol_c\ dm^{-3}$**				**%**
					0 – 5 cm				
pn	16.1 a	1.2 a	13.5 a	4.0 d	11.1 a	59.6	9.8 b	69.4 a	14 b
p1	19.5 a	1.3 a	15.5 a	5.8 a	0.6 c	49.1	43.5 a	92.6 a	47 a
p2	16.1 a	1.1 a	14.6 a	4.8 c	1.9 bc	40.8	32.2 a	73.0 a	44 a
p3	21.6 a	1.3 a	16.2 a	5.3 b	3.9 b	51.9	40.1 a	92.0 a	44 a
p4	16.4 a	1.0 a	16.3 a	5.4 a	1.5 bc	33.7	32.5 a	66.2 a	49 a
					5 - 10 cm				
pn	10.8 a	0.8 a	13.4 a	4.0 c	14.6 a	56.1	6.1 b	62.2 ab	10 b
p1	9.2 a	0.6 b	15.4 a	5.5 a	1.5 b	39.2	24.1 a	63.3 a	38 a
p2	10.1 a	0.7 ab	14.3 a	4.7 b	2.4 b	38.4	21.1 a	59.5 ab	35 a
p3	9.3 a	0.7 ab	13.8 a	5.0 ab	9.6 a	38.2	22.2 a	60.4 ab	37 a
p4	8.3 a	0.6 b	14.6 a	5.2 ab	3.8 b	31.3	17.5 a	48.8 b	36 a
					10 – 20 cm				
pn	9.3 a	0.7 a	13.1 a	4.1 c	13.8 a	48.7	4.9 b	53.6 ab	09 b
p1	7.4 ab	0.5 b	15.3 a	5.2 a	2.2 c	42.5	20.0 a	62.5 a	32 a
p2	8.3 ab	0.6 ab	14.1 a	4.5 bc	2.6 c	38.4	22.1 a	60.5 a	37 a
p3	8.0 ab	0.6 ab	14.2 a	5.0 ab	10.2 ab	35.3	21.4 a	56.7 ab	38 a
p4	6.8 b	0.5 b	14.1 a	5.0 ab	5.7 bc	28.2	15.0 ab	43.2 b	35 a

* Means followed by the same letter do not differ by the Tukey test (α 0.05).

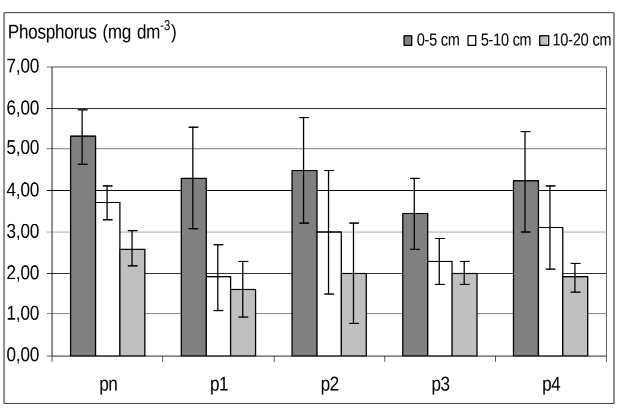

FIGURE 1: mean phosphorus contents determined by Mehlich I extractant. Bars represent the limits of the confidence interval (95%).

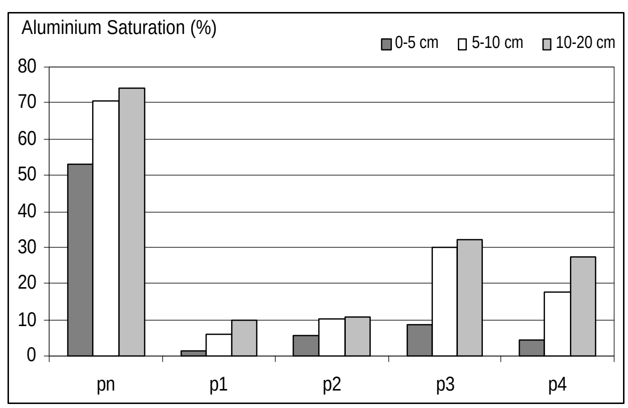

FIGURE 2: aluminium saturation values ($Al^{3+}/_{ef}CEC$) of forest and pasture plots in Jacundá-PA.