Scientia Agricola
ISSN 0103-9016 *versión impresa*

Sci. agric. v. 54 n. 1-2 Piracicaba Ene./Ago. 1997

EFFECT OF FALLOW LAND, CULTIVATED PASTURE AND ABANDONED PASTURE ON SOIL FERTILITY IN TWO DEFORESTED AMAZONIAN REGIONS

J.A. DIEZ[1]; A. POLO[1]; M.A. DIAZ-BURGOS[1]; C.C. CERRI[2]; B.J. FEIGL[2]; M.C. PICCOLO[2]

[1]*Centro de Ciencias Medioambientales-CSIC. Calle: Serrano 115, 28006, Madrid, Spain.*
[2]*Centro de Energia Nuclear na Agricultura-USP, C.P. 96, CEP: 13400-970 - Piracicaba, SP.*

ABSTRACT: The effect of two practices adopted by settlers (abandoned pasture and fallow land) on soil fertility of two deforested Amazonian regions (Belém-Pará and Ariquemes-Rondônia) was studied. Whenever possible, cultivated pasture, over similar time periods in both cases and in natural forest, were employed as soil fertility reference standards. Nutrient dynamics was studied using the electroultra-filtration technique. In general, deforestation, as practiced in these areas, has a degrading effect on soil fertility. The effect of burning normally leads to a pH rise caused by ash. This usually yields a favorable transitory effect, improving soil fertility conditions, however not sufficient for plant needs, as inferred from the low P and K levels. Cattle excrements, improved the K level for cultivated pastures. Qualitative differences related to N were observed between cultivated pasture and both, fallow land or abandoned pasture. In the first, a certain recovery of available N levels was detected, mainly affecting the EUF-Norg fraction. On the other hand, a regeneration of organic compounds, in the fallow land and the abandoned pasture, closely related to those existing in the natural forest, was verified. This is mainly due to the presence of a higher proportion of NO_3^- - N and, consequently, a EUF-Norg/EUF-NO_3^- ratio close to 1.
Key Words: deforestation, fallow land, abandoned pasture

EFEITOS DO POUSIO, PASTAGEM CULTIVADA E PASTAGEM ABANDONADA SOBRE A FERTILIDADE DO SOLO DE DUAS REGIÕES DESMATADAS DA AMAZÔNIA

RESUMO: Comparou-se o efeito de duas práticas de manejo, ou seja, o abandono da pastagem e o pousio, sobre a fertilidade do solo de duas regiões desmatadas da Amazônia (Belém-Pará e Ariquemes-Rondônia). Quando possível, pastagens cultivadas por períodos semelhantes e florestas nativas foram usadas como padrões da fertilidade do solo. A dinâmica dos nutrientes foi estuda pela técnica da eletroultrafiltração (EUF). De um modo geral, o desmatamento, como praticado nessas regiões, tem efeito degradador sobre a fertilidade do solo. A queima da biomassa vegetal normalmente leva a um aumento do pH causado pelas cinzas, resultando em um efeito favorável transitório. Manifesta-se um melhoramento das condições de fertilidade do solo que, no

entanto, não é suficiente para a nutrição das plantas, considerando-se os baixos níveis de P e K. Os excrementos do gado geralmente causam um aumento do nível de K do solo sob pastagens cultivadas. Foram observadas diferenças qualitativas relacionadas aos teores de N entre as pastagens cultivadas e as áreas em pousio ou pastagens abandonadas. Nas primeiras, observou-se certa recuperação na disponibilidade de N, principalmente da fração Norg-EUF. Por outro lado, verificou-se uma regeneração de compostos orgânicos nas áreas em pousio e nas pastagens abandonadas, que alcançaram valores próximos aos observados na floresta natural. Isso se deve, principalmente, à proporção maior de N-NO_3^- encontrada nessas áreas, resultando em uma relação Norg-EUF/ NO_3^--EUF próxima a 1.
Descritores: desmatamento, pousio, pastagem abandonada

INTRODUCTION

The intense deforestation process which the Amazon forest is undergoing has led to large areas of land being abandoned. The effects on soil fertility have not yet been sufficiently assessed (Fearnside, 1987, Cerri *et al*., 1989).

In the early stages of deforestation settlers chose intensive crops and they soon realize that soil fertility levels substantially dropp in time periods of not more than three years. This prevents the continued use of the land for agricultural purposes.

The currently most widespread practice is implanting pasture, generally cultivated with low nutrient demanding crops (*Brachiaria humidicola*), well adapted to the environment (Diez *et al*., 1991a). In most cases, implanting these pastures enables cattle to be brought in, which largely contributes towards maintaining and, in some cases, improving the soil fertility (Diez *et al*., 1995; Andreux *et al*., 1989).

However, situations are often found where pasture has been abandoned by settlers, probably due to a decrease in productivity, or, after having exploited the land with intensive crops (Diez *et al*., 1991a), it is left fallow for several years. The aim in this case is to recover soil fertility naturally, so that another crop can be planted subsequently, generally after burning.

The object of this paper is to study the comparative effect of these two above described systems (abandoned pasture and fallow land) on soil fertility, taking the natural forest and cultivated pasture, whenever possible, over similar time periods, as references.

MATERIAL AND METHODS

Experimental Study Areas: A farm located 200 km west from Belém (Pará) in Capitão Poço, at Trópico Úmido Research Centre (CPATU-EMBRAPA) on highway PA-253 (01^o 44' S and 47^o 09' W), was chosen to undertake this work. The climate is of the wet type. The soils studied are medium sandy textured yellow latosols. After deforesting and burning, the following land uses were considered:

1) 6-year fallow land: rice, maize and bean were grown for 2 years and then left fallow for 6 years. It was burned again and rice grown the first year and bean the second.

2) 8-year fallow land: this situation was found in another experimental site, close to the foregoing, the fallow land lasted a period of 8 years, at the end of which samples were taken.

3) 9-year cultivated pasture: *Penissetum maximum* (elephant grass), a fodder grass well adapted to this type of soil with a low demand for phosphorus. The pasture was maintained for 9 years during which it received no fertilizer.

The other selected site was located in the vicinity of Fazenda Nova Vida, 50 km south-east from Ariquemes (Rondônia) at Km 472 of the BR-364 highway (10^{o} 30' S and 62^{o} 30' W). The climate is of the wet type with an annual precipitation of 2270 mm. The dry season usually occurs from June to August.

The following types of operation were chosen at this location:

4) A pasture abandoned for the last 12 years which had been previously exploited as a meadow.

5) Pasture cultivated for 20 years, sown with *Brachiaria humidicola* and kept under good management conditions, using the pasture for cattle. The natural forest was taken as a reference.

Samples and methods: Soil samples were collected at depths of 10, 20, 40 and 60 cm, dried and sieved (2mm). Different physico-chemical parameters were determined and the fertility evaluated. Carbon content by the CARMOGRAPH-12 and total N by the Kjeldhal method. The pH in water with saturated paste, was performed using calomel glass electrodes.

Nutrient dynamics was evaluated by the electroultra-filtration technique (EUF) (Nemeth, 1979 and 1981), using the following program:

Fraction I: 30 min, 20^{o}C, 2OOV, 15mA maximum

Fraction II: 5 min, 80^{o}C, 4OOV, 15OmA maximum.

The samples were extracted with 5 g of 1 mm sieved soil with a 5:50 soil/water ratio.

For each fraction, the EUF extracts from the cathode were mixed with those from the anode. The K content was determined by flame photometry and P by a Technicon auto-analyzer, using the ammonium molybdate method (Cadahia, 1972). The N-total extracted by EUF was determined by an auto-analyzer, oxidizing all nitrogenous compounds to NO_3^--N using an ultraviolet radiation digester to break up the free nitrogenous compound radicals when passing through the coil, with subsequent treatment with potassium persulphate in an alkaline medium (Diez, 1988). The NO_3^--N content was determined in a parallel fashion using automated spectrophotometry with naphthylethylenediamine. The EUF-Norg content, mainly made up of low molecular weight nitrogenous compounds, was estimated by the difference between EUF-N and EUF-$N0_3^-$.

RESULTS AND DISCUSSION

The pH observed in the natural Capitão Poço forest (Table 1) is appreciably low (4.4 in the topsoil) although it tends to increase with depth due to a shift of the exchangeable bases. A similar sequence is observed in the 8-year fallow land. On the other hand, in the youngest fallow land (6 year), this sequence is reversed, still showing the effect

caused by the ash coming from burning. The 9-year pasture displays highest values. The higher values are detected in the top layers. However, the increase in pH observed in this treatment shows a positive effect on the conservation of soil fertility since the levels of K, Ca and Mg improve in depth.

Table 1 - Effect of different treatments on pH, C and N (Capitão Poço, Belém - Pará).

Treatments	Depth cm	pH	%C	%N
natural forest	00-10	3.6	1.54	0.19
	10-20	3.6	0.80	0.07
	20-40	4.2	0.41	0.04
	40-60	4.4	0.07	0.03
6-year fallow	00-10	6.8	1.43	0.09
	10-20	6.4	0.72	0.06
	20-40	5.9	0.31	0.04
	40-60	5.4	0.08	0.03
8-year fallow	00-10	4.8	1.38	0.07
	10-20	4.7	0.95	0.05
	20-40	4.7	0.51	0.04
	40-60	4.9	0.03	0.03
9-year pasture	00-10	5.3	1.28	0.08
	10-20	5.0	0.60	0.06
	20-40	4.8	0.26	0.04
	40-60	4.7	0.03	0.03

The phosphorus figures observed (Table 2) are appreciably low and insufficient for plant nutrition, but among them, the native forest shows the highest values compared to the rest. It must be stressed that any of the treatments mentioned has degrading effects on soil P (Nemeth, 1981), both, on the potentially available EUF-P 20°C P and on the EUF-P 80°C reserve. The use of low P demand fodder plants, like *Brachiaria humidicola* and fertilization with natural phosphates may be a practice of potential utility (Lobato *et al.*, 1986).

Table 2 - Effect of the treatments on P, K, Ca, Mg, Fe and Al dynamic, through EUF technique (Capitão Poço, Belém - Pará).

depth (cm)		mg . 100 g^{-1}				mg . kg^{-1}			
		P		K		Ca**	Mg**	Fe***	Al***
		20°C	80°C	20°C	80°C				
natural forest	0-10	0.14	0.10	2.52	0.40	7.5	1.55	—	0.72
	10-20	0.03	0.02	1.04	0.20	7.8	0.59		1.20
	20-40	—*	—	0.56	—	8.7	0.33	—	2.50
	40-60	—	—	0.26	—	8.0	0.30	—	1.80
6-year fallow	0-10	0.01	0.01	3.30	0.60	15.3	1.10	—	0.36
	10-20	—	—	1.04	0.20	12.6	0.50	—	0.34
	20-40	—	—	3.08	0.40	13.6	0.40	—	0.38
	40-60	—	—	7.13	1.20	8.9	1.10	0.8	0.48
8-year fallow	0-10	—	—	1.30	0.20	9.9	0.80	—	0.40
	10-20	—	—	0.48	—	10.9	0.10	—	0.26
	20-40	—	—	0.30	—	9.9	0.10	—	0.82
	40-60	—	—	0.20		6.8	0.25	—	0.22
9-year pasture	0-10	—	—	1.75	0.20	9.2	0.90	—	0.26
	10-20	—	—	0.72	0.20	10.2	0.30	—	0.22
	20-40	—	—	0.22	—	8.3	0.60	—	0.30
	40-60	—	—	0.22	—	9.3	0.62	—	0.44

* invaluable

** I+II fractions+filter

*** filter

Potassium was clearly influenced by burning (Table 2), which causes an appreciable increase of this element in the soil and this is more intense for shorter times after burning. Both the 8-year fallow land and the 9-year pasture show lower K contents than the natural forest, in which major contributions from plant residues originate. Despite the mentioned inputs, soils are K deficient and only reach levels close to the optimum in the stage subsequent to burning.

Calcium and magnesium contents reflect with the low pH of these soils, particularly in the natural forest, where at the same time, the lowest calcium contents were detected. It is the 6-year fallow land which, in fact, stands out for its highest calcium values, probably due to the burning effect.

Aluminum contents were low in general. Their origin is related to the degradation of silicates from the kaolinite structure due to the effect of soil acidity.

Figure 1 shows the diagram of nitrogen parameters for each situation. It can be seen that the EUF-N level obtained in the natural forest soil is clearly higher than those observed in the remaining treatments. This indicates the degrading effect on soil fertility which takes place after deforestation, whatever the exploitation alternative may be. The EUF-Norg/EUF-NO_3^- ratios found in the natural forest (Table 3) are in general higher than those found in other Amazonian forests.

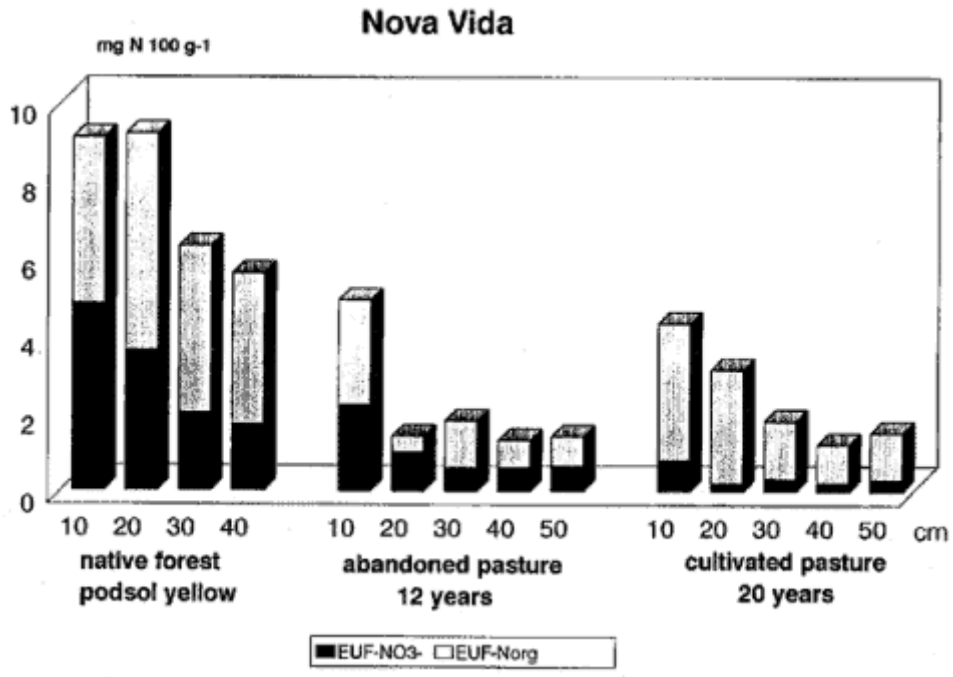

Figure 1 - Diagram of EUF-$N0_3^-$ and EUF-Norg in native forest, fallow 6 and 8-year and pasture 9-year at different depths (Capitão Poço, Belém-Pará)

Table 3 - Effect of the treatments on soil N dynamics, through EUF technique (Capitão Poço, Belém - Pará).				
Treatments	depth (cm)	EUF-Norg	EUF-Norg $80^{0}C$	EUF-$N0_3^-$
		EUF-$N0_3^-$	EUF-Norg $20^{0}C$	EUF-N
natural forest	0-10	1.67	0.42	0.37
	10-20	1.14	0.57	0.46
	20-40	1.07	1.40	0.48
	40-60	1.55	1.62	0.39
6-year fallow	0-10	1.00	10.60	0.50
	10-20	0.70	32.00	0.58
	20-40	0.09	12.00	0.91
	40-60	1.26	2.00	0.44
8-year fallow	0-10	0.22	32.00	0.81
	10-20	-	12.00	1.59
	20-40	0.06	12.00	0.94
	40-60	-	12.00	1.13
9-year pasture	0-10	1.29	16.00	0.43
	10-20	1.12	10.60	0.46
	20-40	4.16	2.76	0.19
	40-60	1.26	12.00	0.44

Despite the low N level observed in the other situations, a clear differentiation was detected in the behavior of the 9-year pasture with respect to fallow lands. In the former, a heavy increase in the EUF-Norg content was found, wile a higher proportion of NO_3^--N was detected in fallow lands, particularly the 8-year one. This makes fallow land nitrogenous organic compounds very similar to those found in the natural forest. This would seem to be related with the nature of the organic matter generated by the pasture, whose compounds are in general of a low molecular weight. This would seem to depend, in turn, on the type of vegetation the soil supports. In the case of fallow land, an obvious accumulation of leguminous crops was detected.

With respect to the EUF-Norg $80^{o}C$ / EUF-Norg $20^{o}C$ ratio, indicative of the soil capacity of mobilizing its organic N reserves, (Nemeth, 1988), it can be seen that the lowest values occur in the natural forest, followed by 6-year fallow. The pasture and the 8-year fallow land show a more easily degradable organic N.

Moreover, except for the 8-year fallow land, the rest of the samples showed a major capacity for immobilizing N, considering the relatively low values observed in the EUF-NO_3^-/EUF-N ratio (Nemeth, 1988). In this case also, for the natural forest, pH tends to increase with depth as a consequence of the exchangeable base washing (Table 4). A similar sequence is observed in the 20-year pasture, although the pH values are higher (6.2 in the topsoil, indicative of an improvement of fertility). However, this sequence is reversed in the 12-year abandoned pasture, since the highest values are detected in the top surface horizons.

Table 4 - Effect of the treatments on the pH, C and N (Fazenda Nova Vida, Ariquemes- Rondônia).

Treatments	Depth cm	pH	%C	%N
natural forest	0-10	5.1	2.62	0.16
	10-20	5.4	0.76	0.08
	20-40	5.3	0.45	0.05
	40-60	4.9	0.37	0.04
12-year deserted pasture	0-10	5.7	4.37	0.25
	10-20	5.6	1.86	0.12
	20-40	5.3	1.02	0.07
	40-60	5.4	0.91	0.06
20- year pasture	0-10	6.2	1.91	0.16
	10-20	6.2	1.24	0.13
	20-40	6.4	0.77	0.08
	40-60	6.7	0.44	0.06

* invaluable
** I + II fractions + filter
*** filter

Just as it was observed in the Capitão Poço fallow lands, phosphorus was generally low, but its highest values were, in fact, detected in the natural forest (Table 5). However, in this case, it should be recognized that the P availability was more linked to soil Ca content, since the abandoned pasture displayed the lowest Ca and, therefore, phosphorus values. The 20-year cultivated pasture showed a similar behavior with respect to the forest, both for calcium and phosphorous levels.

Table 5
Effect of the treatments on P, K, Ca, Mg, Fe and Al, through EUF technique (Fazenda Nova Vida, Ariquemes - Rondônia).

	mg .100g^{-1}								
	P		K		Ca		Mg	Fe	Al
	20 °C	80 °C	20 °C	80 °C	20 °C	80 °C	**	***	***
natural forest									
0-10 cm	0.09	0.14	6.00	1.80	11.00	10.80	3.18	0.10	0
10-20 cm	0.06	0.05	2.58	0.90	12.80	3.60	2.01	0.18	0
20-30 cm	-*	0.04	3.00	1.00	9.00	4.00	1.78	0.28	0
30-40 cm	-	-	3.00	1.00	6.00	2.00	1.18	0.26	0
12-year deserted pasture									
0-10 cm	0.03	0.05	7.28	3.42	7.28	3.42	2.27	0.26	0
10-20 cm	0.02	0.01	11.20	4.50	6.65	3.00	1.45	0.28	0
20-30 cm	0.03	0.02	4.20	1.90	4.80	1.80	2.34	0.22	0
30-40 cm	0.03	0.02	3.64	1.80	3.64	1.80	2.28	0.06	0
40-50 cm	0.02	0.02	5.98	1.68	5.52	2.16	2.94	0.12	0
20-year pasture									
0-10 cm	0.08	0.01	16.80	2.10	10.08	5.32	1.66	0.10	0
10-20 cm	0.01	0.01	22.40	3.50	7.00	4.20	0.44	0.28	0
20-30 cm	-	-	22.40	3.08	7.84	4.48	0.44	0.20	0
30-40 cm	-	0.01	2.10	3.06	10.50	5.44	0.79	0.12	0
40-50 cm	-	-	13.50	2.70	11.34	7.20	1.19	0.12	0

At Fazenda Nova Vida, the natural forest shows potassium levels (Table 5) higher than Capitão Poço's natural forest, however insufficient for adequate plant nutrition. The highest K values were detected in the 20-year cultivated pasture, which would seem to be closely related to the number of livestock it can support.

With regard to nitrogen (Figure 2), the highest values are generally shown in the top horizons where the input of residues and also biological activity are greater. With respect to the biological activity of the soils based on the C/N ratio and considering only the superficial horizons, it was observed that in Capitão Poço (Table 1) the natural tree cover showed the lowest value, which would indicate the highest level of evolution. In tilled areas, there is an increase in this ratio with time and coincidently a decrease in C/N with increasing depth, which is probably due to the decrease in microbial activity.

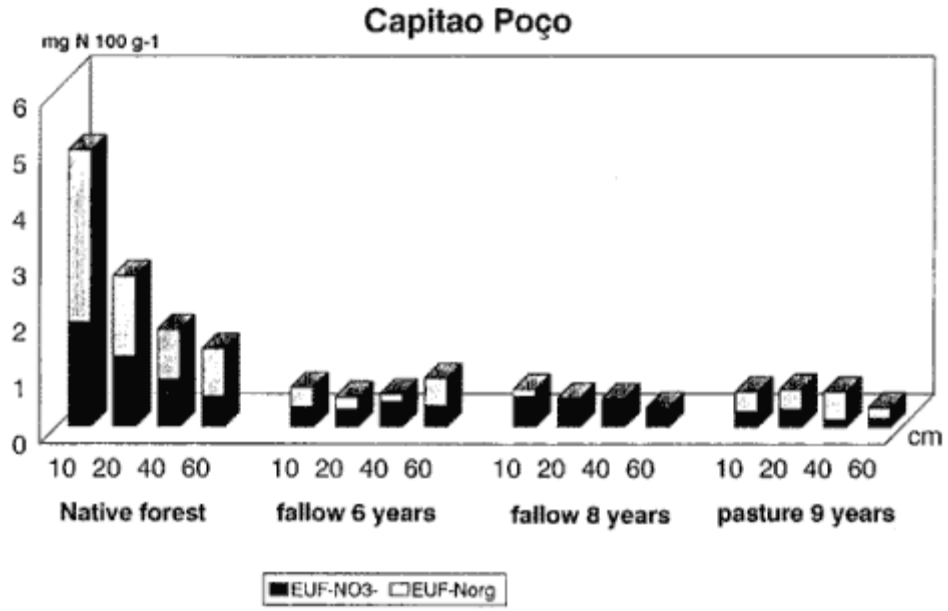

Figure 2 - Diagram of EUF-NO_3^- and EUF-Norg in native forest and abandoned and cultivated pasture at different depths (Fazenda Nova Vida, Ariquemes-Rondônia).

In Nova Vida, it was observed that the C/N ratio under the natural tree cover (Table 4) is higher than in Capitão Poço which would indicate a lower biological activity, which at the same time is highlighted by the much higher content of organic material, particularly obvious in the 12- year old pasture. Again, there is a decrease in the C/N ratio with increasing depth.

With respect to N content and forms in relation to the exploitation systems, a behavior similar to Capitão Poço was observed, since the N level in the natural forest is the highest, with a Norg/NO_3^- ratio close to 1 (Figure 2). N levels detected in the cultivated pasture and in the abandoned pasture are similar, but the NO_3^--N proportion is higher in the second. This makes it similar to the nature of the original forest organic compounds.

CONCLUSIONS

It can be conclused that deforestation has a degrading effect on soil fertility, in general. The burning effect turns into a rise in pH because of the ash effect. This is transitory, somewhat favorable for improving soil fertility conditions, but insufficient as inferred from the low P and other nutrient availabilities, as it is the case for K.

An improvement was usually obtained in K levels in cultivated pastures when these were used by cattle, through the excrement effect.

Qualitative differences between pasture, cultivated and fallow lands or abandoned pastures were found with respect to N. A slight recovery of available N levels was observed in the first, which mainly affects the EUF-Norg fraction. On the other hand, both in fallow and abandoned pasture land, a regeneration of organic compounds, closely linked to those which existed in the original forest, was observed on the basis of the higher proportion of NO_3^- they displaied and, as a consequence of a EUF-Norg/EUF

NO_3^--N ratio close to 1. This generally turns into a higher microbial activity and low N immobilization capacity.

In the quantitative aspect, the N levels detected in Nova Vida are far higher than in those Capitão Poço, where the higher precipitation level leads to the leaching of part of the nutrients to greater depths.

ACKNOWLEDGMENTS

The authors thank the Commission of the European Communities for funding project No.324, included in the Second R&D Program Science and Technology for Development. This cooperation made this research possible.

REFERENCES

ANDREUX, F.; CERRI, C. C. Current trends in research in soil changes due to the deforestation, burning and cultivation in the Brazilian tropics. **Toxicological and Environmental Chemistry**, v.20/21, p.275-283, 1989. [Links]

CADAHIA, C. Determinación simultanea de nitrogeno y fósforo en suelos y plantas con un sistema auto-analizador. **Anales de Edafologia y Agrobiologia**, v.32, p.479-498, 1972. [Links]

CERRI, C.C.; VOLKOFF, B.; ANDREUX, F. Nature an behavior of organic matter in soils under natural forest, and after deforestation. Burning and cultivation near Manaus. In: INTERNATIONAL SYMPOSIUM ON AMAZONIA; INTERNATIONAL CONGRESS OF AMERICANISTS, 46, 1989. **Deforestation and possible effects.** Amsterdam, 1989. [Links]

DIEZ, J.A. Revisión del método de determinación automatizada de nitrogeno U.V. oxidable en extracto de suelo. **Anales de Edafologia y Agrobiologia,** v.47, p.1029-1039, 1988. [Links]

DIEZ, J.A.; POLO, A.; CERRI, C.C.; ANDREUX, F. Estudio de la capacidad nutriente de dos oxisoles desarrollados sobre bosque tropical de Amazonia. **Anales de Edafologia y Agrobiologia,** v.48, p.391-402, 1989. [Links]

DIEZ, J.A.; POLO, A.; CERRI, C.C.; ANDREUX, F. Influencia do pousio e da pastagem sobre a dinamica de nutrientes em oxisoles recentemente desflorestados na Amazonia oriental. **Pesquisa Agropecuária Brasileira,** v.26, p.77-83, 1991a. [Links]

DIEZ, J.A.; POLO, A.; CERRI, C.C.; ANDREUX, F. Efectos comparativos en cultivos intensivos sobre nutrimentos en oxisoles desforestados. **Turrialba,** v.41, p.150-159, 1991b. [Links]

DIEZ, J.A.; POLO, A.; CERRI, C.C.; ANDREUX, F. Influencia del pastos en diferentes etapas de desarrollo sobre la dinamica de nutrientes en oxisoles recientemente desforestados de Amazonia. **Agricultura Tropical**, 1995. In press. [Links]

FEARNSIDE, P.M. Causes of deforestation in the Brazilian Amazon. In: DICKINSON, R.F., ed. **The geophysiology of Amazonia**: vegetation and climate interactions. New York: John Wiley & Sons, 1987. p.37-53.

LOBATO, E.; KORNELIUS, E.; SANZONOWICZ, C. Adubação fosfatada em pastagem. In: SIMPÓSIO SOBRE CALAGEM E ADUBAÇÃO DE PASTAGEM, I., Nova Odessa, 1985. **Calagem e Adubação de Pastagens**; **Anais...** Piracicaba: Associação Brasileira de Pesquisa da Potassa e do Fosfato, 1986. p.145-174. [Links]

NEMETH, K. The availability of nutrients in the soil as determined by electroultrafiltration (EUF). **Advances in Agronomy**, v.31, p.155-187, 1979. [Links]

NEMETH, K. Nutrient dynamic in some humid tropical soils as determined by EUF. In: NTERNATIONAL CONFERENCE OF "PHOSPHOTROPS", Kuala Lumpur,1991. **Conference of Phosphotrops**; **Proceedings...** Kuala, Lumpur, Malasya, 1991. p.1-14. [Links]

NEMETH, K. UF-Nitrogen determination and EUF-Nitrogen fertilizer recommendation. In: EUF-SYMPOSIUM, Mannheim, 1988. Mannheim, West Germany, 1988. p.14-46. [Links]

Recebido para publicação em 09.10.95
Aceito para publicação em 07.02.97