Table 3. Forage production in response to dolomitic limestone and phosphorus in 8-year-old weedy pasture of guineagrass-kudzu, at Fazenda Melhoramentos-PA.

Lime Kg/ha	*Phosphorus** Kg/ha P_2O_5	*Yield*** %	*Guineagrass* %
0	0	2 a+	7
500	0	5 b	9
1000	0	7 b	6
0	75	56 c	73
500	75	46 c	66
1000	75	38 c	57
0	150	40 c	58
500	150	72 c	64
1000	150	100 d	68

*Phosphorus was applied in the proportion of 1 part of triple superphosphate to 5 parts of rock phosphate, by weight.

**The forage production is expressed as a percentage of the production from the treatment of greatest yield.

+Values followed by different letters are significantly (P<.01) different. Wilcoxon test (Verdooren, 1963.)

Fazenda Melhoramentos, also on a weedy 8-year-old guineagrass-kudzu pasture, an experiment was established to evaluate the effect of P and lime on dry-matter production. The treatment consisted of 0, 500, and 1,000 kg/ha of dolomitic limestone in all combinations with 0, 75, and 150 kg/ha of P_2O_5. The results are presented in Table 3.

When P was applied alone, there were yield increases of 20- to 28-fold, and guineagrass percentages increased from 7% to 73%. Lime topdressing alone had no effect on percentage of guineagrass in the stand. But at 150 kg/ha of P_2O_5, 1,000 kg/ha of dolomitic limestone produced the highest yield. Higher rates than 100 kg/ha of P_2O_5 required the utilization of at least 1,000 kg/ha of dolomitic lime. These results confirmed the need of P and lime for adequate guineagrass production on the Fazenda Melhoramentos.

Additional tests are needed in this and other Amazon areas to determine the extent of deficient P and lime soils and to better quantify the optimum rates for maximum forage response.

Pasture Research Results in the Brazilian Amazon

E.A.S. SERRÃO
EMBRAPA, Centro de Pesquisa Agropecuária
de Trópico Úmido, Brazil

Summary

Natural upland savanna grasslands are represented mainly by well-drained savannas, with the cerrado type predominant, and by poorly drained savannas with the campo alto-type being the most common. The main limitations are low forage-production potential and, especially, low forage quality.

About 3 million ha of rain forest has been replaced by improved pastures of guineagrass (*Panicum maximum,* 80%), jaraguagrass (*Hyparrhenia rufa,* 10%), and *Brachiaria* spp. and other grasses (10%). During the first few years after establishment, pastures are productive. However, with time, a gradual decline of productivity occurs, especially in *P. maximum* pastures. About 0.5 million ha is already in advanced stages of degradation. Limiting factors include climate and plant and soil factors, besides man's influence.

Research was conducted on 14 private ranches representing the most important improved- and native-pasture ecosystems of the Amazon region, with the objective of developing technology for (1) reclaiming sown pastures at varying degrees of degradation, (2) increasing the longevity of still-productive sown pastures in forest areas, and (3) increasing productivity of low-producing native pastures. Similar trials at all sites include the following: (1) introduction and evaluation of commercial forage species; (2) evaluation of grass-legume mixtures; (3) forage fertilization; (4) pasture reclamation, improvement, and management (grazing trials); and (5) adaptation of new forage germ plasm.

Results indicate that (1) maintenance of pasture productivity requires careful management of the soil-animal-plant system; (2) even though guineagrass has been planted on 2.5 million ha, other grasses can be more successful; (3) longevity of still-productive guineagrass pastures can be increased considerably by using appropriate grazing-management systems in combination with strategic use of phosphorus fertilization and legume introduction; (4) reclamation of guineagrass pastures in advanced stages of degradation can be achieved successfully by phosphorus fertilization and by introduction of low-demand grasses such as *Brachiaria humidicola* in combination with legumes, such as *Pueraria phaseoloides*.

KEY WORDS: Amazon region, tropical savanna, tropical forest, guineagrass, Quicuio-da-Amazonia grass, *Brachiaria humidicola, Pueraria phaseoloides,* oxisols, ultisols.

INTRODUCTION

The Amazon region of Brazil has great potential for cattle production in view of its natural grasslands, water systems, solar radiation, temperature, and rainfall. The Amazon area is in the humid climate group A of the Köppen classification. Except for the northern latitudes, the rainy season begins in November-December and ends in May-June. Sunshine hours range from 1,500 to 7,000 annually (35%-65% of potential radiant energy [Bastos 1972]). At present, the region's cattle population is estimated at 7 million head.

In the last 20 years, about 3 million ha of rain forest (which covers about 85% of the region) has been replaced by improved pastures: 80% guineagrass (*Panicum maximum*), 10% jaraguagrass (*Hyparrhenia rufa*), and 10% *Brachiaria* spp. and other exotic grasses. Pasture establishment includes felling of forest, burning of the vegetative biomass, and seeding of forage grasses.

For a few years after establishment, as a consequence of increased soil fertility obtained by incorporating the ash from the burned biomass into the soil (Falesi 1976, Baena 1977, Serrão et al. 1979, Falesi et al. 1980, Toledo and Serrão 1982), pastures are fairly productive. However, with time, the pastures, especially guineagrass, gradually decline. This decline is positively correlated with weed infestations, and, in many cases, an irreverisble degradation results (Hecht 1979). Currently, some 1 million ha of pasture is still productive, 1.5 million ha is in a medium stage of degradation, and 0.5 million is in advanced stages. The main causes of the decline of productivity include climatic, edaphic, and plant factors and management (Serrão and Falesi 1977).

The natural upland grasslands of the Amazon region are represented mainly by well-drained (WD) savanna ecosystems, generically called cerrados. Their main limitations are low forage production and, especially, low forage quality, due to low soil fertility and intrinsically low production potential of the herbaceous species.

PROCEDURES

PROPASTO/Amazonia, an aggressive pasture-research program, has been carried out by Brazil's agricultural research bureau, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), since 1976 on selected private ranches—"experimental fields" (EF)—representative either of improved grassland in forest areas or of native upland grasslands. At each of 14 locations, a problem pasture area ranging from 50 to 150 ha was selected for the EF (Table 1 and Fig. 1). Nine EF are on improved pasture in forest areas, four on WD cerrado-type savanna grassland, and one on a poorly drained (PD) campo alto-type savanna (Island of Marajò, State of Pará). The existing pastures, ranging in age from 6 to 15 years, had been established in the traditional manner (clearing, burning, and grass seeding); they were in various stages of decline in productivity. Grasses were mainly in the genera *Andropogon, Trachypogon, Eragrostis, Paspalum,* and *Axonopus purpusii*. Table 1 shows the type and original vegetation of each EF and some climatic characteristics at the research sites.

Most of the improved pastures in forest areas have been established on oxisols, especially yellow latosol (YL) and red-yellow latosol (RYL) (Table 1). Large areas of improved pasture are also found on ultisols, especially distrophic red-yellow podzolics (RYP). On a rather minor scale, improved pastures also occur on concretionary lateritic soils (LAT), which are petric phases of oxisols and ultisols, and on deep acid sands (AS). In their natural state under primary forest, except for their clay content, the chemical properties of the above-mentioned soils do not differ to any large extent.

The predominant soil group in the WD cerrado-type savanna is also oxisol (especially YL and RYL). Groundwater lateritic (GWL) is the predominant oxisol in the PD campo alto-type savanna ecosystem. Both WD and PD upland savannas have very low soil fertility (organic matter, 1.0-2.5%; N, 0.05-0.1%; pH (H_2O), 4.5-5.0; Ca + Mg, 0.2-0.5 mE%; Al, 1.0-2.0 mE%; K, 10-30 ppm; P, 1-2 ppm).

RESEARCH AREAS

Similar trials were initiated at all sites along the following lines:

1. Introduction and evaluation of forages with and without phosphorus fertilization. About 20 grasses (including those most commonly used in each area) and 15 legumes were compared over a 4-year period for forage production, nutritive value, and disease, insect, and drought resistance. In general, phosphate fertilization was 50 kg P_2O_5/ha (50% each of readily soluble and less soluble phosphate).
2. Evaluation of grass-legume mixtures. Seven grasses and seven legumes were preselected on the basis of their probable success for each general area represented. Grasses and legumes were planted in mixtures of one grass to one legume with a base fertilization of 50 kg of P_2O_5/ha. The performance of each mixture was evaluated for about 4 years for compatibility between grass and legume and for forage yield and persistence. The mixtures were periodically grazed to introduce animal effects into the system.
3. Forage fertilization. In improved pastures in forest areas, fertilizer treatments consisting mainly of missing element or P level were superimposed on selected pastures representing two or three stages of productivity. Fertilizers were broadcast on native pastures or applied at planting time on cultivated pastures.
4. Pasture reclamation, improvement, and management (grazing trials). The experiment included three

The author is a Research Agronomist at EMBRAPA/CPATU.

The author wishes to thank his research colleagues at CPATU/Belém (Pará), UEPAE/Manaus (Amazonas), UEPAT/ Porto Velho (Rondônia), UEPAE/Rio Branco (Acre), and EMGOPA/Araguaína (Goiás) for the technical collaboration rendered, directly or indirectly, in furthering this study.

Table 1. Climate, soil, and vegetation characteristics at different research sites.

Site	Köppen climatic type	Temperature Avg.	Temperature Range (°C)	Average relative humidity (%)	Average annual rainfall (mm)	Original vegetation	Soil type	Predominant pasture grass
Paragominas	Am	26	21-32	82	1950	Dense forest	YL_{ma}^{1}	Guineagrass
Marabá	Aw	26	22-31	87	1530	Open forest	LAT	Jaraguagrass
S.J. Araguaia	Aw	26	20-31	78	1900	Dense forest	RYP_{m}^{2}	Guineagrass
Conc. Araguaia	Aw	25	18-32	80	1650	Open forest	GWL_{a}^{3}	Guineagrass
Ponta de Pedras	Am	27	23-32	85	2200	PD savanna	GWL_{b}^{4}	Native grasses
Macapá	Am	26	23-31	84	2400	WD savanna	YL_{m}^{2}	Native grasses
Amapá	Am	27	23-31	84	3100	WD savanna	LAT_{m}^{2}	Native grasses
Itacoatiara	Am	27	23-32	82	2200	Dense forest	YL_{ma}^{1}	Guineagrass
Boa Vista	Aw	28	23-32	73	1700	WD savanna	RYL_{m}^{2}	Native grasses
Caracaraí	Aw	27	22-31	75	1900	Wd savanna	YL_{m}^{2}	Native grasses
Ji-Paraná	Aw	27	21-32	82	1870	Open forest	RYP_{m}^{2}	Jaraguagrass
Porto Velho	Am	25	21-32	86	2340	Dense forest	YL_{ma}^{1}	*B. decumbens*
Rio Branco	Am	24	20-31	86	1920	Dense forest	RYP_{m}^{2}	Guineagrass
Xambioá	Am	26	20-31	85	2030	Open forest	AS	Guineagrass

[1]ma = very clayey texture. [2]m = loamy texture. [3]a = high phase. [4]b = low phase.
Aw = humid tropical with definite dry season.
Am = humid tropical with short dry season.

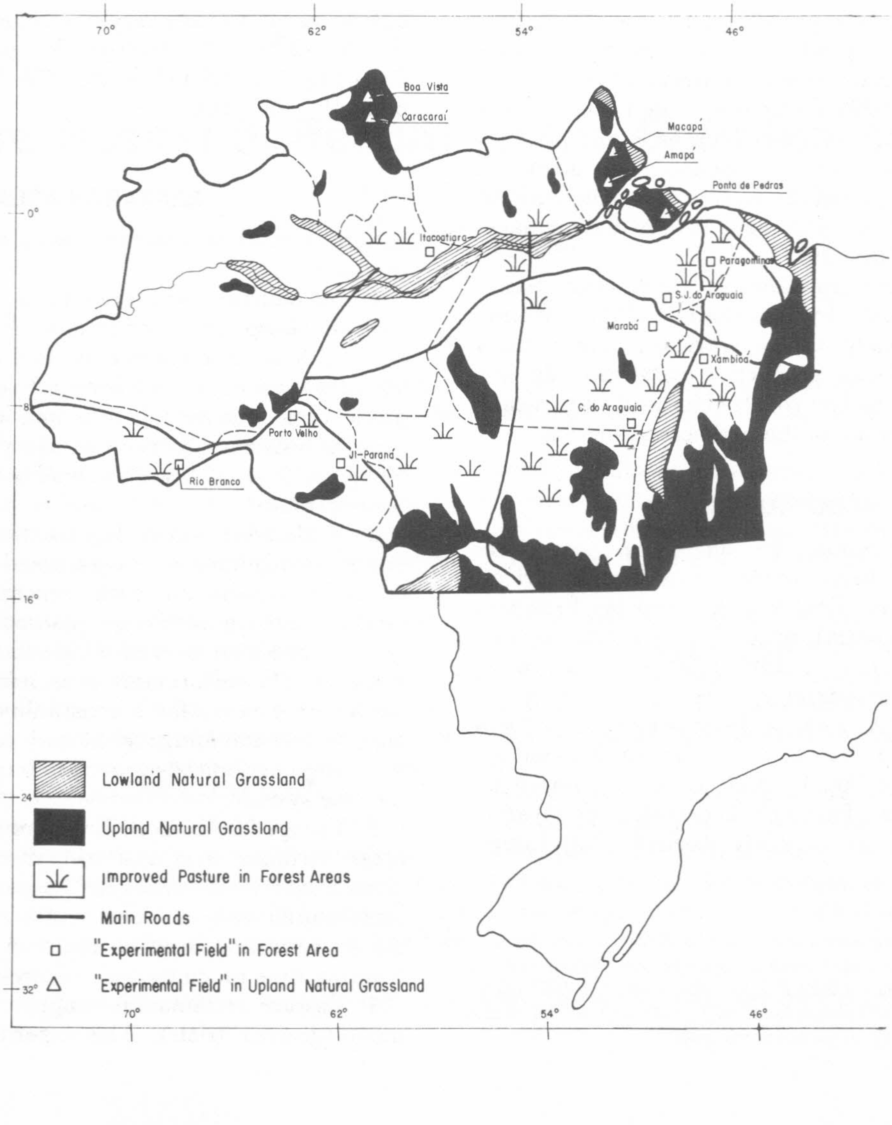

Fig. 1. Natural and improved grasslands of the Brazilian Amazon and pasture research locations (PROPASTO "experimental fields").

agronomic treatments, namely (1) control, improved or native local problem pasture (LPP); (2) LPP + P fertilization + legume introduction (L); and (3) LPP + P + L + introduction of Quicuio-da-Amazonia grass (*Brachiaria humidicola*). In forest areas, legumes and Quicuio-da-Amazonia grass were introduced in open spaces of the pasture where original grass was no longer present. In native pastures, the introduced legumes and grass either partially or completely replaced the native herbaceous vegetation. Each agronomic method was tested under continuous and/or rotational grazing, with stocking rates varying from low to medium to high, in a seasonal put-and-take grazing system

RESULTS

Improved Pastures in Forest Areas

In all EF in forest areas, the results were similar. The most productive and persistent grasses at most sites were Quicuio-da-Amazonia grass, sempre-verdegrass (*P. maximum* cv. Gongyloides), jaraguagrass, buffalograss (*P. maximum*), and setariagrass (*Setaria anceps* cv. Nandi). Guineagrass, the most commonly utilized grass, was not as productive and persistent as these grasses. The most productive and persistent legumes were *Pueraria phaseoloides, Centrosema pubescens, Leucaena leucocephala,* and *Stylosanthes guianensis*.

The results indicate that it is biologically feasible to maintain persistent high-quality guineagrass, sempre-verdegrass, setariagrass, jaraguagrass, and Quicuio-da-Amazonia grass pastures, each in association with either *P. phaseoloides, L. leucocephala, C. pubescens,* or *Stylosanthes* spp., in decreasing order of biological importance. Because of its aggressiveness, *P. phaseoloides* should be planted in strips in order to reduce its competitive effect on the companion grass.

Phosphorus was found to be the most limiting soil nutrient, particularly for guineagrass. It was also found that P limitation increases with increasing clay content of soil (above 40%). In general, the grasses of the genus *Brachiaria* were less demanding for phosphate than those of the genus *Panicum*. Responses to other nutrients were observed, but these were not as decisive and generalized as with phosphorus.

Grazing trials showed that productivity of guineagrass pastures at moderate stages of decline could be significantly improved and maintained by periodic (every 3 to 4 years) application of 50 to 75 kg of P_2O_5/ha, strategic weeding, and introduction of legumes, especially *P. phaseoloides* and/or *C. pubescens*. *P. phaseoloides* proved beneficial for controlling weeds. For pastures in more advanced stages of degradation, the introduction of Quicuio-da-Amazonia grass and legumes in bare spots proved to be a very efficient method of increasing productivity without interrupting pasture utilization for more than 4 to 5 months. Simple rotational grazing systems (three-pasture system, for example) enhanced the longevity of bunch-type grasses (such as guineagrass and jaraguagrass), especially under heavy stocking rates. Grazing trials also demonstrated the importance of forage legumes in animal performance (especially during the dry season).

Preliminary results at all sites indicate that *Andropogon gayanus* CIAT 621 is a promising alternative grass for forest areas. Economic analyses indicate that establishment of new pasture involving the clearing of forest requires a higher investment than improvement or reclamation of existing pastures. Considering a pasture life expectancy of 15 years under traditional conditions (from establishment to advanced degradation), it would be necessary to clear forest and establish more pasture to offset the declining carrying capacity. Ecologically, further pasture establishment would be highly undesirable.

Improved Native Pastures

Results indicate that in native upland grassland, management, phosphorus fertilization, and grass-legume mixtures suitable for acid and low-fertility soils are very important in increasing productivity. The carrying capacity of these grasslands can be doubled or tripled with adequate management, such as grazing pressure and fire control, grazing deferment, and mineral and protein supplementation of grazing animals. Productivity can be increased 5 to 10 times by partial or total replacement of native and guineagrass pastures with less demanding grasses, such as Quicuio-da-Amazonia grass, *B. decumbens, A. gayanus,* or even jaraguagrass, and introducing legumes such as *Stylosanthes* spp., *C. pubescens*, or even *P. phaseoloides*.

In the WD cerrado-type savannas, productive pastures of Quicuio-da-Amazonia grass can be established with 50 kg of P_2O_5/ha. Results are even better when 50–75 kg N/ha are added during establishment. In PD campo alto-type savannas, excellent pastures of Quicuio-da-Amazonia grass have been established with little or no phosphorus fertilization.

At present, the most limiting factors for adopting these new technologies are high fertilizer prices and limited credit for cattle-raising activities. However, the new technologies will probably be adopted on a large scale over the next few years, to take advantage of the residual effect of fertilization of rice and other crops, as is already occurring in the savannas of Roraima.

LITERATURE CITED

Baena, A.R.C. 1977. The effect of pasture (*Panicum maximum*) on the chemical composition of the soil after clearing and burning a typical tropical highland rain forest. M.S. Thesis, Iowa State Univ.

Bastos, T.X. 1972. O estadual atual dos conhecimentos das condições climáticas da Amazônia Brasileira. *In* Bol. Tec. Inst. Pesq. Agropec. do Norte 54. Belém.

Falesi, I.C. 1976. Ecossistema de pastagens cultivadas da Amazônia Brasileira. Centro Pesq. Agropec. Trópico Úmido. Bol. Tec. 1. Belém.

Falesi, I.C., A.R.C. Baena, and S. Dutra. 1980. Consequência da experimentação. agropecuária sobra as condições físicas e químicas dos solos das microreggiões do nordeste paraense. Centro Pesq. Agropec. Trópico Úmido. Bol. de Pesq. 14. Belém.

Hecht, S. 1979. Spontaneous legumes of developed pastures of the Amazon and their forage potential. *In* P.A. Sanchez and L.E. Tergas (eds.) Pasture production in acid soils of the tropics, 65-78. Centro Int. Agric. Trop. (CIAT), Cali, Colombia.

Serrão, E.A.S., and I.C. Falesi. 1977. Pastagens do trópico úmido brasileiro. *In* IV Simpósio sobre manejo de pastagens. Esc. Sup. Luiz de Queiroz. Sao Paulo.

Serrão, E.A.S., I.C. Falesi, J.B. da Veiga, and J.F. Teixeira Neto. 1979. Productivity of cultivated pastures on low fertility soils of the Amazon of Brazil. *In* P.A. Sanchez and L.E. Tergas (eds.) Pasture production in acid soils of the tropics, 195-225. Centro Int. Agric. Trop. (CIAT), Cali, Colombia.

Toledo, J.N., and E.A.S. Serrão. 1982. Pasture and animal production in Amazonia. *In* CIAT. Amazonia Agriculture and Land Use Research, 281-309. University of Missouri, Columbia, Missouri.

Advances in Pasture Research and Development in Santa Cruz, Bolivia

R.T. PATERSON and C.R. HORRELL
British Tropical Agricultural Mission (BTAM),
Santa Cruz, Bolivia

Summary

Cattle production is important in Santa Cruz but is low in productivity, due in part to low grazing value of natural pastures, particularly in the dry season. Other constraints to cattle production include low land values, poor management, high cost of inputs, and relatively low product prices. This program is aimed at providing higher-quality, low-cost pastures for complementary use within traditional grazing systems. Improved introduced species were identified for five agro-ecological zones, and commercial seed production of the following was encouraged: Petri guineagrass (*Panicum maximum*), *Brachiaria decumbens*, buffelgrass (*Cenchrus ciliaris*), glycine (*Neonotonia wightii*, formerly *Glycine wightii*), Archer axillaris (*Macrotyloma axillare*), lablab bean (L. *purpureus*), and stylo (*Stylosanthes guianensis*).

The value of legume-based pastures was measured and demonstrated in grazing trials, where dry-season access to legumes as mixed swards or as a protein reserve significantly improved animal production. Cattle were raised to 400 kg live weight in 30 months without supplementary feeding. These results have been used in model projections to view pasture and animal production in the whole-farm context and to illustrate the economic feasibility of pasture improvement.

Training and extension activities also were undertaken.

KEY WORDS: legumes, grasses, cattle, dry season, ranch production, seed production.

INTRODUCTION

Santa Cruz Department lies between lat 13° and 20° S and long 57° and 64° W and covers 370,000 km², one-third of all Bolivia. Population density averages only 2/km², and much land is undeveloped.

The cattle resource of 1.02 million head (CORDECRUZ 1982) derives from *Bos taurus* Criollo stock. In recent years, 70% of the stock has become crossbred with the *Bos indicus* Nellore and Gir breeds. Females 3 years old or more make up 44% of the population and are increasingly used for crossing in commercial dairy herds. If kept pure, they suffer environmental stress.

Isolated areas of natural grasslands have imperfect drainage, and other such areas have been formed by fire and grazing. The former contain grasses that are valuable for grazing when accessible, including *Paspalum* spp., *Panicum* spp., and *Leersia hexandra*. The fire-formed grasslands occur with scrub forest on sandy and shallow soils and consist of grasses of poor grazing value, such as *Sporobolus poiretti*, *Aristida* spf., *Bothriochloa saccharoides*, and *Andropogon bicornis*. Nutritional value is poor except in the young regrowth after burning (Vaca 1980), and carrying capacity is 3 to 5 ha/animal unit (AU).

Both authors are Technical Cooperation Officers of the Overseas Development Administration, London, UK. R.T. Paterson is a Pasture Agronomist and C.R. Horrell is an Agricultural Team Leader and Pasture Agronomist at BTAM with CIAT.

Many organizations have enabled this work to reach its present stage; foremost among them are CIAT, COTESU, the Universidad Boliviana "Gabriel René Moreno," and the Mennonite Central Committee. Permission to publish this paper was granted by CIAT and ODA.