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Soil, plant and cattle nutrient dynamics on pastures of the western Amazon of Brazil

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Introduction Cattle production on *Brachiaria* pastures is a primary use of cleared forestland in the western Brazilian Amazon. About 6.8 million hectares in the States of Acre and Rondônia have been deforested, where 75% of land is now grazed (IBGE, 1998). The principal pasture species are *B. brizantha* and *B. decumbens* with the latter in decline from spittlebug susceptibility (*Deois incompleta*; Gonçalves et al., 1996). The general pattern of pasture establishment in the Amazon basin includes felling and burning forest biomass, planting annual crops for one to three years (especially on small farms), and then seeding to grasses. The conversion of tropical forest to pasture, the effects of that process on soil properties, and pasture degradation outcomes have been studied in the eastern Amazon region (Serrao *et al*., 1978; Reiners *et al*., 1994; Sanchez and Salinas, 1981; Buschbacher *et al*., 1987; Moraes *et al*., 1996) but not in the remote western region. Most findings showed an initial increase in soil cation concentrations with pasture establishment, except P, which declined to nearly undetectable amounts; and losses in pasture productivity after about five years with little management and poorly matched grasses (Serrao *et al*., 1978). The extent to which this outcome is due to poor management practices (e.g., inappropriate grass species) is unknown, and few studies in the region have examined the impacts of stocking rates, soil-plant nutrient relationships and burning frequencies on pasture degradation. Strategies that account for the cycling of major nutrients are needed to improve management of grasses and grass-legume associations. The objective of this study was to evaluate the hypothesis that low-input pasture use of land with *Brachiaria spp*. effectively sustains cattle production in the western Brazilian Amazon without deteriorating soil nutrient stocks. Three pasture land cover types (*B. decumbens*, *B. brizantha* and a grass association with *Pueraria phaseoloides*) were compared to primary forest and crops (maize and rice). Temporal (i.e., time post-deforestation) effects on the physical and chemical properties of soils and forages were evaluated. The nutrient pools in soil, plants and cattle herds and nutrients extracted in animal products were approximated to help understand the essential management to enhance cattle productivity and to avoid land degradation.

Material and methods The study sites were collaborating private dual-purpose (milk and beef) and beef cattle farms within 80 km of the city of Rio Branco in the State of Acre, Brazil, a moist humid tropical region at 07º 07'south and 66º 30' west with mean annual precipitation ~1800 mm. The predominant soils are Ultisols and Oxisols. Observations were recorded from October 1999 to June 2000. A total of 96 soil samples were collected from the topsoil (0 to 10 cm) at three forested locations adjacent to two cropping areas and 17 paddocks (5 to 243 ha) that varied in pasture species and time (4 to 20 yr) since clearing. Soils from adjacent primary forest and cropping areas were references for soil nutrient changes in pastures. Samples were dried and analyzed for Ca, Mg, Al, K, P, C and acidity. Soil physical properties included bulk density at depths of 0 to 5 cm and 5 to 10 cm. Soil chemical and physical properties were evaluated using a mathematical model containing the fixed effects of farm, land cover and their interaction, linear and quadratic effects of time (years) since forest clearing, and soil clay content as a covariate. Forage samples were collected from the grazed portion (animals selected from the top 20 cm) of plants, separated into leaves and stems, dried, ground and analyzed for Ca, P, Mg, K and N. Monthly plant biomass accumulation was estimated using the cutting-quadrants method with plants cut 20 cm above ground (total plant height was ~80 cm) and separation of leaves from stems and senescent material. Quantities of minerals consumed and excreted by animals were estimated using the Cornell Net Carbohydrate and Protein System model (Fox et al., 2000), assuming daily forage dry matter intake of 2.5% of animal body weight.

Results Type of land cover either directly or by interaction with farm influenced the soil stocks of Ca, K, P ($P < 0.01$) and C ($P < 0.05$). Soil C and P were least under *B. decumbens* (1.2 g kg^{-1} and < 0.5 mg kg^{-1}) and the grass-legume association (1.2 g kg^{-1} and 3.8 mg kg^{-1}). Although the P content of grazed foliage indicated that plant growth was unconstrained, soil P was most limiting. Soil nutrient stocks and pH increased slightly with pasture age, or time post-deforestation, except for Mg. The bulk density (1.4 g/cm^3) in topsoil was similar to other Amazonian pastures. Approximate nutrient exports in sales of milk and animals, mortality and culling for average stocking with two 450-kg animal units (AU) ha^{-1} were 6 kg N, 5 kg Ca and 3 kg of P ha^{-1} yr^{-1} (Table 1), which were relatively small compared to published export values for maize, rice, beans, cassava or coffee crops (Fernandes *et al*., 1997). We estimated that 50% to 90% of the nutrients consumed by animals are potentially returned to the soil in excreta. Topsoil was the largest nutrient stock, containing ~70% of P and K, 98% of Ca and 89% of Mg. Monthly pasture biomass accumulation with average stocking was ~2.8 ton ha^{-1} mo^{-1} (Figure 1). Grazing intensity was low because animals were forced to selectively feed only from the top 20 cm of the plant, with higher nutritional quality. The remaining 60% of accumulated dry matter, consisting of mature and senescent material of limited feed value, constituted the plant litter pool for recycling. Nutrient cycling and productivity potentials of Acre cattle systems may be enhanced by grazing management and plant species choices. Greater stocking with rotational grazing and electric fencing (used by some farmers) is an alternative to currently under-grazed pastures, where most nutrients in this low-equilibrium system are probably returned to the soil via plant litter and burning. With more intensive grazing more forage

Table 1 Estimated quantities of minerals leaving cattle systems[a] in milk and animals in Acre, Brazil.

	Nutrient, kg $ha^{-1} yr^{-1}$				
Cattle system	Ca	P	Mg	K	N
Dual purpose					
Milk	3.3	2.7	0.03	3.30	1.6
Calf mortality	0.1	0.1	< 0.01	0.04	0.2
Male calves sold	0.7	0.4	0.02	0.30	1.5
Culled and dead cows	0.6	0.3	0.02	0.20	0.9
Total	4.7	3.5	0.07	3.84	4.2
Beef					
Finished steers	4.2	2.4	0.13	1.30	5.4
Calf mortality	0.1	0.1	< 0.01	0.04	0.2
Culled and dead cows	0.6	0.3	0.02	0.20	0.9
Total	4.9	2.8	0.15	1.54	6.5

[a] Calculations correspond to average stocking rate of two 450-kg animal units ha^{-1}.

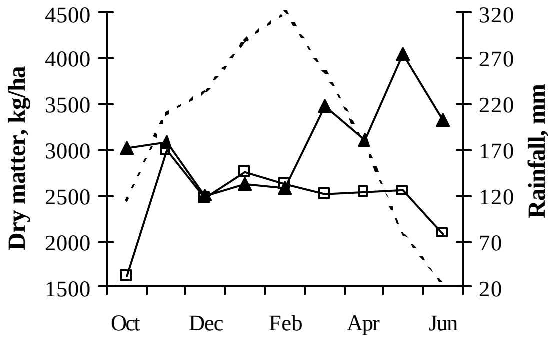

Figure 1 Monthly rainfall (---) and biomass accumulation of *Brachiaria decumbens* (?) and *B. brizantha* (?) on three farms in Rio Branco, Acre, Brazil.

nutrients would be ingested and recycled more rapidly in manure. Shifts in nutrient dynamics would be expected from greater yields of better quality forage, more rapid extraction of nutrients from the soil, a reduction in the amount of plant litter to recycle, and more nutrients from excreta.

Conclusions Low-input land use with *Brachiaria* pastures at these Acre locations has sustained extensive cattle grazing systems without major deterioration in soil resource stocks. However, low topsoil stocks of P indicate potential fragility in the pasture system. Pasture biomass accumulations far exceeded the feed dry matter required for the typical stocking rate of 2 AU ha^{-1}. This low grazing pressure forced animals to feed selectively, and the remaining plant material primarily constituted a pool of slowly recycled nutrients (litter) that is unavailable to animals. This suggests the potential to improve productivity of the system through increasing grazing intensity. Although periodic applications of N and P is a blanket recommendation (Carneiro and Valentim, 1997) that is rarely followed, soil stocks could be maintained at low cost by replacing the nutrients extracted in animal products. More effective (and profitable) management with higher stocking requires further quantification of the dynamics of nutrient stocks and flows under alternative management practices. This includes the decomposition characteristics and nutrients released from feces, urine and litter from plant species.

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