The Environmental Effect of Cattle Development in the Amazon Basin

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In Amazonia, the development decades of the 1960's and 1970's were characterized primarily by the expansion of cattle ranching. Through massive infrastructure development and fiscal incentives, livestock production eclipsed all other agricultural land uses both in area and investment. While colonization programs were well publicized and served important ideological ends, the conversion of tropical forest for pasture is the hallmark of much Amazonian development, especially in Brazil and Colombia. The ~~conversion~~ transformation of vast areas of forest for grasslands has resulted in a great deal of controversy in both biological and social sciences. Questions pertaining to large-scale ecological changes such as species extinctions, climatic effects, and hydrological effects are rife in the literature. Further, expansion of this land use has been associated with bitter land conflicts, increasing peasant marginality, increases in land concentration, and a dramatic rise in rural to urban migration.

This paper explores the magnitude of clearing, emphasizing that ranching is the dominant use for converted areas. General features of tropical forests are briefly discussed, as well as the broad soil changes after conversion. The agronomy of ranching is discussed and the specific effects of conversion of tropical rainforest to pasture are evaluated. Finally some of the social implications of this land use are addressed.

Magnitude of Deforestation

The extent of conversion has been a source of contention with various authors including values as high as 30% (Cox 1978)) to those arguing less than 1% (Lugo and Brown, in press). The unreliability of much of the data base, definitional differences and the historical period encompassed have all contributed to the confusing assertions about the rate and area cleared. Until relatively recently the inaccessibility of the area completely defied anything other than speculation about the magnitude of deforestation. The use of LANDSAT data has improved the situation enormously. In a very interesting study, Tardin, et al. (1977) presented useful results about clearing estimates and reality. In the Barra de Garcas region of Mato Grosso, a major Amazonian ranching area, Tardin interviewed ranchers about how much land they thought they had cleared, and compared these with LANDSAT images. The tendency of the interviewees was to overestimate by about 25%. Some were as much as 68% off. LANDSAT data are not without their problems, especially given the high frequency of cloud cover in the Amazon, but it is certainly a vast improvement.

An important definitional question is whether secondary forested areas should be considered as forest or cleared area. Brown (1979) indicated that about 8% of the Basin is in secondary forests, presumably as a consequence of land abandonment following agriculture or cattle, yet the deforestation evaluations by Tardin, et al. (1979b) do not treat this question. Finally, LANDSAT imagery has only been in use during the 1970's and in many of the southern reaches of Amazonian forest, land clearing has been occurring for more than twenty years. Some Amazonian areas of Northern Goias and Mato Grosso were permanently converted from forest decades ago. These kinds of questions still remain to be publicly resolved and are responsible for the diversity of clearing estimates.

The best data available for clearing in the Amazon are derived from LANDSAT photos, but only Brazil, at this time, has made the results easily available. This information along with other estimates for the other Amazon countries, is presented in Table I. It is emphasized that these are "ballpark" numbers. As Table I suggests, the annual clearing rate in the Amazon at the close of the 1970's was over one million hectares per year. Published data from Colombia (Alarcon, et al. 1980) and Brazil (Tardin, et al. 1979) indicate that at least 14 million ha. have been cleared just in these two countries. The detailed data for the Brazilian Amazon is presented in Table 2 and shows that between 1976-1978 more than one million ha./year were cleared in the Brazilian Amazon alone. Tardin (1979b) has shown that in areas where clearing has been particularly pronounced, almost one-third of the forest areas have been converted to other land uses, usually cattle ranching. Rates of deforestation are erratic, however, reflecting credit policies, subsidies, interest rates, colonization projects, peasant situations in other parts of the country, national and global investment patterns, and speculation.

Amazon forests are among the most ecologically complex and least understood vegetation formations on the planet. Amazonia encompasses the largest reserve of tropical moist as well as seasonal forest (UNESCO 1978). The number of plant species contained in the Amazon is thought to lie between 250,000 and one million (Lovejoy and Schubart 1980). The extraordinary richness of Amazon forests has masked the low fertility of the soils on which they generally occur. The combination of biological exuberance and impoverished soils has made the development and occupation of these regions fraught with difficulties.

At the broadest level, Amazonian forests are generally classified into floodplain (varzéa) and upland (terra firma) forests. However, Amazonian vegetation is far more complex. Vegetation and forest surveys have been carried out in the Amazon by the Food and Agricultural Organization of the United Nations (FAO), the Brazilian Institute of Forestry Development (IBDF), and RADAM (Radar Imagery of the Amazon), but detailed information on Amazonian forest dynamics remains spotty. While 85% of the Amazon is covered by high biomass species rich forests (Prance 1978), these are more usefully perceived as mosaics of relatively analogous structure rather than as essentially of uniform formation. Pest potential after conversion, resilience, and conservation value are also highly variable. The distribution of forest types in the Amazon is correlated with a complex of climatic edaphic and phyto-historical factors, the interrelationships of which are by no means clear.

Changes in biomass, species composition, and to an extent morphology, often correlate with climate. Cochrane and Sanchez (1981) have used the presence of a pronounced dry season to differentiate the moist forest of western Amazonia from the semi-deciduous forests of the eastern Basin.

The existence of high biomass, ecologically complex forests on depauperate soils is primarily a function of nutrient cycling. Amazonian forest cycling pathways are reviewed elsewhere (Herrera 1978, Stark and Jordan 1979, Klinge 1973) but consist of structural, physiological and symbiont associations that recirculate and sequester nutrients in biomass and litter. Table 3 shows the relative amounts of nutrients stored in several different tropical forest systems. As is clear, most of the Ca, Mg and K are held in the living plants.

Soil Dynamics after Conversion

When forest lands are converted to other uses, the nutrients held in the biomass are largely shifted into soil nutrient storage, crop and weed tissues, or are lost through leaching, erosion and exports of the products away from the site. Since high biomass forest systems (as much as 500 tons/ha.) are replaced by agroecosystems with biomass usually less than 20 tons/ha., one of the major questions in conversion concerns the fate of the nutrients when forests are cut and burned. First, as Silva (1979) has indicated, only about 20% of the forest is effectively burned, and even this value is variable. Leaves, small trunks and branches combust, but the larger tree boles are often gathered together and burned again (coivara) or simply left to rot. This means that is is possible to have a delayed release of nutrients as decomposition proceeds, and suggests that in many cases the soil nutrient increases (and later declines) may not necessarily be dramatic. In general, after cutting and burning, soil levels of organic carbon and nitrogen and possibly sulphur drop as a consequence of volatization. Soil pH increases due to the addition of large amounts of Ca, K, Mg, and lesser amounts of P released from the forest with burning. The liming effect of the base rich ash serves to reduce much of the aluminum saturation common in Amazonian soils. P levels initially increase as a result of soil heating, ash additions, and with large pH increases, from "fixed" P in aluminum and iron sesquioxides. These changes reverse themselves with time. The rates and magnitude of nutrient change are affected by numerous factors including initial forest composition, clearing techniques [Silva 1979, Kang 1977] (discussed elsewhere in this vol.) and land use following conversion.

delete

[Tropical species, like those in the temperate zone, accumulate chemical elements differentially, both in the secondary and climax communities. Silva (1979) analyzed the ash from several known species in the Atlantic Rainforests of Bahia, and found a range in composition from .18 to 4.27 for Ca, .17 to 21.03 for Mg, 38.37 to 345.5 ppm for K, and from .44 to 13.39 for P in the 25 species he examined. Differences in nutrient contents for Amazonian pasture weeds have also been documented by Hecht (1979). Kang (1977) has studied the influence of forest species on soil properties after clearing in Nigeria, but the effect of forest composition on soils after burning in the Amazon remains a fascinating research question.]

Land Pressure in Amazonia

The pressure for land acquisition in the Amazon comes from several quarters. Increased mechanization and the decline of a variety of tenancy relationships in other agricultural zones, the closing of older frontier areas, as well as demographic increase, has served to create a huge landless population, who migrate to the Amazon to seek their fortune. These become the squatters on government and unoccupied (though often owned) lands, and the labor force for large scale clearing.

At the same time, the increased importance of land in corporate portfolios, coupled with attractive credit lines for Amazonian investment, low capital gains taxes, and minimal control and monitoring of land acquisition, have created a speculative search for land unparalleled in recent Amazonian history (Mahar 1979, Mueller 1980, Pompermeyer 1979, Schuurman 1979).

High potential profits (up to 100%/year according to Mahar 1979) produce an environment that favors the legal or illegal concentration of land into latifundia. While agronomic research oriented to enhancing small scale production systems is of major merit, the speculative nature of the Amazonian land economies, plus infrastructure, input and transport difficulties at this time, favors larger holdings to the detriment of colonists. In Latin America (Parsons 1976), and particularly in Brazil (Furtado 1963), cattle have historically played a major role in occupying contested land and continue to do so today. Various fiscal incentives and credit lines, ease of implantation, and possibility of discovering other valuable resources (gold, tourmalines, oil, diamonds), and the speculative gains have fueled the transformation of agricultural land and forest into pasture.

Conversion of Agriculture to Pasture

When a cropping phase precedes pasture, several pathways for the transformation of land use are possible. One important way, widely employed by the less capitalized ranchers, is troca pela forma (trade of one year's use for pasture formation). Land is lent to the small cultivator to clear and cultivate for one year in exchange for which the farmer shares his crop and agrees to plant pasture. After the cropping cycle, he may relocate to another parcel on the ranch, or move away. The rancher then introduces his cattle. Another technique is simple appropriation. This may be done through legal or semi-legal means (contested titles or surveys) or by running the farmer off the land through violence or threat of violence (Souza-Martins 1980, Almeida 1980, Pompermeyer 1979). In lands that have been spontaneously settled by small farmers, who are then followed into the region by middle sized, mostly non-corporate ranches, this technique is not uncommon (Souza-Martins 1980, Almeida 1980). Land, of course, can also be bought.

Pasture

Pasture is the ultimate destiny of much of the land initially used for forestry or cleared for agriculture. Toledo and Serrão (1981) estimate that about 6 million ha. of the Amazon forest have been converted to pasture, and of this about 1 million ha. are degraded. I feel that these figures underestimate both the area cleared and the magnitude of degradation. Alarcon, et al. (1980) indicate over 3 million ha. have been converted to pasture in the Colombian Amazon. This information coupled with the Brazilian data in Table 2 argues for an area in pasture of at least 14 million hectares, particularly if we consider that much of the Bolivian, Peruvian, and Ecuadorian Amazon are also in pasture (Gazzo 1981, de la Torre, Pereira and Salinas 1981). Tardin (1979a) analyzing ranches in the Barra de Garcas area of Mato Grosso, generally considered the most successful upland cattle region in the Brazilian Amazon, used LANDSAT imagery and ground truth testing to evaluate the level of pasture decline and weed invasion. He found that about half the pastures in the area he examined were degraded--that is, heavily brush invaded. The poor quality of pasture and extensive weed invasion in Paragominas Para, another major cattle development area, suggest a level of degradation exceeding 50%.

Only a few grass species are used in the Amazon for pasture formation. In the Brazilian Amazon, Panicum maximum, colonial guinea grass, is planted to about 85% of the area (Serrao and Simao-Neto 1975, Toledo and Serrao 1981). Brachiaria decumbens was also initially widely planted, but the attacks of spittle bug, Deois incompleta, has limited the use of this grass. In the Paragominas area, over one-third of the pastures planted to Brachiaria were destroyed by insect attack (Hecht 1981). Brachiaria humidicola, or Kikuyu da Amazonia, with its resistance to spittle bug and tolerance to low nutrient soil, is gaining ascendance. In the western Amazon, Axonopus micay and A. scoparius are the most important forage grasses. A grass of interest due to its high productivity on poor soils is Andropogon guyanus (Toledo and Serrao 1981). Most of the research on ranching has occurred in areas planted to Panicum, so a brief discussion of the major characteristics of this important forage is in order.

Panicum maximum is probably the most widely planted forage grass in Brazil (Martins 1963). The cultivation and the management of this is particularly well developed in southern Brasil, where it is the foundation of the beef fattening industry (Pardi and Caldas 1968, Santiago 1970, da Silva-Dias 1968). Based on the success of Panicum-based cattle production, and the relative success of the Commission for the Development of Cattle Raising (CONDEPE) projects in southern Mato Grosso and Goias, Panicum production systems were transferred in toto to the Amazon from the southern and central Brazilian ranching areas.

The source areas for Panicum in Africa are the savanna regions associated with volcanic, high base soils in areas that are farther than 12 degrees south. These two factors, relatively high nutrient requirements and adaptation to variable day length, are essential to understanding the poor performance of guinea grass in the Amazon. The grass is relatively nutrient demanding for P and N. In the impoverished soils of the Amazon, except for the few years right after clearing, the grass becomes stressed and cannot compete well with better adapted woody and weedy species. N, P, and K deficiencies have all been documented for guinea grass in the Amazon (Koster, et al. 1976).

Coloniao (the Brazilian name for the grass) has low seed viability (about 27% according to Agroceres (1978), a major seed supplier) under the best conditions. Two factors in the Amazon Basis reduce seed viability even further. First, Panicum in optimal situations generally seeds twice a year, but in the Amazon continuous seeding occurs. This results in low quantities of seed at any given time, and lower germination since seed may fall during periods when the climate may not be favorable. The high humidity in the region also favors powdery mildew attack (Serrao and Simao-Neto 1975) that further reduces seed production and success.

Panicum plants become senescent within five years (Vincente-Chandler, et al. 1974), and productivity declines in the Amazon on experimental plots corroborate this trend (Simao-Neto, et al. 1973). Without continuous vigorous establishment of new plants, the yield reductions are quite predictable, and are certainly compounded by the soil nutrient declines that also occur, particularly for phosphorous.

The bunch grass morphology of Panicum results in relatively large areas of open ground between individual plants when pastures are grazed. This can produce erosion between plants, and soil compaction due to rainfall and trampling. Increased compaction further reduces the capacity of Panicum seedlings to establish themselves. The open area between the grass can also be colonized by weeds that, for a variety of reasons (Hecht 1979), can outcompete grasses. Another feature of the bunch grasses in the Amazon is their relatively shallow rooting depths. This may reflect increasing Al levels in the soil subsurface. The roots rarely reach below 30 cm. which limits plant ability to capture nutrients below this depth, and subjects the plants to dessication during the dry seasons.

While there are serious problems associated with <u>Panicum</u>, it is still considered to be one of the best fattening grasses by local ranchers. Seeds are readily available from several suppliers, and the establishment of the pasture is relatively simple: forests are cut, burned, and at the beginning of the rainy season the panicum is usually aerially seeded.

<u>Soil Effects of Conversion of Forest to Pasture</u>

The effect of <u>P. maximum</u> pastures on soil properties has been examined by Falesi (1976), Fearnside (1978), Serrao, et al. (1979) based on Falesi's work, Toledo and Morales (1979), and Hecht (1981).

Studies of the effects of conversion have focused on the Paragominas, the Southern Para Araguaia regions, and the municipios of Caceres and Barra de Garcas in Mato Grosso. These are the areas where conversion has proceeded for the longest time and where investment has been most pronounced. The data on the effects of conversion ~~is~~ are presented in Figures 1 through 8 (Hecht 1981). It is important to look at these data with the sampling methodologies in mind: Falesi's and Serrao, et al.'s data are based on one composite sample of five sub-samples; hence we have no idea of the variability within those samples or how sample sites were chosen. Hecht's data are based on 20 random samples (per age class of pasture) at 4 depths for a total of 80 samples per pasture.

A more complete statistical analysis of this data is presented elsewhere (Hecht 1981), but the salient features of the effects of conversion are easily seen in the figures. As Silva (1979) and as the deviations from the mean indicate, there is great variability in the nutrient contents of the ash added to soil, so pronounced distortions can occur when the sample size is small. The data of Falesi and Hecht are shown together in the figures for comparison.

pH [Fig 1]

When forests are felled and burned, an increase in the soil pH occurs as bases held in the biomass are transferred to soil storage (Nye and Greenland 1960, Sanchez 1976), regardless of the land use implemented. This liming effect is documented for annual crops and is presented for comparison in Figure 2. The pasture data indicate substantial increases in pH for three of the four sites sampled, and in the first years after burning, high variability in the remaining site, reflecting the variation in the distribution and nutrient contents of the ash. In the larger data set (Hecht's), the range in the pH's included some samples that are comparable to the other Paragominas sites, but the overall mean increase was about half a pH unit (similar to Seubert, et al.'s rice cultivation data, discussed elsewhere in this volume), while the other sites registered increases of 2 pH units.

One of the interesting aspects of the pH data is that the "liming" effect is maintained. Sanchez (1981) and Toledo and Serrao (1981) believe that the high cycling capacity of the grass is responsible for the persistence of the pH improvement. While Teitzel and Bruce (1972) have shown that Panicum is a reasonably effective cycler of Ca, Mg and K, there is an additional explanation that should also be considered. When forests are cut and burned for pasture, a great deal of slash remains on the ground. Since about 80% of the ecosystem Ca is stored in the boles and large branches of trees, as was discussed in an earlier part of this paper, their gradual decay could supply this element at a rate that could maintain the pH. This hypothesis does not, of course, exclude the possibility of nutrient cycling by the grasses.

Ca and Mg [Figure 3]

Closely associated with the increase in pH are the additions of Ca and Mg in the soil. The augmented values are most pronounced in the years immediately after clearing (as is the variability in this element) with the initial shift from biomass to soil storage when forests are burned. Since rainforests store close to a ton of Ca and Mg per hectare, and the ash additions immediately add about 100 kg. of Ca/ha. (Seubert, et al. 1977), the increases and the capacity to maintain them are not particularly surprising.

The increases in Ca and Mg (and the commitant pH amelioration) have been used to assert that conversion of forest to pasture actually improves soil properties. It bears pointing out that the values of Ca and Mg for all sites are lower than the soil values for these elements under unfertilized rice studied for four years in continuous cropping (Seubert, et al. 1977), see fig 2 for which no such claims are made. Further, even with the increases after burning, bole decay and cycling by the grasses, Ca and Mg levels oscillate around values that place them in the lower range of Ca and Mg contents of all Amazonian soils according to an analysis of fertility parameters by Cochrane and Sanchez (1981). The larger data set, as well as the Mato Grosso Oxisol and the Paragominas Ultisol, show relatively modest absolute increases.

Potassium [~~Table~~ Fig 4]

K, as mentioned, in a monovalent cation stored largely in the vegetation that cycles relatively quickly and is considered quite vulnerable to leaching. Amounts of K in the vegetation are comparable to those of Ca. When forests are cut and burned, K levels increase in soils, but the values are erratic throughout the pasture sequence reflecting periodic burning, levels of weed invasion, and other management. K values after conversion for both Paragominas sites are roughly similar, and correspond to the values of the Yurimaguas, Peru Utisol examined by Seubert, et al. (1977). The higher Mato Grosso value may reflect higher initial soil K levels, as well as species composition. In the Mato Grosso sample sites of Falesi, the forest is relatively rich in palms (RADAM 1975), which Silva's (1979) and de las Salas'

(1979) data show register high in K. The use of burnt leaves as a salt substitute is well known and documented for many Indian groups in the Amazon. The palm Inaja (Martiana inaja) is an important forest component and pasture weed in the Barra de Garcas area of Mato Grosso and could contribute to the maintenance of these high K values.

Phosphorous [Fig 5]

Phosphorous is the most crucial element for pasture production in the Amazon (Koster, et al. 1976, Serrao, et al. 1979, Toledo and Serrao 1981), and 10 ppm is usually considered the minimum value for sustained production of pastures. After conversion, the P values increase dramatically, but by the fifth year they hover at about 5 ppm, and steadily decline thereafter.

The decline in P has been identified as the major reason for pasture instability in the Amazon (Serrao, et al. 1979). The high demand of Panicum for this element, coupled with losses due to erosion and animal export, and the competition the grass experiences from weeds adapted to low P (adapted weeds) leads to drastic drops in pasture productivity, which often results in pasture abandonment. Serrao, et al. (1979) and Koster, et al. (1976) have shown Panicum's excellent response to P fertilization, but the high transport and application costs, coupled with the erratic availability of P fertilizers in much of the Amazon, make widespread pasture fertilization rather uneconomic at this time.

Nitrogen [Fig 6]

Soil nitrogen is a dynamic between N accumulating functions like N fixation, atmospheric additions, and organic matter decay; and N decreasing processes such as volatization, denitrification, leaching, erosion and plant uptake. Many of these processes are mediated by the biota, and as the rates of loss and addition are also influenced by environmental factors (pH, temperature, soil moisture), this is an element that can vary strongly from site to site. The Paragominas Ultisol shows an initial slight increase after clearing and a subsequent equilibration suggesting that the differences between forest and pasture N storage is insignificant. In the clay loam Oxisol, soil N increased after conversion. Since those pastures were planted to the legume Pueraria phaseoloides it may be that the doubling in soil N reflects N fixation by this aggressive plant. The heavy clay Oxisol from Paragominas and the Oxisol from Mato Grosso both show N declines, although the Paragominas clay is decidedly more erratic. The high N values at the year 13 in Paragominas Oxisol may reflect N fixation by native weedy legumes and other N fixing organisms. The Mato Grosso site shows a decline in N of 50% after conversion.

No N fertilizer is used on Amazonian pastures, and the introduction of legumes with forages is not widely practiced (Serrao and Neto 1975). Management factors that may have affected the variability in the sites include burning (volatization and possible erosion losses), overgrazing, use of weed invasion as a temporary fallow (N possibly increasing) and the use of legumes (N increasing). Since the rangeland management for most of the sites is unknown, the N dynamics of Amazonian pastures remains a promising research area.

Organic Carbon [Figure 7]

The percentage of organic carbon in Amazonian soils is quite variable, ranging in total storage from .92 to over 124 kg/m^2 (Zinke 1976). Carbon levels in pastures are affected by burning, grazing pressure, length of dry season, soil moisutre regime, soil texture, species composition, and decomposition rates: in short, anything that influences organic productivity or decomposition. Not surprisingly, carbon levels are erratic over the time sequence, between sites, and within sites.

Soil carbon levels often drop with burning, but can increase if there is addition of fine charcoal, as probably occurred in the clay loam Oxisol. C levels can increase after burning as a consequence of slash decomposition and the high productivity of Panicum pastures after P becomes seriously deficient. Heavy weed invasion can also increase soil C values. The high carbon values in the clay loam Oxisol at year 11 and in the clayey Oxisol at years 11 and 13 reflect heavy weed infestation. Increases in soil organic matter by secondary vegetation rise to levels almost equal to those of virgin (documented by Schubart 1976), that can affect the rate of sheet erosion. Erosion rates under young pastures have been studied by MacGregor (1980) in the Caqueta region of Colombia, where it was found that pastures have low erosion losses. The study did not include the grazing animal, or the influence of periodic soil exposure after burning, so the results must be extrapolated with caution.

Amazonian pastures are rapidly invaded with weeds, and these also act to reduce pasture productivity by competing with forage grasses for nutrients and water. Although many weed species are in fact browsed by animals (Hecht 1979), weed control is expensive, and absorbs about 20% of a ranch's operating costs. Ranches that do not receive fiscal incentives are squeezed between the declining productivities, escalating weed and infrastructure repair costs. Not surprisingly, when ranches pass the five-year mark, they are frequently sold or repossessed. By 1978, about 85% of the ranches in Paragominas had failed, according to the director of the Para cattlemen's cooperative, Dr. Claudio Diaz.

The productivity declines that follow the first years after conversion, coupled with the enormous speculative gains in land value in the Amazon (Mahar 1979), result in a situation that further exacerbates the instability of existing pastures while favoring the expansion of this form of land use. Speculative ranchers employ two basic strategies to maximize their returns over the short run: steer fattening operations and overgrazing.

Fattening operations involve buying young stock and fattening them and selling when the prices are good. Fat steers are relatively liquid assets and can be sold or withheld in response to market conditions. Fattening animals require little more than a few cowboys and can be handled in large paddocks. This reduces labor and infrastructure costs (fences, handling corrals) substantially in comparison with the labor demands, high quality and smaller pastures, and high costs associated with managing cow-calf operations. Steers are robust and can tolerate weedy pastures better than breeding cows with calves, without the risk of damaging expensive brood stock and excessive calf mortality. This tolerance also means that pastures do not need to be cleaned as often, further reducing labor requirements. Credit for fattening operations is relatively easy to obtain, because the banker can expect to see his money returned within three years. When inflation rates are high (in Brazil they have been well over 40% since 1977), short-term notes are favored by financial establishments. Brood cow operations involve the initial purchase of fairly expensive animals (heifers and bulls) with a delayed return on the investment of at least five years (Serete 1972). In an attempt to break the
(Conselho de Desenvolvimento de Pecuária)
fattening cycle, CONDEPE and SUDAM (Superintendency for the Amazon) developed preferential credit lines at low, subsidized interest rates to promote cow-calf production systems, but the credit, extension and fiscalization requirements are such

that only the larger, well-capitalized corporate entities can afford to take advantage of them.

Given the high productivities of the first years, ranchers try to maximize their returns as quickly as possible, and they do this simply by overstocking. Pastures often experience stocking rates four times the "optimal" rate of .75 to 1.0 animal units per hectare. Overgrazing exacerbates the fertility decline (Toledo and Serrao 1981) and favors weed invasion, but with this practice the landowner is still likely to get a reasonable return on his initial animal and clearing investment. Since land values increase by about 100% per year in the active development areas, the rancher can pocket a tidy profit on the land itself (since even tho' the productivity of the land is declining, its value is increasing) and begin a new cycle elsewhere. While clearly not all ranchers are as predatory as the situation just described, the speculative nature of Amazonian land economics makes this pattern a common one. As a consequence, the turnover in land titles in the cattle and development areas of the Amazon has increased dramatically in the last fifteen years (Santos 1980, Pompermeyer 1979, Hebette and Acevedo Marin 1979).

Land values increase both for pasture as well as virgin forest. Mahar (1979) points out that investors in Amazonian rural property consider it as a store of value rather than a factor in production. In the state of Para, for example, on farms of more than 1,000 ha. only about 26% of the land is cultivated. These establishments account for 84% of the land in private domain, but include only 8.4% of the farms. The area in use on farms of greater than 10,000 ha. drops to only 14% (INCRA 1978).

Small agriculturalists, on the other hand, cultivate an average of 66% of their claim, and this value can range up to 97%. The small scale farmer's acquisition of land, legally or through squatting, is for its use value, since the amount of land he owns and his labor expenditure rarely add up to grand speculative gains. He must have an annual rate or return on his production that is sufficient to support himself and his family.

In spite of the low rates of use, large groups have consistently captured land released from government tenure sold to the private sector. These lands, known as terras devolutas, often have been colonized by squatters. In areas wher both large and small owners have claims on land, either by title or simple occupation, the process of land acquisition has been accompanied by bitter contention (Souza-Martins 1980, da Silva-Rodriguez and da Silva 1977). In the state of Para, well over 5,300 titles were contested in the main colonizing and ranching areas of Paragominas, Altamira, Maraba, and Conceicao de Araguaia, and involved well over a million hectares. Because small farmers can neither afford the time nor the lawyers, they often lose these conflicts. As a consequence, there is a tendency toward land concentration. In the Paragominas area of the Belem-Brasilia highway, the

Gini coefficients increased from .60 to .77 between 1960 and 1970 (Santos 1980), indicating an increasingly regressive land tenure situation. Further, if land tenure patterns in predominantly livestock areas are compared with those of Amazonia ingeneral or with small farmer zones, an extreme tendency toward land concentration is evident.(Table 4,5,6) Land tenure systems in Amazonia in general are by no means progressive with about 3.3% of the farms controlling about 55% of the area in private domain. It is also notable that only about .1% of the farms are greater than 10.000 ha, but these control about 30% of the land. Small farms of less than 100 ha. occupy about 11% of the land and constitute about 70% of all the agricultural establishements in Legal Amazonia.

In areas domianted by ranching, not only is the percentage of farms greater than 10,000 ha greater by a factor of 10, but these establishmentd control some 56% of the land. If all ranches over 1000 ha are caculated, they occupy more than 85% of the privately owned land. The small farms (less than 100 ha) account for about the same percentage of establishements in livestock regions as they do in Amazonia as a whole, but in ranching regions they control only 6% as opposed to the regional average of 11%.

By contrast, small farms in the predominantly agricultuarl areas of eastern Amazonia are 95% of the holdings and control almost 62% of the land. If farms less than 1000 ha are included, more than 86% of the land is occupied by small or medium scale farmers. These areas are essential to the food supply of Belem.

Conclusions

The effects of deforestation on species extinction (Prance and Pires 1976), global and local climates)Salati et al 1979) and hydrological changes (Gentry and Lopez Parodi 1980) are only beginning to be assessed. There are however, several statements one can make about ranching. First when a large random enough sample is used, the assertions made about the capacity of pasture to improve soil characteristics become questionable. While conversion does increase pH by less than 1 unit, this amelioration is quite likely to be more related to the gradual decomposition of tree boles and branches,(the major Calcium sink in tropical forests)than to any unusual nutrient cycling capacity on the part of the grasses. Further, increases in pH are not unique to pastures but have been documented for no fertilization rice systems as well, for which no similar soil improvement claims are made. Increases in Ca and Mg occur in most sites, but their absolute values are very low, equilibrating at about 2 meq/ 100 grams or lower, and this places these soils among the lowest in terms of Calcium reserves for the acid soils of South America (Cochrane and Sanchez 1981). For other elements the conversion to pasture reduces nutrientlevels of pasture soils below those forests. Pastures are associated with increased bulk densities, an indicator of compaction. Further brush invaders rapidly occupy pasture areas, and this tends to increase over-grazing in the sites that are not occupied by secondary invasive species, exacerbating soil nutrient decline. Maintenance of pastures at this time requires P additions and continual hand labor for weed control. While credit lines for pasture fertilization have been in existence since 1979, the erratic availability and rising costs of transport and application have limited their use. Other approaches, such as the use of lo nutrinet tolerant grasses has been an active area of research on species such as Brachiaria humidicola and Andropogon guyanus . Unfortunatle B. humidicola is now attacked by spittle bugs, and A guyanus is still experimental in the region.

In spite of the essenrially ephemeral productivity of areas cleared for pasture, the speculative gains associated with Brazilian land markets have resulted in a situation where land increases in value even though the productivity may be declining. Such speculative environmentas create a situation where there is little incentive to manage carefully. Thus, while it is clear that conversion to pasture degrades soil resoruces, the economic climate actually favors ranching expansion. Large scale holdings, acquired through legal and in some cases illegal means. permitted enormous capital gains given the credit lines available, the inflation rate and the land markets in Brazil. This rapid consolidation of holdings has often brough ranching groups into sharp conflict with peasants, Indians and often with other elites. Further, ranching has exacerbated the trend of rural to urban migartion through land conflict and peasant marginalization.

While ranching was partially justified in policy documents as a creator of jobs(SUDAM 1968, SUDAM 1975) after the initial clearing an implantation period, ranches are very low labor absorbers. Even the highly subsidized SUDAM ranches have employed only half the laborers initially projected. After the forest clearing and initial construction those workers hired through labor contractors tend to enter the migration stream to either Amazonian, or Southern Brazilian cities. (Aragon 1980, Martine 1980) Amazonia abosorbed less labor over the 1970-1980 census period than did the <u>municipio</u> of Sao Paulo (Martine 1981)

Expansion of cattle ranching resulted in large scale and negative social effects like soil resource degradation, extreme land concentration, peasant marginalization and enchanced rural outmigration through land consolidation, land conflict and low labor absorption. Cattle ranching in the Brazilian Amazon is an excellent example of growth without development.

Table I. Tropical lowland forests of the Amazon Basin: Approximate area of forest clearing rate, and dominant replacement land use(s).

Country	Amazon Forest Area (millions ha)	Current clearing* (ha/yr)	Dominant Land Use
Brazil	280	1,000,000[1]	Cattle ranching (95%)
Peru	65	no data on rates but 10% thought to be cleared[2]	Subsistence, cash crop cattle (15%)
Bolivia	51	3,000[2]	Cattle, citrus, cacao, coffee
Colombia	31	150,000+ [2]	Cattle, rice
Guyana	13	10,000 [2]	Subsistence
Surinam	13	3,000[2]	Susbsistence, forestry
Venezuela	13	no data on rates	Subsistence, cattle
Ecuador	10	no data on rates	Cattle (81%)[2]
French Guiana	8	Negligible	Susbsistence
	484	1,166,000	

Sources: 1) INPE ~~IBDF~~, 1980; 2) Myers, 1980

Clearing here implies total replacement for and alternate land use. Selective logging etc. is not included. All these figures are at ~~best~~ only approximations.

Estimates of

Table II. Deforestation in the Brazilian Amazon.

State	Area cleared in 1975 (ha)	Area cleared in 1976-1978 (ha)	Increase in clearing 1975 to 1976-1978 (%)	Total cleared as of 1978 (ha)	Cleared area 1980* (ha)
Mato Grosso	1,012,425	1,823,075	180 %	2,825,500	5,085,900
Pará	865,400	1,379,125	159	2,244,524	3,575,528
Maranhão	294,075	439,325	149	733,400	1,092,766
Rondônia	121,650	296,800	243	418,450	1,016,833
Acre	116,550	129,900	111	246,450	273,559
Amazonas	77,950	100,625	129	198,575	230,361
Roraima	5,500	8,875	161	14,375	23,000
Amapa	15,250	1,800	11	17,050	20,119
TOTAL	2,859,525	4,857,650		7,717,175	11,318,860

Source: INPE/IBDF, 1980
* Estimate calculated by multiplying the % increase in clearing with the deforested totals of 1978.

Table 3 . Above ground biomass element storage in cosystem compartments; kg/ha and percent .

Element		N	P	K	Ca	Mg	Site	Source
Total Reserve (Biomass)		741	27	277	431	133	Carare, Colombia [1]	De las Salas (1979)
Leaves	%	13.3	3.6	10.5	5.8	8.3		
	kg	101.4	9.7	28.0	25.0	11.0		
Wood	%	60.0	60.3	63.8	72.8	68.0		
	kg	447.6	16.2	176.7	313.7	90.4		
Total Reserve (Biomass)		---	144.2	2982.3	3576.5	382.3	Darien, Panama	Golley et al (1975)
Leaves	%	---	11	4.5	6	6.5		
	kg	---	16	135.0	221	25.0		
Wood	%	---	88	95	93	90		
	kg	---	128	2846	3355	357		
Total Reserve (Biomass)		3995	170	4678	973	730	Gran Pajonal, Peru	Scott (1978)
Leaves	%	12	10	4	5	4		
	kg	478	17	229	57	32		
Wood	%	88	90	96	95	96		
	kg	3517	153	4449	916	689		
Mean percent element storage								
Leaves	%	12.6	8.2	6.3	5.6	6.3		
Wood	%	74	79	84	86	84		

1. When total are less than 100% understory biomass storage has been excluded.

Land Tenure in Predominantly Agricultural
Areas of Eastern Amazonia

		0-100 ha	100-1,000 ha	1,000-10,000 ha	+ 10,000 ha
Sao Domingos do Capirn	% Farms	88.8	10.3	.7	.2
	% Land	36	35.3	20.7	8
Tome Açu	% Farms	95	4.5	.5	—
	% Land	65	22.5	12.5	—
Capitão Poco	% Farms	95.4	4.3	.3	—
	% Land	64.8	25	10.2	—
Irituia	% Farms	94.2	5.5	.3	—
	% Land	68.3	20.6	11.1	—
Sao Miguel do Guama	% Farms	97	2	1	—
	% Land	74.9	20	5.1	—
MEAN	% Farms	94	5.3	.7	.1
	% Land	61.8	24.7	11.9	1.6

Land Tenure in Major Eastern Amazon Cattle Areas:
% Total Farms and % Land

		0-100 ha	100-1,000 ha	1,000-10,000 ha	+ 10,000 ha
Paragominas	% Farms	41.6	43.3	14	1.1
	% Land	2.9	16.7	49.6	30.8
Conceicao do Araguaia	% Farms	87.2	10.5	2	.3
	% Land	22.7	12.3	29.6	35.4
Maraba	% Farms	73.6	16.7	8.5	1.2
	% Land	5	6.1	55	34
Santana do Araguaia	% Farms	80	14	4	2
	% Land	6	3	16.3	74.7
Barra de Garcas	% Farms	71	20.5	6.5	2
	% Land	2.3	6.8	21.6	69.3
Luciara	% Farms	49.4	39.6	5	6
	% Land	1	3	9	87
Caceres	% Farms	88.6	8.6	2.3	.5
	% Land	8	13	37.5	41.5
Campos do Marajo	% Farms	81.6	14.6	3.4	.4
	% Land	5.7	14	44.2	36.1
Alta Mira	% Farms	47.4	52	.8	.1
	% Land	1.4	5.8	.8	92
MEAN	% Farms	69	24	5.2	1.5
	% Land	6.0	9	29.1	56

Land Tenure in Amazonia: % Farms and % Land

		0-100 ha		100-1,000 ha		1,000-10,000 ha		+ 10,000 ha	
Country	Year	% Farms	% Land	% Farms	% Land	% Farms	% Land	% Farms	% Land
Amapa	1970	75.4	(7.4)	19.6	(19.0)	4.1	(43.3)	.1	(30.3)
	1975	79	(12)	19	(23)	2	(28)	.1	(37)
Acre	1970	40	(6.2)	58.5	(64.3)	1	(13.3)	.1	(16.2)
	1975	43	(8)	56	(73.2)	1	(7.8)	.1	(11)
Amazonas	1970	79.9	(26.6)	17	(59.0)	1.5	(6.8)	.1	(7.5)
	1975	26.2	(22.7)	3.4	(16.0)	.2	(13.6)	.1	(47.7)
Para	1970	93.3	(19.4)	4.2	(15.2)	.7	(30.4)	.1	(35)
	1975	90	(16.7)	9.1	(19.2)	.7	(25.3)	.1	(36.7)
Rondonia	1970	47.0	(6)	51.3	(56)	1.3	(15)	.1	(23)
	1975	47	(10.4)	52	(56.1)	1	(16.5)	.1	(16)
Roraima	1970	31.5	(1)	33.9	(17)	34.3	(78)	.1	(4)
	1975	37.1	(1)	15	(10.5)	13	(52.5)	1	(36)
MEAN		70.4	(11)	25.2	(32.3)	3.2	(26.3)	.1	(29.4)

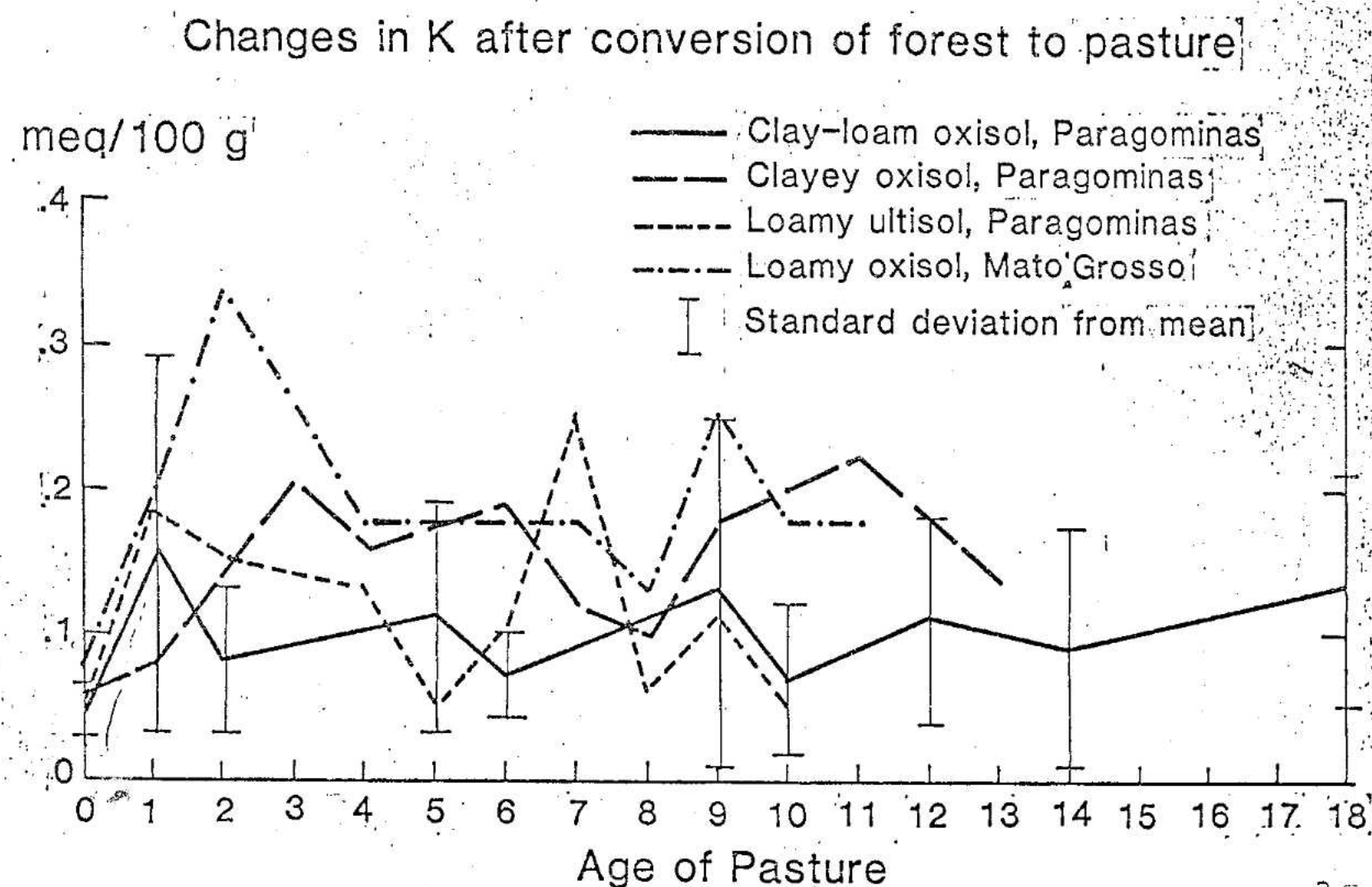
Changes in K after conversion of forest to pasture
meq/100 g
Clay-loam oxisol, Paragominas
Clayey oxisol, Paragominas
Loamy ultisol, Paragominas
Loamy oxisol, Mato Grosso
Standard deviation from mean
.4
.3
.2
.1
.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Age of Pasture

Fig 4

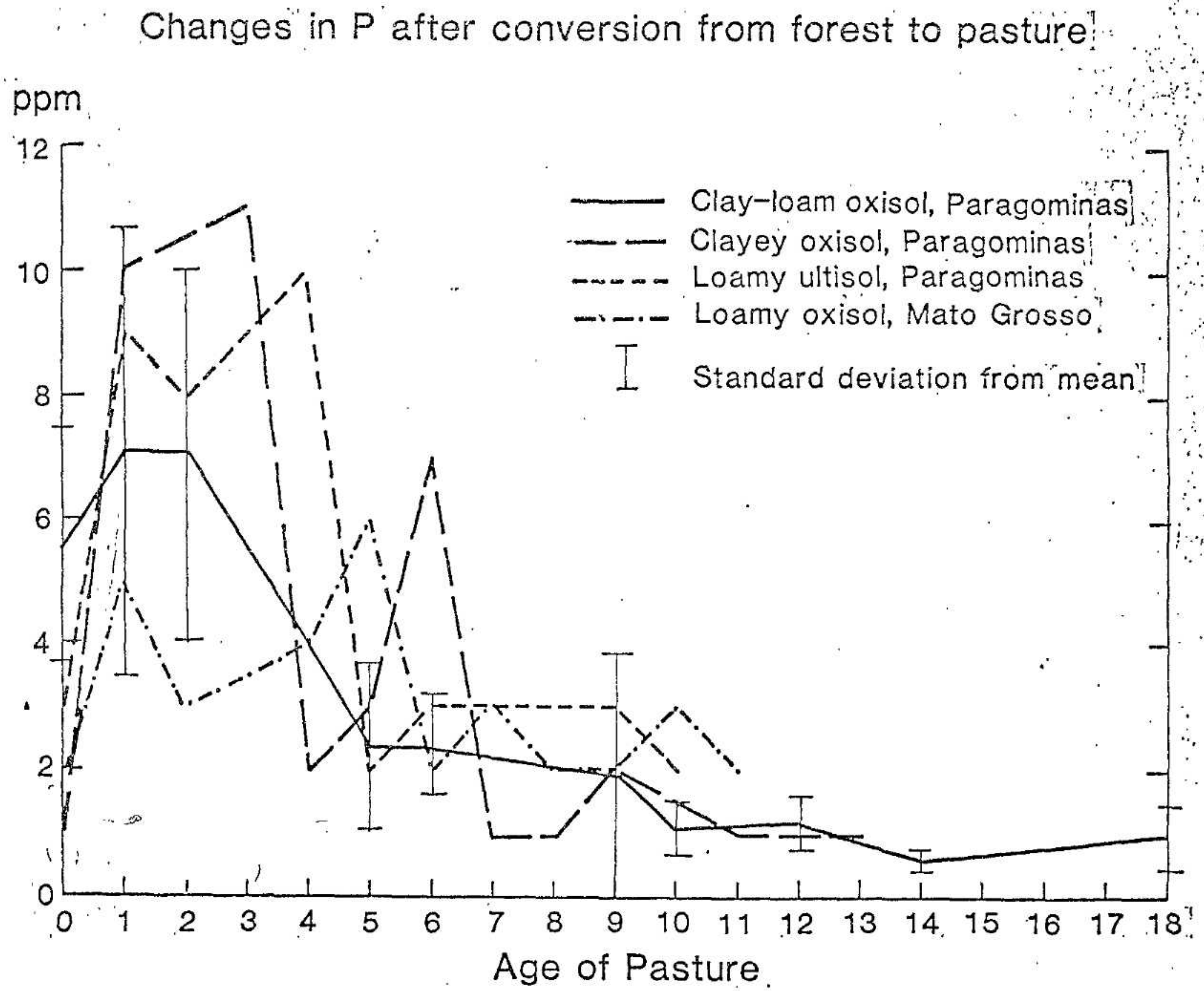
Changes in P after conversion from forest to pasture
ppm
12
10
8
6
4
2
0
Clay–loam oxisol, Paragominas
Clayey oxisol, Paragominas
Loamy ultisol, Paragominas
Loamy oxisol, Mato Grosso
Standard deviation from mean
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Age of Pasture

Fig 5.

Changes in N after conversion from forest to pasture

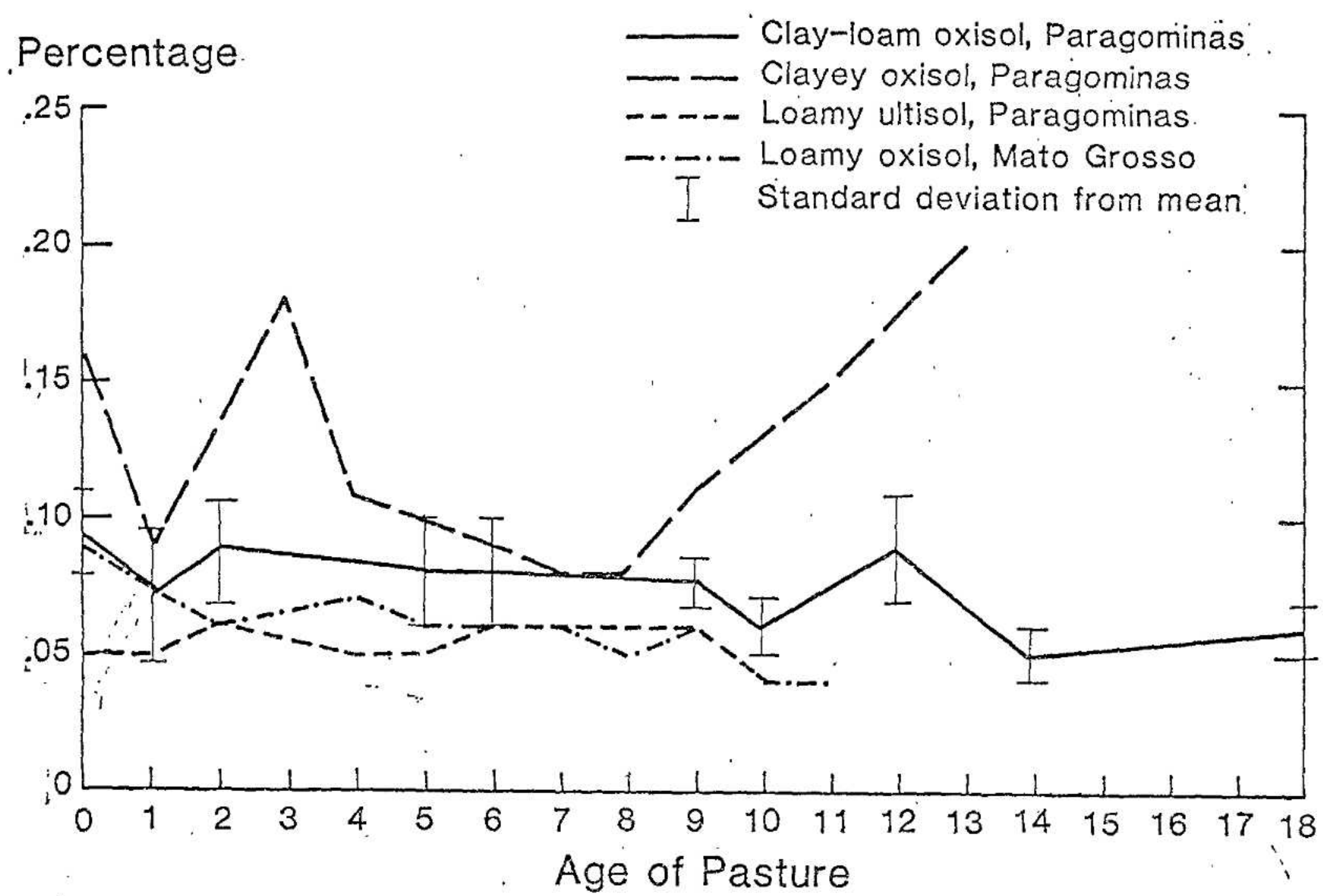

Fig 6

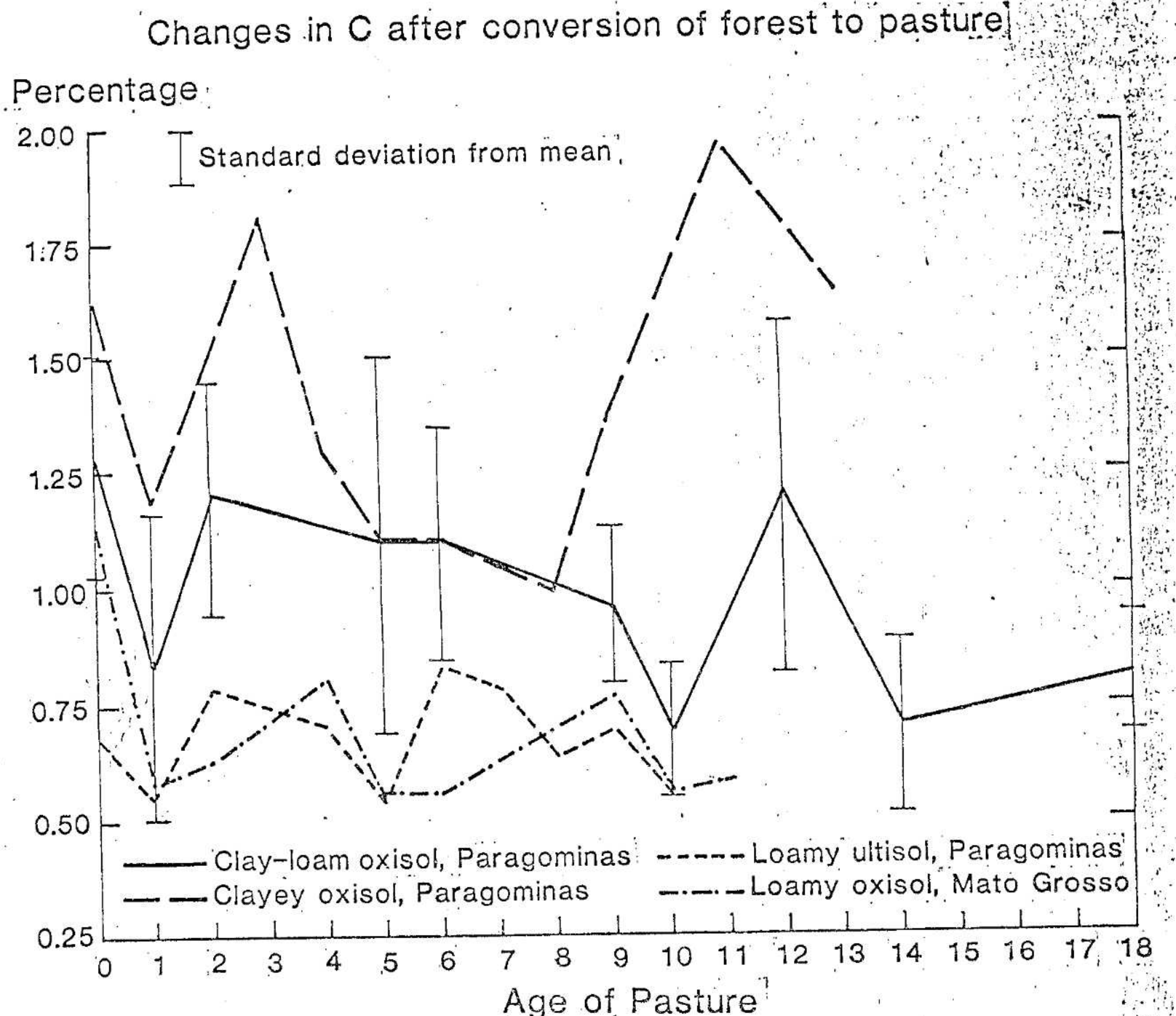
Changes in C after conversion of forest to pasture
Percentage
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
Standard deviation from mean
Clay-loam oxisol, Paragominas
Clayey oxisol, Paragominas
Loamy ultisol, Paragominas
Loamy oxisol, Mato Grosso
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Age of Pasture

Fig 7