Smallholder Farming Systems in Amazonia: Livestock Production and Sustainability

Part I Literature Review

Introduction

The first image that comes to mind when external observers think about livestock[1] production in Amazonia is the environmental destruction it causes. Cattle ranching is often highlighted as the major cause of deforestation in the region (Anderson, 1990; Fearnside, 1993; Serrão, 1990). Although deforestation rates are cause of much dispute between different sources, it can be accepted that not less than 426 000 km^2 have been cleared during the last thirty years, and some observers consider that pasture establishment accounts for at least 70% of this in the case of Brazil (Fearnside, 1993). Numerous analysts have examined the link between cattle and the causes of deforestation. One of the links hypothesised is the 'hamburger connection', proposed by Myers (1981), where beef exports to developed countries were identified as the main cause of forest conversion to pasture[2]. Currently this connection is interpreted as a result of official incentives to colonise the region, the heavy subsidies for livestock production, especially in Brazil (Mahar, 1989) coupled with policies that accrue land rights and higher land prices to 'improvements' as clearance and pasture establishment. In the early 1970s some scientific arguments suggested that the region had environmental conditions suited to cattle production (Falesi, 1976). The 1980s saw a revision of this view, and to many observers cattle raising in Amazonia was considered unfeasible in biological and sociological terms, as well as being economically unprofitable (Fearnside, 1990). Ranching was reported to represent 'the worst of all conceivable land-use alternatives for Amazonian development' (Hecht, 1985: 673).

However, as Nicholson et al. (1995) observed, analysing the Central America case, cattle production systems on previously forested land are often more a symptom than a cause of deforestation, and the driving forces of livestock production should be analysed in the broader context of land and natural resources use opportunities and livelihoods strategies. For those involved in cattle production, once well-established, it is a profitable enterprise. It is still expanding, despite the withdrawal of government incentives and subsidies. Livestock production, however, exists in many forms in

Amazonia, and in locations where such facilities have previously never existed. Moreover, livestock is present in diverse eco-zones and farming systems in the whole region, from the extensive ranches (*fazendas)* in Brazil to indigenous people's *centros* in Ecuador (Rudel and Horowitz 1993).

Cattle production in Amazonia is a continuing and important part of the rural economy. Even those who advocate the removal of cattle from the region as a primary strategy to decrease deforestation in Amazonia probably know that it is an unrealistic goal. A deeper analysis into the main causes of deforestation, beyond the incentives for cattle production, shows that improving methods of cattle production by the different types of farmers in the region is an essential step towards the development of more sustainable farming systems in the region.

This review addresses current and future opportunities for the improvement of cattle production in Amazonia and the strategies to make it less harmful to the environment. Some observers argue that the intensification of cattle production is unlikely to have a significant impact on deforestation (Nicholson et al., 1995), and that destructive pasture management is not related to the absence of suitable technologies (Hecht, 1993). This paper argues, however, that a distinction must be made between large-scale production by cattle ranchers, and small-scale production by farmers who may be driven to non-sustainable cattle ranching due the absence of alternatives.

Currently, in different parts of Amazonia, there are important grassroots organisations which campaign for policy changes, and which have been directly involved in targetting and promoting technology innovation (Bebbington, 1996; Bebbington and Thiele, 1993). These innovations could help small farmers to remain on their land and so avoid further frontier expansion. One of the aims of this review is to present and discuss the basis for a research program to work with farmers and these organisations with these aims. To achieve this, the debate about livestock in Amazonia must be broadened to try to address an important gap in most studies to date concerning the subject: the combination of narrowly focussed technological research with broader social, economic

and environmental analyses. Therefore, the review first presents an overview of livestock production in Amazonia, aiming to explain livestock's presence and role in different farming systems.

The review focuses on colonist farmers, one of the most numerous group of actors involved in natural resources use and cattle raising in the area, through an examination of the dynamics of cattle production in pioneer frontier systems in greater depth, using the Marabá and Altamira regions in Eastern Brazilian Amazonia as case studies. Subsequently, the technical problems and ecological impacts of cattle ranching in Amazonia are presented and discussed, focusing especially on aspects related to pasture management and degradation, identified as the main reason for the non-sustainability of cattle raising in the region. This is followed by a critical assessment of the options currently proposed for livestock systems improvement, mainly by research institutions working in the area, discussing why some of the new livestock and pasture management technologies available have failed to reach farmers and smallholders. In doing so this document presents a framework for future work to be conducted in partnership with colonist farmers.

Notes

[1] Although the term livestock refers to domesticated animals raised for production purpose, in this text it refers exclusively to cattle.

[2] Uhl and Parker (1986) analyse how this has been incorrectly applied to Amazonia.

1 Cattle production and farming systems in Amazonia

Cattle production in Amazonia is almost as old as the first European incursions into the area, but very few reports exist about the evolution of cattle raising in the region. For a long time livestock production was restricted to areas of natural grasslands along the Amazon river, mainly on Marajó Island, where cattle were raised on large ranches. These were first owned by the Jesuits during the sixteenth century (Hemming, 1987), and later were passed to local people, who came to constitute one of the most influential élites of Belém, alongside the rubber barons at the end of last century (Weinstein, 1983). In this extensive system of production, the main problem was reported to be the considerable losses experienced though the depredation of alligators, mainly during the dry season (Shanahan, 1927). Cattle production could also be found in districts around Santarém in the lower Amazon valley, where agriculture production tended to be relatively diversified (Weinstein, 1983) and in the Rio Branco valley, where large herds were managed with the use of Indian labour, and meat produced there was sent to the Manaus region (Hemming, 1987). With the rubber boom in the late nineteenth century, and the expansion of local markets, the first measures to improve cattle production were taken. In 1893 the State of Pará Congress decided to award cash prizes to farmers who imported improved cattle, but this measure was not very effective because only the wealthiest ranchers could afford it, and brought Zebu and Holstein breeds to the region (Weinstein, 1983). With the decline of the rubber economy earlier this century, livestock production was one of the few remaining vigorous economic sectors in Amazonia. The only rubber barons to survive the collapse were those who had diversified their business to include cattle (Hennessy, 1978).

Although cattle had been present in the region for some time, it was only during the 1950s that forest conversion to pasture began, coinciding with renewed, stronger attempts by various Amazonian countries to integrate the region into their economies, and expand beyond extractivism. Road building, credit and tax exemptions encouraged massive investment in large cattle ranches in Brazil. But also at this time cattle rearing was no longer the privilege of large landowners, and as colonisation projects were set up, cattle rapidly became an important element of many farming systems, as illustrated in the

cases of Bolivia (Thiele, 1991), Ecuador (Hiraoka and Yamamoto, 1980; Rudel and Horowitz, 1993; Bromley, 1981; Collins, 1986; Pichón, 1997), Peru (Loker, 1993), and Brazil (Fujisaka et al., 1996; Mattos and Uhl, 1996; Reynal et al., 1995). In addition to the planned expansion of livestock production, spontaneous adoption occurred; small herds were introduced to long- established faming systems on the region , including Indian areas and *caboclo* lands due to the multiple advantages of pasture establishment and cattle production. Amongst the *caboclo,* the cattle herds more than doubled between 1974 and 1985, at least half of the *caboclo* families living in the *várzea* (swamp) areas of the Amazon own some cattle (Barrow, 1996). For many rubber tappers, cattle production presented the dual possibilities of becoming released from systems of debt peonage and increasing their autonomy in decision-making, so cattle became an element of their livelihoods strategies (Almeida and Menezes, 1994). According to Stockes and Harthorn (1993: 120), the Peruvian Yanesha Indians 'discovered that the path towards wealth lay in cattle operations'. Today cattle are particularly important for these groups of people and are managed in private and common land, sometimes on their best lands.

Due to the need for capital investment to acquire the animals and the infra-structure needed to raise cattle, the poorest sectors of the rural population did not have access to them. However, wealth could be measured by number of cattle one possesses.

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These developments were accompanied by a significant research effort to improve cattle production in the region. National research institutions throughout the Amazon basin, and also an international research centre (CIAT in Colombia) have been concerned with livestock production, working mainly with the development of improved grasses, stock breeding and health, and more recently with pasture ecology and agro-silvo-pastoral systems.

Although very important for the regional economy, cattle production in Amazonia occupies only a marginal role in meat and dairy production in South America, given that expansion in ranching has not generally been due to demand for beef or other cattle products, but results from other benefits this activity provides, as will be discussed later.

Thus cattle numbers in Brazilian Amazonia comprise just 12% of the total Brazilian cattle stock (Tourrand et al., 1997). However, the notion that the region is a beef importer is disputed by certain studies (Hecht, 1993). For example, Pará State consumes only 25% of meat it produces (Correio-do-Tocantins, 1997). Low capital costs in relation to other producers' regions make Eastern Amazonia competitive, despite its distance from the important consumer centres in Southern Brazil (Arima and Uhl, 1996). The region, however, cannot produce for the international market due to the ban on meat exports from regions where foot-and-mouth disease is still present, as is the case for the whole Amazonia.

1.1 The diversity of production

An attempt to draw a typology of cattle raising in Amazonia region could start with a division between the major 'eco-zones' of Amazonia, that is the lowlands or *varzeas* and the upland or *terra firme*. In the *varzeas* the cattle are raised in natural grass fields, along some of the large rivers of the region. This is the more traditional system of very extensive cattle raising in Amazonia, practised equally by large ranchers and *caboclo* families. Generally these systems are less productive than those of the cultivated pastures in the *terra firme*.

The *terra firme* livestock rearing systems are as diversified as the population groups and natural ecosystems in Amazonia. They range from being highly specialised (milk production or fattening-finishing) to being only a minor component of diversified farming systems. Scattered all around the region, they are particularly important in frontier zones, where livestock production occurs in a wide range of situations, from smallholders deep in the forest to large ranchers, some with properties over 300 000 ha.

1.2 Factors driving expansion of cattle production in Amazonia

Although some authors attribute the expansion of ranching amongst colonists to cultural heritage and the symbolic value that Hispanic and Portuguese place on cattle, others (Hecht, 1993; Loker, 1993; Nicholson et al., 1995; Reynal et al., 1995) have shown that this is only a minor factor in the choice of ranching. The first set of factors have little connection to cattle production itself, being related to the dynamics of land rights in the region:

Pasture represents a means of securing land: In many Amazonian countries land title can be claimed if it can be proved that the land has been used for productive purposes during a certain period. Since it is difficult to prove this when the land is covered with forest or fallow, the options are to establish either pasture or perennial crops. Not only the government, but also other actors, acknowledge property rights for land under pasture, and for this reason is not rare for 'owners' to plant strips of pasture alongside property borders to show occupation and prevent encroachment by squatters. Because pasture cannot be used for shifting cultivation, in recent years large landowners have promoted forest conversion to pasture in large areas to avoid the action of squatters. This is particularly prevalent in the most densely populated areas, where landless farmers have become very well organised and are trying, thorough planned squatting, to reverse the situation of strong land concentration in the zone.

Pasture increases the value of land: The price of land under pasture can be three times that of the same area of forest. Sowing pasture can therefore be one of the most profitable activities in the region. Forest is valued little as a productive asset, although small farmers will not want to have all their land in pasture, due the inability of growing crops there. However, many potential purchasers are primarily interested in cattle production, and so prices will be frequently linked to pasture quality.

Pasture can provide a profit through rental: Pasture can be rented out, mainly during the dry season, when grazing becomes scarce. Rent can be paid in different ways: cash, crop production, animals, labour, pasture maintenance or fencing, or sometimes

assistance to a cattleless farmer to establish a herd. Through systems called *meia* or *media*, that include not only pasture but also work exchange, a farmer will receive animals to look after in his pasture, and by the end of a certain period calves produced will be shared equally, or each will receive the equivalent of half of the weight gain of the herd. Pasture can also be used freely by relatives or neighbours, part of the more complex arrangements within the exchange and social networks.

Pasture can have low opportunity costs, given that land had already been cleared for crop production, and often pasture is sown simultaneously or shortly after crop planting.

Planting pasture can represent a strategy for extending the useful life of a cleared plot or land, that otherwise could be used for one or two years and would be brought into production again a few years later. Pasture can be grazed for many years, and farmers will recover their investments and accrue marginal returns even from highly degraded pastures.

These factors make it evident why meat production is not the main or sole reason for the conversion of forest to pasture in Amazonia. However, animal husbandry itself has a significant appeal, and makes livestock production one of the most attractive economic activities in the area. Again, a number of factors are involved:

Low risk: Cattle production is generally not as sensitive to climatic variation as crops. Animal health problems, although existent, do not represent a very important constraint, since, in an environment still surrounded by forest, disease transmission is slow. Generally in the Amazon region cattle have good numeric productivity and low mortality rates. These elements combined with the economic advantages described below make the investment in animals a safe one. Cattle raising coupled with crop production spreads the risks of agricultural activity, and cattle are the first option when farmers have some capital to diversify their farming systems.

Investment: In contrast to many other agricultural commodities in the region as a whole, the price of cattle has been maintained, and has not been adversely affected by the high

inflation rates in Latin American countries. The relative price is high and cattle are a highly liquid investment. In a region where the infrastructure is generally poor and farmers have little access to information, cattle represent a bank account, where savings can be kept for use during an emergency or for future investments.

Marketability: Cattle can be more easily transported than other agricultural products as they can walk to market. This is an enormous advantage in a place with few roads, many of which allow only dry season access. Moreover, in the absence of production seasonality, animals can be sold at any time, and maintaining them in the pasture when the price is not high is cheap. The existence of a very organised market chain, not oligopolised as some forest products are, enables family farmers to sell their products in conditions they consider fair.

Flexible and low labour demand in comparison to other activities. Activities that require low labour demand are well suited to frontier zones, where labour generally is scarce. This is attractive for the large cattle ranchers who will avoid large costs associated with salaries, and is also good for small farmers, who depend on family labour . Because there is no seasonality in labour demand for cattle production, farmers can use their labour flexibly, so that in regions with a marked dry season, farmers undertake pasture or fence maintenance during the low season, where otherwise there is little to do apart from selling labour. Because many of the tasks involving cattle husbandry and pasture management after establishment are arduous, it will be attractive for farmers at different stages of life. Farmers may also try to build up their herds whilst they are relatively young, so they will have less hard work in later life.

Dual purpose production: Although subsistence production of meat may not be an incentive for smallholders to keep livestock, subsistence production of dairy products is a very important benefit for many small farmers. In contrast to other regions of the world, the use of manure is very rare.

Cash flow from dairy production: Close to urban centres there is a significant demand for dairy products. In these circumstances, there is the opportunity to sell milk throughout the whole year, and even in small amounts this can represent a regular cash income.

These advantages explain why cattle production is so widespread in Amazonia, and make it almost unbeatable when compared to other alternatives. One of the few commodities that has competed with cattle was the illegal cultivation of coca, in certain areas of Western Amazonia, which is both profitable and represents a very good use of family labour throughout the year. Although there is need to diversify farming systems and to seek alternatives to cattle ranching, it will remain an important element in the region's farming systems even if new policies can be adopted to organise property rights and claims, and to remove the incentives for land clearance. In this sense the search for sustainable farming systems in the area must consider the livestock component of the system. In order to improve the livestock systems in the region, the first step is to understand in detail how these systems are organised and to understand their technical, economic and social problems.

2 Livestock production in frontier farming systems

Although the reasons that impel Amazonian farmers to introduce livestock into their farming systems are not different from region to region, the role of cattle changes significantly, even within the same region. This is particularly the case in frontier farming systems where the importance of cattle in farming systems and management patterns will be very different according to the time of occupation and the particular dynamics of settlements. Cattle's role should be contextualised in relation to all other activities performed by farmers. These activities change as the farming systems evolve. A 'standard' evolution sequence of the farming systems for one frontier region, Marabá, is described by the LASAT team in that region (de Reynal et al., 1995 and Muchagata, 1997):

First phase - installation: a farmer (sometimes alone - he may bring his family one or two years later) occupies a plot completely covered by forest, in a recently opened locality (for this reason without any kind of infrastructure). There, he will clear a plot in the forest (around three ha on average) in a slash-and-burn system, and will install the first rice *roça*. At this time, the family will be very dependent on forest resources: almost everything in the house is home-made with forest products, and timber and non-timber products can provide an important revenue. Another important cash source can be labour, sold to neighbour *fazendeiros*. Given the instability of land tenure, the plot boundaries are not clearly defined and need to be protected. Moreover, many farmers are not sure whether they will stay in the area long-term, so they will try to sell as much timber as possible and establish pasture to add value to the land.

Second phase - system diversification: after four to five years of settlement the plot changes significantly. The family improve their house and build structures to produce cassava flour. They also produce beans and maize, mainly for household consumption, but sell any surplus. They may start a small but diversified orchard around the house and have some poultry and pigs. Although the forest cover remains important, practically all the plots have some pasture around the house and, depending on the farmers' strategy,

there will be also some fallow land. Farmers who had more capital initially may have acquired cattle, but generally do not have not more than 10 or 15 animals at this stage.

Third phase - the system specialisation: if there are no significant economic constraints, due to the advantages mentioned earlier, cattle are the main activity and the farm becomes dominated by pasture. At this stage, local infrastructure is well developed and farmers are probably able to sell milk or cheese. The revenue is complemented by sale of calves. The herd can be up to 120 animals. Crops like rice or cassava remain for subsistence, if at all, and the forest's role remains as a nutrient reserve. This imposes serious restrictions on the sustainability of the farming systems, as the forest is being reduced each year.

Farms in all these stages can be found in Marabá. However, the speed in which these systems evolve has changed dramatically during the last 30 years. As will be discussed later (Section 2.4), changes in meat prices and the development of markets for milk transformed some of the basic conditions that propelled technical modifications in livestock production in recent years. Changes have also affected smallholders' cattle raising patterns in another frontier region, Altamira, also in Pará State. There, the first settlers in the early 1970s received incentives to cultivate perennial crops, like pepper, cacao and to a lesser extent coffee, which performed well at that time due to very fertile soils and good prices at international markets. These conditions were reinforced by there being less contact with ranchers than in Marabá, and more stable land rights arrangements. This meant that until recently the role of cattle was confined to investment and consumption. In the mid 1980s, the drop in cacao and pepper prices, associated with disease problems, as well as the development of credit facilities for livestock production in the 1990s, provided incentives for cattle raising, and the region has seen also a process of ranch establishment. At the same time, whilst some farms became specialised in cattle (with more than 40 animals), many of them have a very diversified system, where cattle may or may not be the main component, along with perennial and annual crops, where the herd can vary from 10 to 30 units (Veiga et al., 1995). This ranch establishment

process has led to land reconcentration in the region and has contributed to making farming systems less stable.

With this brief overview of farming systems in Para State frontier zones, some of the characteristics of livestock systems in these areas will be described. The focus here will be Marabá and Altamira region, given the existence of detailed information about these zones. This is complemented with data from other regions when available.

2.1 Herd characteristics

In the Marabá region the herd is dominated by Zebu races. The Gir and Nelore are pre-dominant and Indu-Brasil and Tabuapuã are common. Smallholders try to select animals for dual-purpose production. Gir are very well-adapted and very often Zebu are crossed it with Dutch animals. In a detailed study conducted by Topall (1991) in one Marabá locality, smallholder herds were found to constitute 30% of cows and 25% of heifers, with the rest calves and only one or two bulls. There were no *steers*, because male calves are sold to ranchers, who specialise in meat production. As stated previously, the size of the herd will vary partly as a function of evolution stage of the farm, land and family labour available. However, the structure described above demonstrates farmers' strategy that favours the numerical yield of the herd, when all the females are kept in the herd.

In Altamira, the herds present similar characteristics. In a study conducted by Veiga et al. (1995) including 144 small and large holders they found more than 50% farms had less than 50 animals. These animals were also dual purpose with a genetic mix similar to Marabá; in some cases the herd can be slightly more selected to milk production, animals mixed blood with Semental and Swiss found in 4% of the lotes. The average herd structure there was 45% of cows, 3% of bulls, 19% of heifer, 12% of steers and 20% of calves. The higher proportion of steers can be explained by the greater ranches in this sample compared to Marabá.

2.2 Animal husbandry practices

Cattle feed almost exclusively on pasture (see Section 2.3). In the frontier regions of Marabá and Altamira, when farmers have more than 10 animals, they commonly divide the herd into groups. The suckler herd and calves are collected every evening in a coral (the size and quality of which is very dependent on farmers' economic conditions), and milked early the following day. Other animals are kept in paddocks and will stay several days without being brought together in the coral, but are monitored daily *in situ* (Topall, 1991).

Vaccination and other kind of health treatments represent an important variation in cattle management, as some farms rarely adopt disease prevention practices, and others try to apply all standard technical recommendations. In general, health problems are not critical in either region. In almost all cases a common practice is the use of disinfectants to treat injuries. Ectoparisites are a serious problem only in older areas, where nutrition problems are alsolikely to be present. Generally most farmers use mineral salt (NaCl) as a dietary supplement, but it often proves to be insufficient to combat other deficiencies caused by lack of minerals like phosphorus and micronutrients (Lau, 1995). In Altamira region only 10% of farmers adopt the use of mineral supplements, apart from salt (Veiga 1995).

2.3 Pasture characteristics and management

The main grass species in Eastern Amazonia are *Panicum maximum*, *Brachiaria brizantha*, *Brachiaria humidicola, Brachiria decubems* and *Brachiaria mutica*. (Serrão and Toledo, 1992; Veiga et al., 1995). The importance of each species in a given locality depends very much on the age of locality and the importance of livestock in the area. *P. maximum* was a very popular species during the 1970s and 1980s due to its facility for multiplication via seeds or seedlings, and other advantages of its high palatability and good nutritive value. This species was used for the rapid establishment of new pasture areas, thus supporting the quick expansion of livestock activity. However, the growth of *P. maximum* in 'cabbage' can lead to erosion and degradation (see Section 3) and other

species such as *B. Humidicola* and *B. Brizantha* are required for more intensive and durable pastures. *B. mutica* grows in low, very humid areas, and is useful for providing fodder for animals during the peak of dry season and when other pasture is unavailable. Brachiaria grasses, mainly *B. humidicula*, are, however, sensitive to a pasture pest, the spittle-bug, that is becoming more common with the expansion of these grasses in the region (Serrão 1990). The use of legumes as forage has generally been rare in Amazonia.

The method of pasture planting depends greatly on farmers' strategies of fertility management of their farms. Only ranchers sow pasture directly after forest is burnt, and this is still a rare practice. More frequently, after the forest is burned, rice will be sown and then pasture is sown with seeds or seedlings when the rice is well developed. Often, in the case of smallholders, pasture will be sown only in the following year, when cassava, established soon after rice, is about to be harvested. The other options are either to leave the area in fallow for 3-5 years, then sow pasture in the method just described after the fallow is slashed and burnt, or to sow pasture straight after fallow is burnt.

Generally pasture areas are weeded and burnt annually. The ways in which these operations are undertaken are very dependent on farmers' resources and tactics, and an understanding of these practices is the key to understanding the process of pasture degradation (see Section 3). For a farmer, fire is the best way to control weeds and to stimulate the growth of grass at the end of the dry season, when dried grass, inadequate for cattle consumption, is dominating the pasture biomass.

Farmers generally adopt a rotational system for pasture grazing, and they will have several pasture paddocks. Poor farmers will have two or three, but farmers with more capital will have up to twenty paddocks (as found in Altamira region, Veiga et al., 1995). Stocking rates are very variable, and change as the farming systems evolve, as seen in one Marabá example in Figure 2.1. Even in periods of excess stocking, some paddocks can be under low stocking rates. (Veiga et al. 1995) found for Altamira region rates varying from 0.68 to 0.88 animals per hectare. Arima and Uhl (1996) found rates

between 0.64 to 0.74 animals/ha. In both cases higher rates are found amongst small-medium size farms.

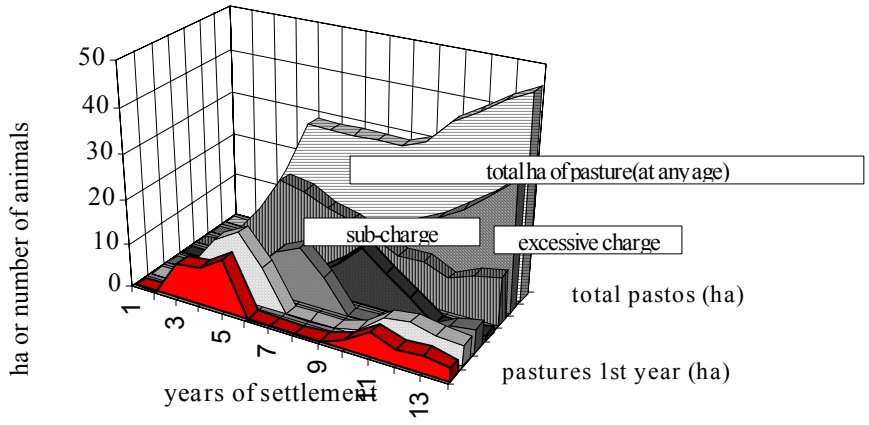

Figure 2.1: Evolution of stocking rate(potential and effective) - real case for a family farm in Marabá region
Source: de Reynal et al. 1995

2.4 Economics of Livestock Production

2.4.1 Productivity

Indicators of productivity, like weight gain and milk production have been little studied and few accurate measures exist for smallholders in Amazonia. This is also true for the ranching sector, where estimates only are available. More accurate data are found only under experimental conditions, which are very different to the on-farm situation.

Almost all the data available are for ranches in frontier regions. One of the few studies of diversified family systems was conducted in Marabá region by Topall (1991). However, the data presented are still estimates rather than actual measures. The weight gain found was around 100kg/ha/year, with milk production varying between 2 and 4 litres/cow/day. In a study by Mattos and Uhl (1996) analysing ranches estimated cattle weight gain on an average medium ranch to be 47 kg/ha/year, with a figure of 64 kg/ha/year for large ranches in Paragominas. Similar work conducted in Southern Pará by Arima and Uhl (1996) found cattle weight gain ranging between 46 and 101 kg/ha/year, depending on the size of property and husbandry systems. The lower value was found amongst smallholders with dual purpose cattle and the higher value for medium sized farms specialised in fattening systems. No study has been undertaken to explain the differences in productivity within the same region or between different regions. Such an investigation would demand an evaluation of the effect of natural environment variables soil and climate, and the effect of farmers' practices on productivity, and would need to be associated with detailed socio-economic studies.

2.4.2 Income

Previous analyses of the economics of cattle ranching in Amazonia, especially in frontier zones, have shown that cattle production alone is economically viable only under very specific conditions in the cattle cycle (Hecht, 1992). During the 1980s and early 1990s, the link was made between the existence of fiscal incentives to larger ranches and land speculation. Since then economic conditions have changed and also other studies

focusing on smallholders have shown that other factors, including those outlined in Section 1, influence farmers. Even so, these analyses are rarely based on detailed farm studies evaluating the profitability of this enterprise. As for yields, economic costs and returns are generally estimates, although fairly accurate. Once again, studies tend to concentrate on ranching, instead of family farms. For example, Arima and Uhl (1996) estimated the profitability of ranching in Southern Pará where, depending on the livestock systems, returns vary from US$ 1 to US$ 25/ha. Similar, but more detailed studies have been conducted in Paragominas. Mattos and Uhl (1996) have shown variations in the range of US$ 6 to US$ 34/ha. Ranchers have relatively good returns to cattle because of the large size of their properties and herds.

Studies conducted with family producers in Altamira by Tourrand et al. (1995a) show economic returns of between U$34/ha and US$ 512/ha, depending very much on farms structures and farmers' strategies. The higher returns were found in milk-specialised farms, whereas the lower returns were from fattening systems. However, when discussing economic parameters to evaluate the profitability of cattle raising for smallholders, they need to be compared to the activities of other farmers. Topall (1991) found that a farmer will receive US$ 3.50 per day of work with livestock, whereas for rice, the main crop production, this return will be US$ 2.70.

2.4.3 Markets for livestock products - chains and prices

Meat

The meat market is controlled by ranchers, who buy young animals from family farmers and finish fattening them. The existence of great number of buyers and seller guarantees that generally small farms sell their animals at reasonable prices, normally lower ranchers prices. When farmers have cows to sell (normally old or unproductive ones) they sell them to local or regional butchers. Sautier (1993) points out that in Altamira in many localities there is a collective organisation for weekly meat selling.

The frontier regions of Altamira and Marabá have only slaughterhouses and no freezing plants, preventing the exportation of processed meat. Marabá exports live animals to consumers' regions in southern Brazil (Sautier 1993).

The meat market is one of the main reasons for the expansion of cattle production in the region, as prices have not been adversely affected by inflation rates. In addition, the distance to urban centres does not appear to interfere with prices. However, in the long term, prices have been changing significantly and this has affected the economy of cattle raising in the region. As can be seen in Figure 2.2, there was a significant drop in meat prices from the mid-1980s to mid- 1990s. Today meat is almost one third cheaper than it was during certain years of the 1980s. One the one hand, this has made cattle production less profitable and has forced ranchers to improve their productivity and to decrease production costs. On the other hand, it is now easier for smallholders to initiate cattle raising or to expand herd size. Both tendencies tend to lead to the intensification of cattle raising.

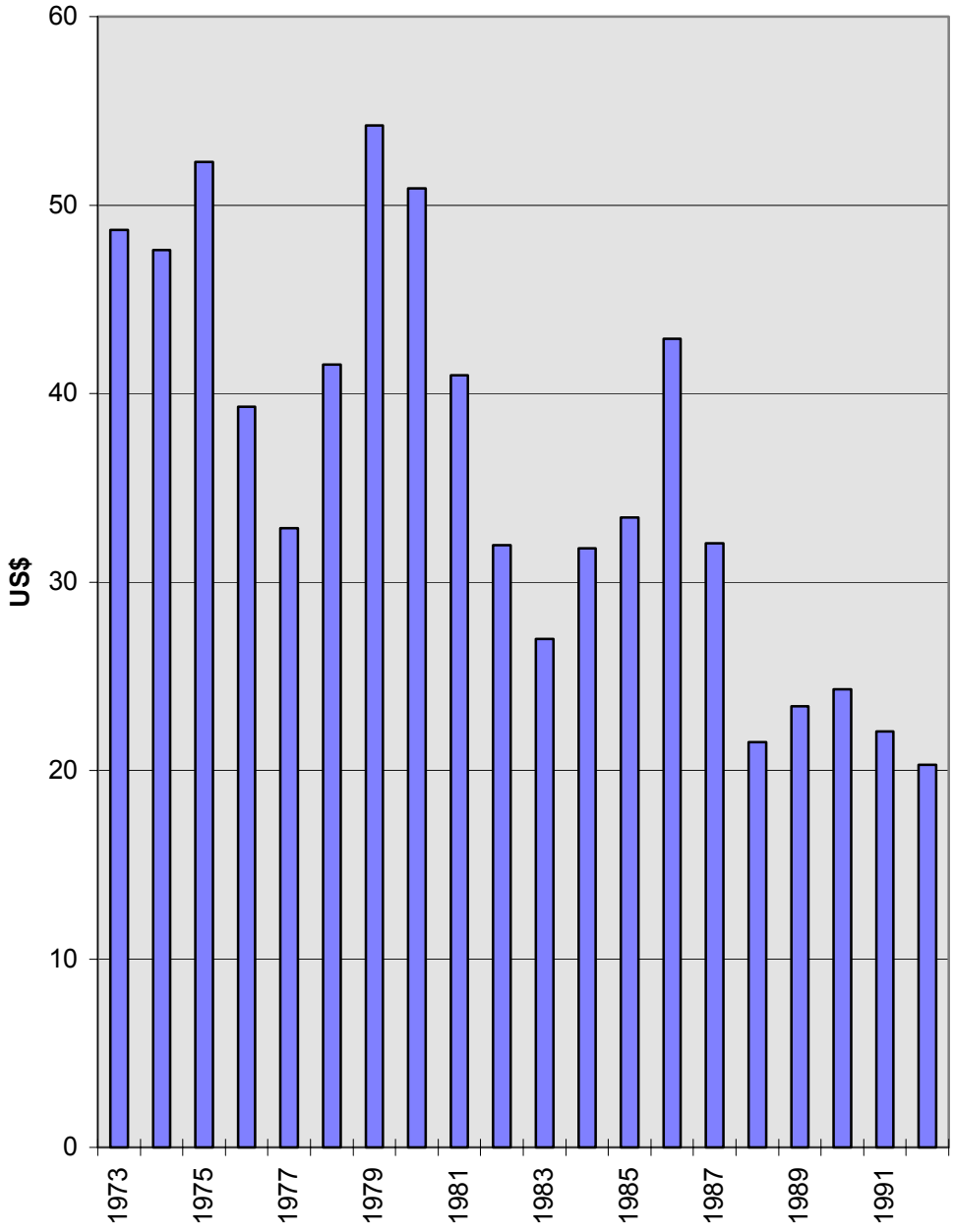

Figure 2.2: Evolution of Meat Prices in Para State- 1973-1992

Source: Pinto et al., 1995

Milk

In contrast to meat, the way milk is marketed and prices received are highly dependent on distance and transport conditions. In remote regions, when the herd size increases, there is a need to commercialise milk production, but it is impossible to sell it fresh. Therefore cheese production is the main option for a monthly source of income. However, the revenue may not be regular, given that prices are highly seasonally variable. For example, Sautier (1993) found a price variation from US$ 0.50/kg during the wet season to US$1.50 during the dry season in Marabá region. Cheese can be sold to middle-men at the locality level or at the urban centres, and it is exported to other regions of the country. Another option is to sell it at urban centres to small shops or weekly markets, at better prices.

The development of dual purpose livestock for small farmers in longer-established localities with more infrastructure has generated 'milk lakes' in some regions. For example in Marabá region, that until very recently suffered deficiency of milk in urban areas today has dairy companies capacity of 80 000 litres/ day (Sautier and Muchnik 1997). The dairies are able to pasteurise milk for regional urban centres, and also export cheese to other regions. The opportunity to sell milk fresh however, is only possible for farmers living close to urban centres, where dairies exist and organise 'milk routes' to collect milk daily, which only occurs where there are all-weather routes. Even if farmers receive a low price per litre of milk - at current prices between US$0.10 and US$ 0.17, this represents a better price than processing milk to cheese, especially if labour and other costs are taken into account.

In some cases farmers can try to increase income by the direct sale of milk. This is generally the case for only a few farmers, since its requires some type of transport. However, in Uruará in Altamira, 75% farmers use this method to sell their milk, according to Tourrand et al. (1995b).

The incentives for milk production have increased with the stabilisation of currency, since during periods of high inflation farmers used to be penalised by receiving their payments 30 to 45 days after delivery.

2.5 Trends in Livestock Production at the Frontier

As the frontiers become more stabilised, there have been significant changes in the way cattle production is organised. With the withdrawal of incentives, associated with increase in land prices, the expansion of the area under pasture slows and the process of intensification starts to occur. In the case of Marabá, the analysis of LANDSAT images shows the following trend, observed in Table 2.1.

Vegetation type	land cover(%)	
	1984	1993
Forest	77.8	72.3
Fallow	4.9	9
Pasture (weeded)	3.7	8
Degraded Pasture/crops	8.6	6.4
Burnt fields	0.2	0.2
Other (rivers, towns, etc)	4.8	4.1
Total	100	100

Table 2.1: Changes in land use between 1984 and 1993 in the Marabá region

Source: ENGREF-SILVOLAB- LASAT- 1997 from analysis of LANDSAT images from a region of 21500 km^2 around Marabá

These data show us that deforestation rates were about 0.6% per year between 1984 and 1993 (ENGREF et al. 1997), similar to the 0.5% found by Fearnside (1990) analysing LANDSAT images from 1988 and 1989. An important point in the analysis of the development of livestock production in the zone is the decrease in the area of degraded pasture. At the same time, well-maintained pasture more than doubled, increasing by 0.5 % per year. This reflects a change in technology, which results from the substitution of less capital-intensive farms by richer ones and the process of land reconcentration in older zones. The process of intensification is stimulated by the trend in meat prices as explained earlier. With prices decreasing ranchers in established areas

have to intensify, otherwise production in these zones becomes unprofitable. They have to intensify or sell, which also leads to intensification. Land reconcentration at this is limited, because it is mainly small to medium size farms that disappear. However, very large ranches do not follow this pattern. They are generally very extensive, and intensification requires much greater monitoring and investment per hectare, which is not an economically viable option.

In addition to changing prices and the evolution of farming systems, other factors lead to the higher participation of smallholders in livestock production. Policies have changed in the last six years in the Brazilian Amazonia, mainly due to pressure from organised social movements and farmers' organisations. Credit is more available to family farmers than it was during the 1980s, and has been offered at low interest rates. This type of credit, called FNO, supports livestock production and perennial crops for small producers. Around 55% of credit to family agriculture between 1989 and 1993 was destined to initiate or to consolidate livestock production in Amazonia, though in some frontiers regions this rate can rise to 70%. (Tourrand et al, 1997). In 1996 around 293 000 animals were bought using FNO funds in Pará State, whereas only 60 000 ha were planted with perennial crops (BASA 1997).

These changes are supposed to increase the opportunities of family farmers to stabilise production in the frontier. However, not all the farmers have access to credit. Investment levels using FNO credit have doubled the capital of some farmers in Marabá region. This produces tremendous inequalities rapidly within the locality, which in turn increases changes in the frontier. It will only be possible to evaluate the effect of this policy in a few years' time, but one assumption is that this will propel those who are unable to access credit deeper into the frontier, and to increase forest conversion caused by family farmers.

In some intermediate zones small farmers will continue to survive. Given the synergistic relation between ranchers and small farmers, small farmers will continue to exist, with the former selling calves and labour to *fazendeiros*. If some smallholders

remain in localities in the longest established zone, this is due to evolution in the frontier as well, with the creation of the 'milk lakes'. When specialised milk production becomes feasible small farms can survive and resist change in an environment where forest becomes scarce. Milk production represents an opportunity for the creation of economically sustainable, and probably also ecologically sustainable, farming activity, without forest areas. However the challenge is to maintain the diversified farming systems and forest cover, and at the same to promote increased revenues and improvement of infrastructures.

3 Principal issues related to livestock production in the region

Despite the diversity of cattle production systems in Amazonia, the debate on its sustainability has focused on two issues: the environmental impacts of cattle production and the social and economic consequences of expansion of cattle production. These two issues are examined in this section.

There are a number of different aspects of environmental impacts of livestock production. One of the most controversial issues is related to pasture degradation. Pasture degradation will be analysed here, highlighting some of the different approaches for explanation and analysis.

3.1 Pasture degradation

Much previous research has focused on the environmental degradation associated with the process of forest conversion to pasture. In our analysis of the degradation process it is important, as Chauvel et al. (1997) proposed, to make a distinction between *forest ecosystem degradation*, which means the environmental damage caused by forest conversion to other land uses, and *agroecosystems degradation*, the subsequent environmental changes that cause a decline in agricultural productivity. This is a useful distinction, because it helps us to clarify what we consider to be degradation, since from a forest ecosystem perspective, the process of pasture degradation that interests us is in reality a first step in forest recovery.

Understanding the process of degradation

Explanations, and consequently, alternatives to halting pasture degradation have traditionally highlighted the decline in soil chemical fertility as the main factor influencing degradation, sometimes linked to overgrazing and pasture management. This explanation, dominant in the scientific literature, has been partially replaced by others that stress the role of pasture management and weed control in the process of pasture degradation. Both these approaches are discussed in the following section:

Toledo and Serrão (1982) propose a model that illustrates the role of soil fertility decline, as shown in Figure 3.1. Through this model, degradation is found to be most significant when soil fertility levels become lower than under forest cover.

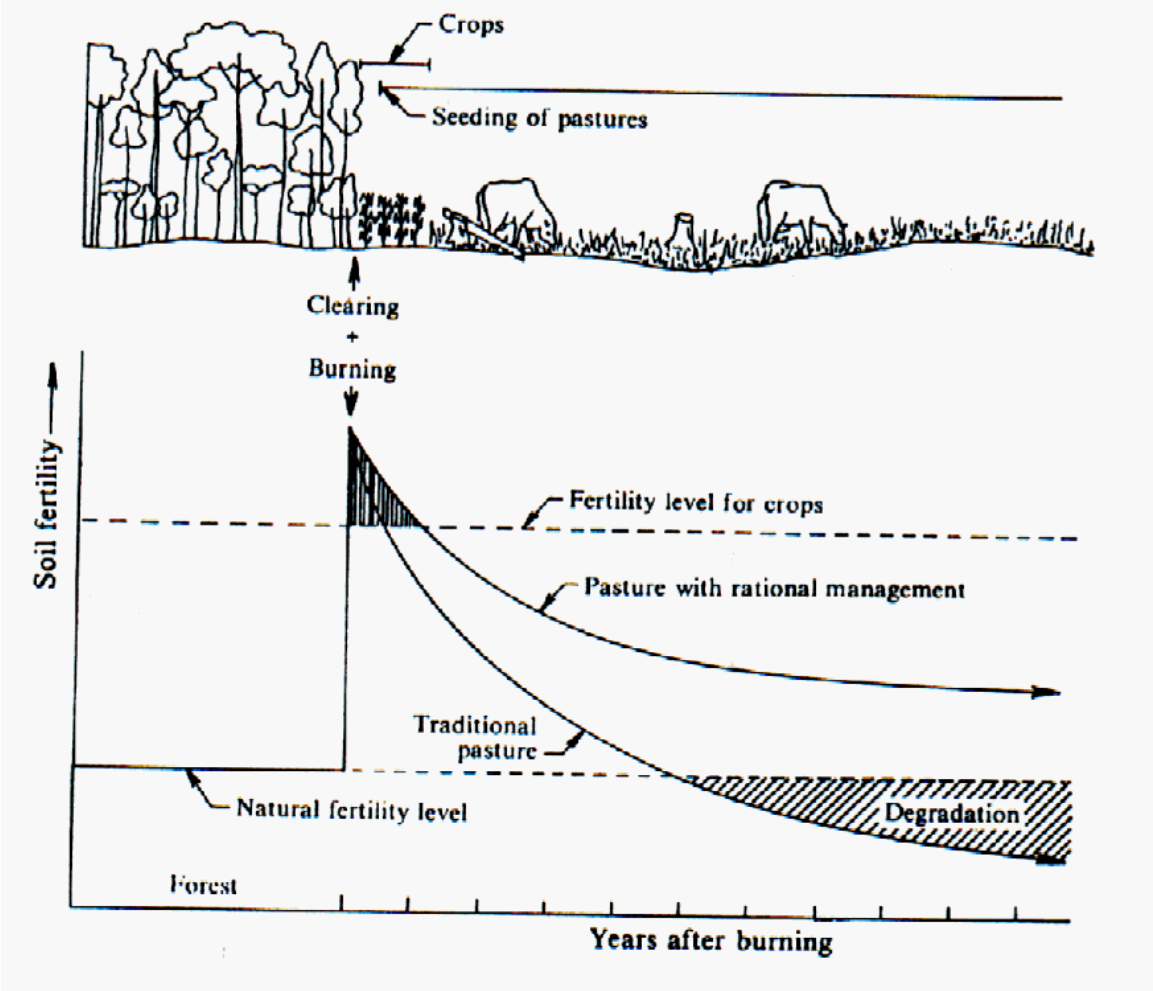

Figure 3.1: Model of pasture degradation illustrating the evolution of soil properties under grazing using varying management strategies.
Source: Toledo and Serrão, 1982

Data from authors working in different parts of Amazonia (Falesi, 1976 in Mato Grosso and Paragominas; Hecht, 1985, in Paragominas; Correa and Riechardt, 1995 in Manaus; and Moraes et al., 1996 in Rondônia) have evaluated the dynamics of soil fertility comparing soil under forest and pastures of different ages, generally up to 10 years but sometimes as much as 81 years, as discussed in the Rondônia study. Although differences exist due to site diversity and different research methodology, these studies

display similar patterns. The most important changes happen during the first five years, as a result of burning and first establishment of cultivated grass or crops. Generally after burning there is an increase in pH and in the levels of Ca and Mg, as well as very important increase in K and P. After the first years of pasture there is a rapid decrease in P and K levels, although K stocks remain high. Ca and Mg, as well as pH show a slower but steady decline. These levels remain relatively stable after 10 years of pasture, and generally in levels above those previously existing under forest cover (see Figure 3.2). This contradicts the model proposed by Toledo and Serrão, since even in pastures 81 years old the level of nutrients has been maintained higher than their original level under forest. The organic matter level, also affected by changes in soil cover, shows a decrease in original levels after burning but increases with pasture development. This is thought to be due mainly to the deposition of root biomass, as evidenced in works conducted by Teixeira and Bastos (1989) in the Manaus region.

For those who support the hypothesis of low levels of fertility as a main cause of pasture degradation, the issue is not the comparison between soil under forest and pasture, but the low levels of phosphorus present in any situation, except for the 2-3 years immediately after burning. One of the main pasture grass species used in the 1970s-1980s, Panicum maximum, is very sensitive to decline in soil phosphorus levels and the competition from weeds adapted to low P levels, leading to significant decrease in pasture productivity (Hecht 1983).

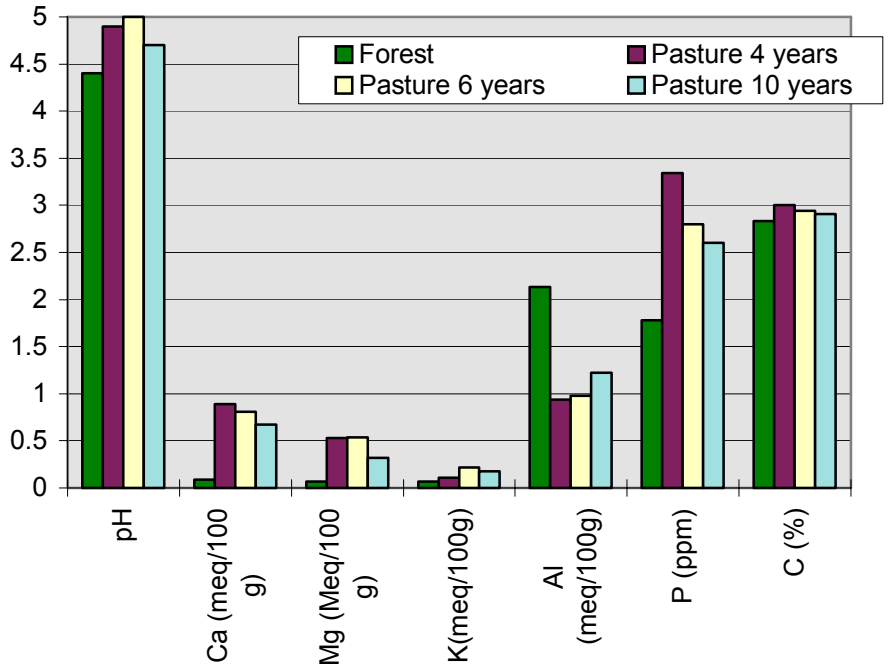

Figure 3.2: Chemical characteristics of the first 10 cm of a Ultisol in Manaus, Central Amazonia under forest and pasture of *Brachiaria humidicola* at different ages.

Source: Correa and Reichardt, 1995

Some scientists have also tried to understand the role of soil physical changes in pasture degradation. A process of compaction and reduction of porosity in soils under grazing was pointed out by Chauvel et al (1997) and Correa and Reichardt (1995). This occurs due to forest clearing, the use of fire for clearance and for pasture maintenance, and cattle trampling. This compaction constrains the development of grass roots and hence the supply of water to plants and the diffusion of oxygen, affecting plant nutrition. These physical changes have a greater impact if levels of chemical nutrients are also in decline. Excessive rainfall in some regions interferes with grass growth rates and accelerates soil compaction. Yet, in comparison to soil changes, very few studies have tried to analyse the relation between soil fauna and pasture degradation. A study in Peru conducted by Lavelle and Pashanasi (1989) points out that pastures present the highest microfauna biomass when compared to the same soil under forest, fallow or crop, although the biodiversity of the soil fauna is very low. Within this biomass, they found a

very high population of a type of earthworm that is thought to have a very important role in the conservation of soil fertility.

The role of weeds in pasture degradation, which is associated with pasture management, has been acknowledged as an important factor but remains under-researched. However, some detailed studies of forest regeneration after pasture provide an insight to the process of pasture degradation. Studies conducted by Uhl and others in Paragominas evaluating different areas of abandoned pastures, shown that forest recovery after pasture abandonment is a fairly rapid process, the ease and speed of which being related to the intensity of its use (Nepstad et al., 1991, Uhl et al., 1989a, Uhl et al., 1991, Uhl et al., 1989b, Buschbacher et al., 1988, Vieira et al., 1996). Under light use (when grass establishment is poor and pasture is quickly abandoned), sites can accumulate significant biomass (up to one third of forest biomass) within 8 years of abandonment. However, under more intensive use, incorporating better pasture establishment and more frequent weeding, the conditions for forest re-growth become more difficult. The more frequent use of fire is one of the most important obstacles to forest regeneration, because firstly it hinders tree regrowth in pasture and secondly it decreases the diversity of the forest next to the pasture, which could provide seeds for forest regrowth. Soil nutrient concentration in these studies was hardly affected by the intensity of pasture use and age since abandonment. In addition, soil nutrient concentration was not found to be correlated with biomass or species diversity (Buschbacher et al., 1988). The authors however, do not show that intensity of soil use has no influence on soil nutrient concentration, but that for forest recovery this effect is short lived. (ibid. p.693). If we identify forest re-growth in pasture as a form of pasture degradation, the role of pasture management and weed control are evidently the key elements to the understanding of the pasture degradation process.

Studies that have been conducted in Marabá have also emphasised the role of pasture management and weed control, with the soil deficiency hypothesis taking second place. Topall (1995) has pointed out that farms in the same region, using the same type of grasses and with similar technical resources, can demonstrate very different levels of

pasture degradation, implying that soil chemical fertility is central to the process of pasture degradation. This process is influenced by farmers practices in the early phases of pasture establishment. Key factors are the species utilised, and the effectiveness of the sowing/planting process. Low initial densities allow not only the growth of weeds but also increase erosion. *Panicum maximum*, although very palatable, grows patchily, and thus not providing complete ground cover. Species used in late 1980s and 1990s like *B. humidicola* and *B. brizantha* provide more even cover.

Another important factor is the stocking rate. Current ideas about the role of stocking rates in pasture degradation indicate that overgrazing and the premature use of recently established pastures are significant factors contributing to pasture degradation. However, Topall (1995) and Duru (1994) have observed that low stocking rates are responsible for low grass cover, as this means that animals do not consume enough to stimulate grass sprouting. As a result, weeds can invade, and in the Marabá region, farms with higher stocking rates have been observed to have less weedy pastures. Low consumption of grass by stock also results in an accumulation of dry matter, making the use of fire necessary to stimulate grass sprouting. The frequent use of fire has three very negative effects: selective plant extermination, decrease in plant density, and the encouragement of fire-resistant weeds, making pasture control much more difficult. When pasture is completely dominated by fire-resistant weeds, manual pasture recuperation or natural forest recovery becomes very difficult.

In short, pasture degradation is associated with different processes. However, the main influencing factor is how pasture has been managed. This is in turn related to farmers' objectives, knowledge, and economic conditions. For example, according to Uhl and Buschbager (1988), the use of fire for weed control was rarely employed in the late 1970s, but during the 1980s, it became more common due to the lack of capital for manual cutting or purchase of herbicides. In order to understand and control process of pasture degradation it is essential to identify and evaluate different farmers' practices of pasture management and to put these practices in their farming systems context. The

study of farmers' practices can potentially provide many insights for researchers to enhance sustainability of livestock production in the region.

3.2 Other environmental issues

Some arguments claim that pasture does not have a bad impact on the environment: it is a renewable system, that it provides a dense plant cover, it extracts only limited quantities of mineral elements from soil, and that it should be able to maintain its fertility. In short, amongst the different options for land use after forest conversion, this is claimed to be one of the less harmful.

Most of the negative impacts of pasture expansion are closely associated with deforestation, so it is often difficult the environmental consequences of deforestation from those of pasture establishment. For example, the pasture-ecosystem itself does not contribute to increases in atmospheric CO_2 concentrations, but in fact, acts as a sink, storing 9 to 18% more C in the soil than original forest cover, according to Cerri et al (1985). However, the process of burning the forest releases significant amounts of CO_2 to the atmosphere. In addition, the loss of biodiversity cannot be directly attributed to pasture development.

Nevertheless pasture itself can be harmful to the environment. Pasture also alters climate at local and regional level. Some models predict that equilibrium climate for a pasture vegetation in the region would have the actual levels of precipitation reduced. In relation to forest, pasture increases both surface and soil temperature, the diurnal fluctuation of temperature and changes levels of humidity and reduces evapotranspiration.

The creation of landscapes dominated by pasture, increasingly found in areas of smallholders in some frontier regions as well as on larger cattle ranches, has consequences to natural and agro-ecosystems. One of the most important concerns the spread of fire. Pasture vegetation is extremely susceptible to fire, in comparison to

ground cover types: in Eastern Amazonia only 6 days without rain are enough to make pasture flammable (Uhl et al., 1990). In these conditions fire accidents can be very common, mainly because fire is a constant presence in pasture management and land preparation. Fire threatens to forest ecosystems, other pasture areas, crops and homes. The presence of fires as a ubiquitous pasture management tool in these regions is a critical constraint to perennial cropping and orchard establishment, which is more common in the longest established colonised zones which have good infra-structure links. So the presence of pasture jeopardises the opportunities and success of other land uses, which could eventually be more environmentally and economically desirable.

3.3 Social effects of livestock production

The expansion of cattle production in Amazonia has had significant impacts on rural development. The large cattle ranches have been highlighted as the main cause of serious social problems in Amazonia. In the process of establishment of such large projects, existing traditional populations have often been displaced or have their means of livelihood destroyed, such as the Indians or brazil-nut gatherers in some regions. Government incentives to large enterprises increased inequalities in the region, resulting in land concentration and centralised control of productive resources and their associated outcomes: landlessness and rural violence (Schmink and Wood, 1992). As practised by small or large- scale farmers, one common criticism of livestock production is the low level of employment it requires, so income generated by this activity remains in the hands of a few. As pointed out by Hecht (1992 p.382) the combination of large ranches, violence and limited employment opportunities associated with ranching have resulted in extraordinary rates of urbanisation as small farmers suffer from decreased access to land and jobs.

Because livestock production demands much more land than most other production systems to support each household, it results in low-density patterns of land settlement (Ledec, 1992). This increases per capita costs of infrastructure like roads or

schools, and people living in low-density zones very often forgo access to these vital services.

The process of land occupation in certain frontier regions illustrates the problems described above very well: in localities where cattle become important, it is very difficult for a farmer to continue to rely on crops or forest products. The general decrease in forest cover associated with past or present pressure on resources does not allow the remaining forest to maintain the same productivity; moreover fire penetration into forests becomes more frequent in a landscape dominated by pasture. With the local shortage of production, buyers of crops and forest products do not have an incentive to visit the locality, therefore decreasing marketing opportunities. In this situation the poorest families, without cattle, will be severely penalised by environmental degradation and poor economic opportunities. The tendency is that just the wealthiest will remain in localities where cattle keeping is really advanced, because the need to increase pasture areas will provide an incentive for them to buy neighbours' land. Poorer farmers will be compelled to move as a result of the constraints to practising a diversified system (Muchagata 1997). The remaining farmers will live in conditions where roads have been improved and some services are already present, but cannot survive for long. As the number of children decreases at the school, the local government refuses to continue to pay teachers or to maintain roads. Social links that were important in early times of colonisation, like support in times of illness or other difficulties, do not exist anymore. The creation or continuance of some types of organisation, like unions, co-operatives or even churches, becomes more difficult when distance increases and new and wealthier newcomers arrive, replacing some of those who have already left.

It is apparent that trends are towards more intensive livestock systems As will be shown in the following chapter, there are some technical solutions to make this activity more sustainable, but it is unlikely that these can provide any improvement on the negative social effects of cattle raising in Amazonia. In relation to small farmers, the issue of livestock production should be tackled beyond the cattle production conditions itself, but should consider the whole farming systems and farmers' livelihoods strategies

in order to maintain agro-ecosystems diversity and limit the intensification and specialisation in cattle production.

4 The proposed alternatives and the research work on livestock systems sustainability in Amazon region

This section reviews research into the alternatives to enhance sustainability of livestock production in Amazonia. It focuses primarily mainly on the adaptability to some of these proposals to diversified smallholders farming systems.

As discussed in earlier sections, although cattle have been in Amazonia for a long time, it was only during the last 30 years that this activity has become prominent. The problems associated with livestock started to be analysed in detail in the early 1980s, when problems of degradation and social inequalities became evident. In such a short time major research efforts have concentrated on understanding processes at work, which is where knowledge gaps are still important. In relation to alternatives, although they have been discussed in theory, many of them are in very early stages of development and have not been fully assessed or evaluated. Moreover, if technical alternatives exist, they should be complemented by effective policies to guide the direction of livestock production and natural resource management in general. These policies are often difficult to implement, even when there is political will.

4.1 Technical alternatives

The unsustainable mature of livestock production in Amazonia is caused mainly by the way the activity extends into new areas of forest. One of the main aims of technical proposals is to make the activity more intensive, so relying less on the constant need of expansion of pastures at the expense of forest. From the technical point of view pasture degradation is identified as the major problem to be tackled. The starting point is in the diagnosis of the main cause of this degradation: declining fertility of pasture lands. The sustainability of pasture relies on good management of soil chemical fertility, but Section 3 pointed out that this is not the main cause of degradation. Studies based on the declining fertility hypothesis should be complemented by others addressing problems of weed control and the techniques of pasture management.

Proposals to tackle the problems of fertility management have followed two lines of reason: one that proposes methods for reclaiming degraded lands with classic steps in intensification steps (mechanisation, improved genetic material, etc.); and another that focuses on the establishment of agro-silvopastoral systems.

The first approach has dominated research until very recently. According to Simão (1995), the research in Brazilian Amazonia has concentrated in three foci: forage adaptation; forage fertilisation; and pasture reclamation. The forage adaptation programme conducted by the Brazilian Agricultural Research Enterprise (EMBRAPA) in association with CIAT was able to identify many grasses and legumes species with potential for the region, and are primarily responsible for disseminating the currently widely used *Brachiaria humidicola*. The other programs have resulted in developing techniques for reclamation of degraded pasture using mechanisation, fertilisation and weed control. In the same way EMBRAPA developed technology for extending productivity of first-cycle pastures, including phosphorus fertilisation, weed control and subdivision of paddocks for improved grazing management (Serrão and Toledo 1992). A reclaimed pasture can support from 800-1000 kg/ ha without signs of degradation, but that requires the investment of US$ 250/ha. (Tourrand et al., 1997:185). Although these systems can be profitable for a rancher, they are still difficult for small farmers to adopt, since this level of investment is too high for them and they lack machinery.

Researchers investigating the agro-silvopastoral systems, follow the reasoning that it is very difficult to sustain the type of livestock production methods developed in the industrialised countries (use of mechanisation, dependency on fossil fuel and agrochemicals, etc.). Instead, the appropriate strategy is to take advantage of tropical environmental conditions (Murgueitio 1990), such as the capacity of certain crops to - generate high rates of biomass production and the diversity of nitrogen-fixing plant species in the natural forest flora.

Although trees are not a new component in pastures in some Amazonian regions, as many farmers keep some desirable trees from the forest in their pasture areas (Muchagata, 1997), agro-sylvopastoral experiments have tried to increase the tree component in farming systems. They do this by mixing adapted legume and grass forages with trees of multipurpose use: including nitrogen fixation, wood production and forage. Experiments have been conducted in different parts of Amazonia: Brazilian Eastern Amazonia , Bolivia, Ecuador, Peru (Peck and Bishop, 1992, Saldías et al., 1994, Venator et al., 1992, Ramírez et al., 1992; Loker, 1994, Brienza et al., 1995), both on station and on farm.

The difficulties encountered in such experiments are threefold. Firstly discovery of suitable combinations that combine the best grazing conditions with tree development. They have found critical problems with tree shading and to determine adequate stocking rates. Secondly, even when conducted in on-farm conditions, these experiments do not consider how they actually fit into farming systems. For example, only one of the experiments analysed presents data about labour demand. However, one of the main problems is the difficulty in implementing these types of systems in areas where fire is still the dominant tool for pasture management. In Brazil even field experiments have been destroyed by accidents with fire. Fire is also the reason why live fences are impossible to introduce into farming systems. In this sense one promising alternative is the system proposed by Loker (1994), that adapts the common farmers' practice of allowing fallow regeneration on pasture land after several years of grazing in order to recover fertility and to improve weed control. In the proposed system the common sequence burn-crop- pasture-fallow is improved by the introduction of a mix of leguminous forage species in the pasture phase, and by the sowing of a few legume tree species in the fallow phase, but still relying mainly on natural re-growth. After a period of 2 to 3 years of fallow regeneration, this is slashed and burned again in a new cycle. Unfortunately this system has not been tested yet in the field.

Another technical alternative to intensify livestock production is to change from solely pasture-based to an integrated forage system supply. Species tested for this system

are those used in other South American regions, including as elephant grass and sugar-cane. A key problem in implementing this system in present farming systems is once more the higher labour demand.

Research conducted to date in Amazonia is very narrowly focussed, concentrating solely on ecological aspects of sustainability, and on researchers' definitions of it. The constraint to the adoption of technical alternatives can be overcome only if technical proposals consider the limitations and constraints of existent farming systems and if alternatives evolve from farmers' actual practices. Recent research on pasture degradation highlights problems of management as the principal problem. Therefore, the reasons and motivation underlying current pasture management practices should be investigated and understood. In some regions, farmers have found methods to slow the process of degradation, and these practices could be supported with research. According to Schelhas (1996), farmers in Sarapiquí, Costa Rica have intensified their cattle grazing using only locally developed pasture management methods. So farmer knowledge and experiments are potentially very useful in finding locally appropriate strategies to improve pasture management.

Other areas of research that could reinforce farmers' practices and perspectives is the identification of fire tolerant species which could be used in silvopastoral systems. Even if fire is not purposely used in farming systems, accidental fires will probably always be present. Another point of entry for research is to invest more in the animal component. Farmers are very interested in cheaper and available animal health control methods. Also research in genetic improvement of stock is generally developed outside the region, and of course, without farmers' participation. With the development of cattle for milk production, the increase in productivity depends very much on the genetic potential of the animals, that need to be adapted to the region. Amongst small farmers successful work concerning animals should allow the opportunity to discuss and improve pasture management.

4.2 Policy alternatives

Policies that only promote the intensification of cattle production are unlikely to reduce deforestation rates because incentives for forest clearing transcend the market demands for livestock products (Nicholson et al., 1995: 723). If intensification is possible in 'old' frontier zones, where land prices are higher and access to market is relatively easy, the same does not occur in newly opened areas, where new land is easily appropriated.

The intensification of livestock activity relies on the development and implementation of policies that do not provide incentives for clearance of new areas. This process will necessarily lead to intensification of the activity. It is important also to support other types of production that could represent an alternative for cattle production. Of course these measures are not simple, but are critical to the intensification of livestock and other land uses in Amazonia.

In the case of small farmers restabilisatoin of land use in the frontier requires supporting infrastructure and market conditions. Since the small farmers are always looking alternatives for diversification, the improvement of infrastructure would facilitate the adoption of perennial crops, as occurs in some other regions. Moreover, infrastructure usually leads to an increase in land prices, pushing the process of intensification. Common solutions like credit for other activities or for the improvement of pastures instead of expansion of cattle production, associated with research directly related to family farmers' needs would have a better chance of producing feasible alternatives for more sustainable land use and production systems.

5 Identifying gaps in the literature for further research

Early sections discussed livestock systems in Amazonia and pointed out the relationship between livestock production and sustainability of colonists' farming systems. Numerous issues regarding cattle raising in Amazonia have been analysed by scientists working in the region. However, little is understood of how farmers perceive these problems. The research has been driven by the scientific agendas of the research institutes, not by the farmers' needs. Questions remain as to what farmers think could be done. Pasture degradation has been identified by researchers as the major problem for non-sustainable livestock production in the area but is this perception shared by farmers? What are the main constraints identified by farmers to intensification rather then extensification?

Current research in Marabá conducted in a partnership between the Overseas Development Group, University of East Anglia, the Laboratório Sócio Agronômico do Tocantins, University of Para and smallholders' unions (STRs) and associations from Marabá region, aims to build up farming systems models which incorporate farmers perceptions. This modelling work will produce elements for assessment and evaluation of livestock production that links biological systems with elements of decision-making. As proposed by McClintock and Ison (1994:214) the framework for this work 'emphasises the position of the researcher as part of a constructed system, and the process of initiating changes in understanding by emergence through dialogue'. In this sense it goes beyond pure research, penetrating into the field of participatory action-research.

Figure 5.1: Marabá region: the study area

5.1 Research questions

Previous parts of this document have stressed the associations between pasture/livestock production and land clearance. The use of space, which in the frontier case is initially inextricable with the use of forest, is an important concern for the study of livestock farming systems, because at the same time as being an element of production, it is also a result of livestock activity (Gibon et al. 1994). Are there any chances for livestock intensification in the frontier? Under what conditions? Do the small farmers have a technical basis for this intensification? These are the principal questions for this research programme. The intensification here is viewed as a decrease in the pressure of livestock on natural resources, limiting its use of space/land/forest, with an increase of AU per area and/or output of beef or milk per AU.

Even if there are reasons besides technical reasons for pasture establishment by family farmers (see section 1), a diversity of practices have been observed in the study

region: practices regarding herd aggregation, animal husbandry, farming, and promotion of livestock products, following a typology proposed by Landais (1987). The analysis of farmers' practices is a way by which we formalise their model of action. Given the diversity of natural, economic and social conditions within the region, a great diversity of practices will probably exist. Some of them may help improve the sustainability of livestock systems. Thus, there is a need to identify and evaluate these practices and to assess its consequence to the sustainability of the enterprise as a whole. This introduces another research question: to identify what sustainability means for smallholders, (i.e., what sort of sustainability are they aiming for and the role of livestock production). How do they evaluate the level of sustainability of their farming/extractive activities? What could be the indicators of sustainability that make sense for them?

A secondary research question for this work is how the scientific research effort could interact with farmers' perceptions and objectives in order to search for alternatives to make farming systems in frontier zones, and particularly the livestock component, more sustainable.

The results of this research will present a comparative analysis of practices, analysing their efficiency and will the point out new research needs and provide support for policy making in order to promote more sustainable farming/ livestock systems

The main contribution of this research will be doing that using farmers references and perceptions, so turning possible the inclusion of farmers in decision making process, increasing the chances of possible development proposals.

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Smallholder Farming Systems in Amazonia:

Livestock Production and Sustainability

Part II Annotated Bibliography

Organization

The bibliography is divided in 12 sections:

1. Farming Systems in Amazonia
2. Livestock Systems in Amazonia
3.Animal Husbandry
4. Pastures General
5. Pasture Degradation
6. Pioneer Frontier
7. Livestock Economy
8. Livestock Production: Environmental Issues
9. Livestock Production: Social Issues
10. Nutrient Cycling
11. Livestock Systems and Issues in Tropical America (outside Amazonia)
12. Methodologies

The section aims to bring together findings from Anglophone and other literature. It has approximately 180 single entries, but almost half of them have been multiple sections. About half of the documents were written in English, but the remainder are from Brazilian, French and Spanish literature. The database entry consists of the complete bibliographic reference, followed by a brief summary, the language, and 5 key words: 3 to 4 about the subject and 1 to 2 identifying the place where research was carried out.

Examples of complete entries

- Loker, W. M. 1994. Where's the beef? Incorporating cattle into sustainable agroforestry systems in the Amazon Basin. *Agroforestry Systems* 25:227-241.

Low external input agroforestry systems hold great promise as alternative, sustainable production systems for small-to-medium farmers in the Amazon Basin. The design of such systems is considered essential to stabilize agricultural production and avoid the cycle of continuing destruction of primary forest. In order to be successful, these systems must be compatible with local ecological conditions and adaptable by farmers. Currently, many producers in the Amazon Basin use a slash-and-burn agricultural strategy that combines annual cropping with cattle grazing in mixed farming systems. While cattle play an important role in household economic survival, grazing-induced land degradation threatens the long-term viability of these farms. The paper presents a model of a low external input agroforestry system that incorporates farmer preferences and practices but uses well-adapted grass-legumes pastures, rotational grazing and the management of natural forest regeneration to enhance productivity in an ecologically sound manner.

Language: English

Key words: Agro-silvo-pastoral systems; livestock systems; livestock systems experimentation; pasture management; Peru

- Gibon, A., Matheon, G., Vissac, B., Flamant, J.-C., Revilla, R., and Sibbald, A. R. 1994. "Systèmes d'élevage en ferme: le zootechniciens européens à la recherche de concepts et d'outils." *Systems-Oriented Research in Agriculture and Rural Development International Symposium, Montpellier, 1994*, pp. 34-38.

A series of symposia were initiated by the European Association for Animal Production and the European Economic Community in 1990 to encourage discussion between animal production scientists concerned with on-farm livestock systems. Approaches implicitly or explicitly refer to systems analysis and systems modeling, an aim to define an approach to animal science adapted to the operators of livestock production. The objective is to contribute more effectively to sustainability in livestock farming. These discussions complement exchanges with other agricultural scientists and sociologists in the research and development field. The symposia focus on theoretical and methodological bases for assessing the farmer as a manager, integration of specialist knowledge from the different branches of animal science, assessment of land use by livestock farming, and protocols and designs for field work in animal science.

Language: French

Key words: methodology; livestock system; systemic modelling; participatory research; Europe

1 Farming Systems in Amazonia

Documents in this section describe and analyze aspects of farming and land use systems in different Amazonian regions, and practiced by very diverse population groups. Generally systems that do not include cattle have been excluded, which explains the omission of most of the Indian groups land use systems.

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Thiele, G. 1991. *The Barbecho crisis: revisited*. *Technical Report nº 1*. Santa Cruz: CIAT/MBTA.

Thiele, G. 1993. The Dynamics of Farm Development in the Amazon: The *Barbecho* Crisis Model. *Agricultural Systems* 42:179-197.

Trujillo-Arriaga, J. 1992. “Integrated Production Systems,” in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 293-301. Boulder: Westview Press.

Walker, R., and Homma, A. K. O. 1996. Land Use and land cover dynamics in the Brazilian Amazon: an overview. *Ecological Economics* 18:67-80.

2 Livestock Systems

This section groups papers that contain a description of the detail organization and characteristics of livestock systems in different parts of Amazonia.

Arima, E., and Uhl, C. 1996. *Pecuária na Amazônia Oriental-desempenho atual e perspectivas futuras*. *Série Amazônia nº 1*. Belém: IMAZON.

Azevedo, G. P. C. de, Carvalho, R. A. de, Teixeira, R. N. G., Sarmento, C. M. B., Rodrigues, J. A., Filho, Gonçalves, C. A., and Oliveira, R. P. de 1994. *Características dos Sistemas de Produção de Gado de Corte na Região Bragantina*. Belém: EMBRAPA-CPATU.

Billot, A. 1995. "Systèmes d'élevage en Zone Bragatine," , pp. 46-78 (140): EMBRAPA-CPATU-EMVT.

Bonnal, P. 1994. *Economie de l'exploitation agricole et systemes d'elevage sur le front pionnier en Amazonie*. CIRAD-SAR.

Dedieu, B. 1987. "Elevages bovins-viande en Guyane: premiers résultats des suivis techniques et essai de typologie," in *Systemes d'elevage et herbager en milieu equatorial*, pp. 23-40. Paris: INRA.

Dutra, S., Serrão, E. A. S., Veiga, J. B. de, Simão, M., Neto, and Vasconcelos, R. A. 1990. "Sistemas de Produção Pecuária na Região de Paragominas, Pará, Brasil." *I Reunion de la Red Internacional de Evaluación de Pastos Tropicales RIET-Amazonia, Lima-Peru, 1990*, pp. 1083-1089. Documento de Trabajo nº 75 2.

EMATER-PA, and EMBRAPA-CPATU. 1979. *Sistemas de Produção para Bovino de Corte. Microrregião do Araguaia Paraense*. *Sistemas de Produção Boletim 162*. Belém: EMATER-PA and EMBRAPA-CPATU,.

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Landais, E. 1995. *Rapport de mission au Brésil*. INRA-SAD.

Lhoste, P., and Toutain, B. 1993. *Etude de la Reprodutibilite des Systemes de Production a Forte Composante Elevage en Milieu Amazonien*. CIRAD.

Loker, W. M. 1993. The Human Ecology of Cattle Raising in the Peruvian Amazon: The View from the Farm. *Human Organization* 52:14-24.

Loker, W. M. 1994. Where's the beef? Incorporating cattle into sustainable agroforestry systems in the Amazon Basin. *Agroforestry Systems* 25:227-241.

Mattos, M. M., and Uhl, C. 1996. "Perspectivas econômicas e ecològicas da pecuária na Amazônia Oriental na década de 90: o caso de Paragominas," in *A evolução da Frontiera Amazônica. Oportunidades para um desenvovolvimento sustentável*. Edited by O. T. de Almeida, pp. 39-65. Belém: IMAZON.

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Tourrand, J.-F., Veiga, J. B. de, Quanz, D., and Ferreira, L. A. 1995. "Produção Leiteira na fronteira agrícola na Amazônia: O caso do município de Uruará-PA na Transamazônica," , pp. 18. Belém: EMBRAPA-CPATU.

Tourrand, J.-F., Veiga, J. B. de, Guia, A. P. de O. M., and Carvalho, S. A. 1995. "Stratégies et pratiques d´élevage en Amazonie brésilienne. Dynamisme et diversité dans l'agriculture familiale." *Fertilité du milieu et stratégies paysannes sous les tropiques humides, Montpellier, 1995*, pp. 251-259.

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Veiga, J. B. de, Tourrand, J.-F., and Quanz, D. 1995. "O perfil da pecuária no sistema de produção do município de Uruará-PA. Primeiros resultados de um diagnóstico," , p. 19. Belém: EMBRAPA-CPATU.

Veiga, J. B. de 1995. "A situação atual e perspectiva da pecuária na Transamazônica: Resultados e recomendações de uma levantamento sócio-económico,", p. 18. Belém: EMBRAPA-CPATU.

Veiga, J. B. de, Tourrand, J.-F., and Lau, H. D. 1995. "Pecuária Familiar na Amazônia. Uma abordagem desta realidade esquecida," , pp. 4. Belém: EMBRAPA-CPATU.

Venator, C. R., Glaeser, J., and Soto, R. 1992. "A silvopastoral Strategy," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 281-292. Boulder: Westview Press.

Vera, R., and Seré, C. “Los Sistemas de Produção Pecuaria Extensica del Trópico Sudamericano. Analisis Comparativo,” , pp. 432-450.

3 Animal husbandry

Papers in this section describe practices developed by farmers or by researchers' experiments describing and analyzing practices related to animal health care, herding practices, herd management, breeding techniques and animal husbandry practices in general.

Azevedo, G. P. C. de, Carvalho, R. A. de, Teixeira, R. N. G., Sarmento, C. M. B., Rodrigues, J. A., Filho, Gonçalves, C. A., and Oliveira, R. P. de 1994. *Características dos Sistemas de Produção de Gado de Corte na Região Bragantina*. Belém: EMBRAPA-CPATU.

Lau, H. D. 1995. “Recomendações básicas. Práticas sanitárias para bovinos na região Amazônica,” , pp. 7. Belém: EMBRAPA-CPATU.

Lau, H. D. 1995. “Diagnóstico Preliminar da Sanidade de Bovinos na Agricultura Familiar do Município de Uruará-PA,” , pp. 9. Belém: EMBRAPA-CPATU.

Gonçalves, C. A., Simão, M., Neto, Oliveira, F. W. R. de, and Azevedo, G. P. C. de 1993. *Diagnóstico Tecnológico-econômico de Propriedades Leiteiras na Região Bragantina*. *Documentos, 74*. Belém: EMBRAPA-CPATU.

Toledo, J. M., and Serrão, E. A. S. 1982. “Pasture and Animal Production in Amazonia.” *Amazonia: Agriculture and Land Use Research, 1982*, pp. 281-309.

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Wilkins, J. V. 1992. *Mejoramento Genetico de Ganado Vacuno en America Latina: una revision de los recursos, practicas y perspectivas*. *Informe Técnico n 3*. Santa Cruz: CIAT-MBAT.

4 Pastures - General

Papers listed here discuss different topics related to pasture and pasture management in Amazonia: main species and characteristics; pasture ecology; pasture management techniques in real situation and experimentation.

Azevedo, G. P. C. de, Veiga, J. B. de, Camarão, A. P., and Teixeira, R. N. G. 1992. “Recuperação e Utilização de Pastagens de Capim-Jaraguá (*Hyparrhenia rufa*) na Engorda de Novilhos em Marabá, Pará,” in *Boletim de Pesquisa,134*, pp. 38. Belém: EMBRAPA-CPATU

Azevedo, G. P. C. de, Camarão, A. P., and Gonçalves, C. A. 1992. *Produção Forrageira e valor nutritivo dos capins: quicuio da Amazônia, mandaru, tobiatã, andropógon e tanzânia-1 em quatro idades de corte*. *Boletim de Pesquisa nº 126*. Belém: EMBRAPA-CPATU.

Barbier, M. F., and Andrieux, P. 1987. “Gestion d'un pâturage dégradé: comportement d'un tropeau de zébus et essai d'amélioration,” in *Systemes d'elevage et herbager en milieu equatorial*, pp. 85-113. Paris: INRA.

Bereau, M., and Sarrailh, J. M. 1987. “Un aspect de la pérennité de Digitaria swazilandensis paturé: évolution du rendement en milieu déforesté,” in *Systemes d'elevage et herbager en milieu equatorial*, pp. 63-84. Paris: INRA.

Duru, M., and Rellier, J.-P. 1982. Quelques déterminants de l'utilisation des surfaces pastorales dans les Pyrénées centrales. Example de la Vallée du Luron. *Agronomie* 2:599-609.

EMBRAPA-CPATU. 1984. “1º Simpósio do Trópico Úmido. Volume 5 Pastagem e Produção Animal” *1º Simpósio do Trópico Úmido, Belém, 1984* .

Falesi, I. 1976. *Ecosistema de Pastagem Cultivada na Amazônia Brasileira*. *Boletim Técnico 1*. Belém: EMBRAPA

Moreira, N. 1995. *Pastoreio. Interações Animal-Pastagem e seus Reflexos no Manejo e na Produção*. *Série Didatica Ciências Aplicadas*. Vila Real: Universidade de Trás-os-Montes e Alto Douro.

Nepstad, D. C., Carvalho, C. R., Davidson, E. A., Jipp, P. H., Lefebvre, P. A., Negreiros, G. H., Silva, E. D. de, Stone, T. A., Trumbore, S. E., and Vieira, S. 1994. The role of deep roots in the hydrological and carbon cycles of Amazonian forests and pastures. *Nature* 372:666-372.

Peck, R. B., and Bishop, J. P. 1992. Management of secondary tree species in agroforestry systems to improve production sustainability in Amazonian Ecuador. *Agroforestry Systems* 17:53-63.

Roberts, J., and Cabral, O. M. R. 1993. ABRACOS: a comparison of climate, soil moisture and physiological properties of forests and pastures in the Amazon Basin. *Commonwealth Forestry Review* 72:310-315.

Serrão, E. A. 1990. "Sustainability of Pastures Replacing Forests in the Latin American Humid Tropics: The Brazilian Experience." *Humid Tropical Lowlands Conference: Development Strategies and Natural Resource Management, 1990*, pp. 69-92 VI.

Serrão, E. A., and Nepstad, D. C. 1995. "Pastures on Amazonia Forestlands: A Review of Environmental and Economic Performance." *Interdisciplinary Research on the Conservation and Sustainable Use of the Amazonian Rain Forest and its Information Requirements, Brasília, 1995*, pp. 221-238.

Serrão, E. A., and Toledo, J. M. "Sustaining Pasture Based Production Systems for the Humid Tropics,", pp. 256-279.

Serrão, E. A., and Toledo, J. M. 1992. "Sustaining Pasture-based Production Systems for the Humid Tropics," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 257-280. Boulder: Westview Press.

Simão, M., Neto. "Pastagens no Ecossistema de Trópico Úmido: Pesquisas para o Desenvolvimento Sustentado." *Anais do Simpósio sobre Pastagens nos Ecossistemas Brasileiros. Pesquisas para o Desenvolvimento Sustentável. XXXII Reunião Anual da Sociedade Brasileira de Zootecnia*, pp. 76-93.

Souza, A. P. de, Filho, and Neto, J. F. T. 1992. *Resposta de Pastagem Degradada de Capim-Colonião à Consorciação com Leguminosas e Fertilização com Fósforo, Enxofre e Micronutrientes*. *Boletim de Pesquisa,127*. Belém: EMBRAPA-CPATU.

Teixeira, L. B. 1987. Dinâmica do Ecossistema de Pastagem Cultivada em Área de Floresta na Amazonia Central. PhD, Universidade do Amazonas.

Toledo, J. M., and Serrão, E. A. S. 1982. "Pasture and Animal Production in Amazonia." *Amazonia: Agriculture and Land Use Research,* pp. 281-309.

Topall, O., Veiga, J. B., da, Tutain, B., Mitja, D., Chauvel, A., and Desjardins, T. 1994. "Gestion durable des pâturages en Amazonie bréslienne. Relations entre systèmes de production et écosystèmes forestiers." *Systems- Oriented Research in Agriculture and Rural Development, Montpellier, 1994*, pp. 503-504.

Topall, O. 1995. "L'arbre et l'herbe en zone tropicale humide. Gestion des pâturages sur une frontière agricole amazonienne dans la région de Marabá, au sud de l'Etat du Pará, Brésil." *Fertilité du milieu et stratégies paysannes sous les tropiques humides, Montpellier,* pp. 260-265.

Vivier, M., Coppry, O., and Bereau, M. 1987. "Incidence du niveau de chargement sur la composition floristique et la production des praires pâturées par les zébus Brahman en Guyane française," in *Systemes d'elevage et herbager en milieu equatorial*, pp. 41-62. Paris: INRA.

5 Pasture degradation

Texts listed in this section analyses the different aspects of the process of pasture degradation, such as soil chemical and physical fertility, soil and grass biology and pasture management. Some papers about forest recovery have also been selected, since they help to elucidate some aspects of degradation process, as it is discussed in detail in sections 3.1 and 4 of the main document.

Balent, G. 1995. *Compte Rendu de Mission*. INRA-SAD 1501-95.

Barbier, M. F., and Andrieux, P. 1987. "Gestion d'un pâturage dégradé: comportement d'un tropeau de zébus et essai d'amélioration," in *Systemes d'elevage et herbager en milieu equatorial*, pp. 85-113. Paris: INRA.

Brienza, S., Jr, Vieira, I. C. G., and Yared, J. A. G. 1995. *Considerações sobre a recuperação de áreas alteradas por atividades agropecuária e Florestal na Amazônia Brasileira*. Belém: EMBRAPA-CPATU.

Buschbacher, R., Uhl, C., and Serrão, E. A. S. 1989. Abandoned Pastures in Eastern Amazonia. II Nutrients Stocks in the Soil and Vegetation. *Journal of Ecology* 76:682-699.

Chauvel, A., Barbosa, E. M., Blanchard, É., Grimaldi, M., Ferraz, J., Martins, P. de S., Topall, O., Barros, E., Desjardins, T., Filho, N. L., Miranda, I. P. de A., Sarrasin, M., and Mitja, D. 1997. "Mise en valeur de la forêt et modifications écologiques," in *Environment et Développement en Amazonie Brésilienne*. Edited by H. Théry, pp. 42-75. Paris: Belin.

Correa, J. C., and Reichardt, K. 1995. Efeito do Tempo de Uso das Pastagens Sobre as Propriedades de um Latossolo Amarelo da Amazônia Central. *Pesquisa Agropecuária Brasileira* 30:107-114.

Eden, M. J. 1996. "Environmental Degradation and Forest Renewability in Amazonia," in *Land Degradation in the Tropics. Environment and Policy Issues*, *Global Development and the Environment Series*. Edited by M. J. Eden and Parry, J. T., pp. 48-60. London: Pinter.

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Falesi, I. 1976. *Ecosistema de Pastagem Cultivada na Amazônia Brasileira*. *Boletim Técnico 1*. Belém: EMBRAPA

Fearnside, P. M. 1980. Os efeitos das pastagens sobre a fertilidade do solo na Amazônia Brasileira. *Acta Amazonica* 10:119-132.

Landais, E. 1995. *Rapport de mission au Brésil*. INRA-SAD.

Lavelle, P., and Pashanasi, B. 1989. Soil macrofauna and land management in Peruvian Amazonia (Yurimaguas, Loreto). *Pedobiologia* 33:283-291.

Moraes, J. F. L. de, Volkfoff, B., Cerri, C. C., and Bernoux, M. 1996. Soil Properties under Amazon forest and changes due to pasture installation in Rondônia, Brazil. *Geoderma* 70:63-81.

Nepstad, D. C., Uhl, C., and Serrão, E. A. S. 1991. Recuperation of a Degraded Amazonia Landscape: Forest Recovery and Agricultural Restoration. *Ambio* 30:248-255.

Serrão, E. A., and Toledo, J. M. "Sustaining Pasture Based Production Systems for the Humid Tropics,", pp. 256-279.

Serrão, E. A. 1990. "Sustainability of Pastures Replacing Forests in the Latin American Humid Tropics: The Brazilian Experience." *Humid Tropical Lowlands Conference: Development Strategies and Natural Resource Management, 1990*, pp. 69-92 VI.

Serrão, E. A., and Toledo, J. M. 1992. "Sustaining Pasture-based Production Systems for the Humid Tropics," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 257-280. Boulder: Westview Press.

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Topall, O. 1995. "L'arbre et l'herbe en zone tropicale humide. Gestion des pâturages sur une frontière agricole amazonienne dans la région de Marabá, au sud de l'
Etat du Pará, Brésil." *Fertilité du milieu et stratégies paysannes sous les tropiques humides, Montpellier, 1995*, pp. 260-265.

Uhl, C., Buschbacher, R. and Serrão, E. A. S. 1989. Abandoned Pastures in Eastern Amazonia. I Patterns of Plant Succession. *Journal of Ecology* 76:663-681.

Uhl, C., Nepstad, D., Buschbacher, R., Clark, K., Kauffman, B., and Subler, S. 1989. Disturbance and Regeneration in Amazonia: Lessons for Sustainable Land Use. *The Ecologist* 19:235-240.

Uhl, C., Nesptad, D., Silva, J. M. C. de, and Vieira, I. 1991. Restauração da Floresta em Pastagens Degradadas. *Ciência Hoje* 13:23-31.

Vieira, I. C. G., Salamão, R. de P., Nesptad, D. C., and Roma, J. C. 1996. O Renascimento da Floresta no Rastro da Agricultura. *Ciência Hoje* 20:38-44.

6 The Pioneer Frontier

Papers and books grouped under 'pioneer frontier' represent a selection of an extensive literature about the formation and evolution of frontier systems in Amazonia. They discuss land use, social, economic and environmental dynamics associated with this process. The criteria to select the papers here was a clear relation between these broader analyses and the integration of livestock in Amazonia, the main focus of this bibliographical review.

Albaladejo, C., and Tulet, J.-C. Editors. 1996. *Les fronts pionniers de l'Amazonie brésilienne. La formation de nouveux territories*. *Recherches et Documents-Amériques latines*. Paris: L'Harmattan.

Bonnal, P. 1994. *Economie de l'exploitation agricole et systemes d'elevage sur le front pionnier en Amazonie*. CIRAD-SAR.

Bromley, R. 1981. The colonization of humid tropical areas in Ecuador. *Singapore Journal of Tropical Geography* 2: pp.15-25.

ENGREF, Silvolab, and LASAT. 1997. *Analyses de dynamiques d'exploitation des ressources naturelles en front pionner amazonien*. Silvolab ENGREF.

Fearnside, P. M. 1979. "Land Use Allocation of the Transamazon Highway," in *Land, People and Planing in Contemporary Amazonia*, *Occasional Publications nº 3*. Edited by F. Barbira-Scazzochio, pp. 114-138. Cambridge: Centre of Latin American Studies, Cambridge University.

Hébette, J. 1991. A ocupação camponesa e uma área de fronteira e sua dinâmica social: O caso do Pau Seco/Cametau. *Agriculture Paysannes et Developpement: Caraïbe- Amérique Tropicale* :65-85.

Hemming, J. 1987. *Amazon Frontier. The defeat of the Brazilian Indians*. Cambridge, MA: Harvard University Press.

Hennessy, A. 1978. *The Frontier in Latin American History*. London: Edward Arnold.

LASAT. 1992. *Agricultures Familiales & Dévelopment en front pionnier amazonien. Rapport du Projet*. GRET-UAG UFPa.

Mahar, D. J. 1989. *Government Policies and deforestation in Brazil's Amazon region*. Washington, DC: World Bank.

Moran, E. F. 1979. "Mobility and Resource Use in Amazonia," in *Land, People and Planing in Contemporary Amazonia*, *Occasional Publications nº 3*. Edited by F. Barbira-Scazzochio, pp. 46-57. Cambridge: Centre of Latin American Studies, Cambridge University.

Moran, E. F. 1983. "Government-Directed Settlement in the 1970s: An Assessment of Transamazon Highway Colonisation," in *The Dilemma of Amazonian Development*, *Westview Special Series on Latin America and Caribbean*. Edited by E. F. Moran, pp. 297-317. Boulder: Westview Press.

Muchagata, M. G. 1997. *Forests and People. The Role of Forest Production in Frontier Farming Systems in Eastern Amazonia*. DEV Occasional Paper OP 36. Norwich: University of East Anglia.

Mueller, B. 1997. Property Rights and the Evolution of a Frontier. *Land Economics* 73:42-57.

Pichón, F. J. 1996. Setter Agriculture and the Dynamics of Resource Allocation in Frontier Environments. *Human Ecology* 24:341-371.

Pichón, F. J. 1996. The Forest Conversion Process: A Discussion of the Sustainability of Predominant Land Uses Associated with Frontier Expansion in Amazonia. *Agriculture and Human Values* 13:32-51.

Pichón, F. J. 1997. Settler Households and Land-Use Patterns in the Amazon Frontier: Farm Level Evidence from Ecuador. *World Development* 25:67-91.

Renard-Casevitz, F.-M. 1979. "Contrasts between Ameridian and Colonist Land Use in the Southern Peruvian Amazon (Matsiguenga Area)," in *Land, People and Planing in Contemporary Amazonia*, *Occasional Publications nº 3*. Edited by F. Barbira-Scazzochio, pp. 249-255. Cambridge: Centre of Latin American Studies, Cambridge University.

Reynal, V. de, Muchagata, M. G., Topall, O., and Hébette, J. 1995. *Agricultures Familiales & Dévelopment en front pionnier amazonien*. Paris-Point a Pitre-Belém: GRET-UAG UFPa.

Reynal, V. de, Muchagata, M. G., Topall, O., and Hébette, J. 1997. "Des paysans en Amazonie," in *Environment et Développement en Amazonie Brésilienne*. Edited by H. Théry, pp. 76-123. Paris: Belin.

Richards, M. 1996. *Stabilising the Amazon Frontier: Technology, Institutions and Policies*. *ODI Natural Resources Perspectives*. London: ODI.

Schmink, M., and Wood, C. H. 1992. *Contested Frontiers in Amazonia*. New York: Columbia University Press.

Smith, N. J. H. 1993. “Colonization Lessons from a Tropical Forest,” in *Tropical Rainforests. Latin American Nature and Society and Transition*. Edited by S. E. Place, pp. 139-150. Wilmington: Jaguar Books.

Stearman, A. M. 1983. “Forest to Pasture: Frontier Settlement in the Bolivian Lowlands,” in *The Dilemma of Amazonian Development*, *Westview Special Series on Latin America and Caribbean*. Edited by E. F. Moran, pp. 51-63. Boulder: Westview Press.

Thapa, K. K., Bilsborrow, R. E., and Murphy, L. 1996. Deforestation, Land Use, and Women's Agricultural Activities in the Ecuadorian Amazon. *World Development* 24:1317-1322.

Thiele, G. 1991. *The Barbecho crisis: revisited*. *Technical Report nº 1*. Santa Cruz: CIAT/MBTA.

Thiele, G. 1993. The Dynamics of Farm Development in the Amazon: The *Barbecho* Crisis Model. *Agricultural Systems* 42:179-197.

Shane, D. R. 1986. *Hoofprints on the Forest. Cattle Ranching and the Destruction of Latin America's Tropical Forests*. Philadelphia, PA: ISHI.

7 Livestock Economy

Documents included in this section analyse economic aspects of livestock production at different levels: from economic returns at the farm level to the economy and economic logic of livestock production and natural resources use at macro-level in Amazonia.

Almeida, O. T. de, and Uhl, C. 1995. Developing a Quantitative Framework for Sustainable Resource- Use Planning in Brazilian Amazon. *World Development* 23:1745-1764.

Almeida, O. T. de, and Uhl, C. 1996. “Planejamento do uso do solo no município de Paragominas utilizando dados econômicos e ecológicos,” in *A evolução da Frontiera Amazônica. Oportunidades para um desenvovolvimento sustentável*. Edited by O. T. de Almeida, pp. 101-136. Belém: IMAZON.

Alston, L. J., Libecap, G. D., and Schneider, R. 1996. The Determinants and Impact of Property Rights: Land Titles on the Brazilian Frontier. *Journal of Law, Economics and Organisations* 12:25-61.

Arima, E., and Uhl, C. 1996. *Pecuária na Amazônia Oriental-desempenho atual e perspectivas futuras*. *Série Amazônia nº 1*. Belém: IMAZON.

Azevedo, G. P. C. de, Carvalho, R. A. de, Teixeira, R. N. G., Sarmento, C. M. B., Rodrigues, J. A., Filho, Gonçalves, C. A., and Oliveira, R. P. de 1994. *Características dos Sistemas de Produção de Gado de Corte na Região Bragantina*. Belém: EMBRAPA-CPATU.

Bonnal, P. 1994. *Economie de l'exploitation agricole et systemes d'elevage sur le front pionnier en Amazonie*. CIRAD-SAR.

Hecht, S. 1985. Environement, development and politics: Capital accumulation and livestock sector in eastern Amazonia. *World Development* 13:662-684.

Hecht, S. B. 1992. "Logics of Livestock and Deforestation: the case of Amazonia," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 7-26. Boulder: Westview Press.

Hecht, S. B. 1992. "Valuing Land Uses in Amazonia: Colonist Agriculture, Cattle, and Petty Extraction in Comparative Perspective," in *Conservation of Neotropical Forests. Working from Traditional Resource Use*. Edited by K. H. Redford and Padoch, C., pp. 379-399. New York: Columbia University Press.

Hecht, S. 1993. "Land Speculation and Pasture-Led Deforestation in Brazil," in *The Struggle for Land and the Fate of the Forests*. Edited by M. Colchester and Lohmann, L., pp. 164-178. London: Zed Books.

Gonçalves, C. A., Simão, M., Neto, Oliveira, F. W. R. de, and Azevedo, G. P. C. de 1993. *Diagnóstico Tecnológico-econômico de Propriedades Leiteiras na Região Bragantina*. *Documentos, 74*. Belém: EMBRAPA-CPATU.

Mattos, M. M., and Uhl, C. 1996. "Perspectivas econômicas e ecológicas da pecuária na Amazônia Oriental na década de 90: o caso de Paragominas," in *A evolução da Frontiera Amazônica. Oportunidades para um desenvovolvimento sustentável*. Edited by O. T. de Almeida, pp. 39-65. Belém: IMAZON.

Pinto, W. S., Santana, A. C. de, Costa, R. M. Q. de, Alencar, M. I. R. de, Mattar, P. N., and Souza, R. F. de 1995. *Estudo Exploratório da Pecuária de Corte no Brasil e na Amazônia*. *Estudos Setorias 4*. Belém: BASA-FICAP.

Seré, C., and Jarvis, L. S. 1992. "Livestock Economy and Forest Destruction," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 95-116. Boulder: Westview Press.

Toniolo, A., and Uhl, C. 1995. Economic and Ecological Perspectives on Agriculture in the Eastern Amazon. *World Development* 23:959-973.

Toniolo, A., and Uhl, C. 1996. "Perspectivas econômicas e ecológicas da agricultura na Amazônia Oriental," in *A evolução da Frontiera Amazônica. Oportunidades para um desenvovolvimento sustentável*. Edited by O. T. de Almeida, pp. 67-97. Belém: IMAZON.

Topall, O. 1991. Sistema de criação de bovinos nos lotes da colonização oficial da Transamazônica, região de Marabá. *Agriculture Paysannes et Developpement: Caraïbe- Amérique Tropicale* :203-228.

8 Livestock Production: Environmental Aspects

Articles in this section report and examine the environmental impacts of livestock production, mainly deforestation, to Amazonia region. Some of these articles also propose alternatives and policies to modify this situation. Some of these papers were discussed in section 3.2 and 4 of the main document.

Anderson, A. 1990. "Deforestation in Amazonia: dynamics, causes, alternatives," in *Alternatives to Deforestation: Steps toward Sustainable Use of Amazonia Rain Forest*. Edited by A. Anderson, pp. 3-23. New York: Columbia University Press.

Barrow, C. J. 1996. "Environmental Impact of Resource Use in Wetland and Riverine Habitats in Amazonia," in *Land Degradation in the Tropics. Environement and Policy Issues*, *Global Development and the Environment Series*. Edited by M. J. Eden and Parry, J. T., pp. 177-189. London: Pinter.

Buschbacher, R., Uhl, C., and Serrão, E. A. S. 1989. Abandoned Pastures in Eastern Amazonia. II Nutrients Stocks in the Soil and Vegetation. *Journal of Ecology* 76:682-699.

C.C.Cerri, Bernoux, M., and Feigl, B. J. 1995. "Deforestation and use of soil as pasture: climatic impact." *Interdisciplinary Research on the Conservation and Sustainable Use of the Amazonian Rain Forest and its Information Requirements, Brasília, 1995*, pp. 177-186.

Chauvel, A., Barbosa, E. M., Blanchard, É., Grimaldi, M., Ferraz, J., Martins, P. de S., Topall, O., Barros, E., Desjardins, T., Filho, N. L., Miranda, I. P. de A., Sarrasin, M., and Mitja, D. 1997. "Mise en valeur de la forêt et modifications écologiques," in *Environment et Développement en Amazonie Brésilienne*. Edited by H. Théry, pp. 42-75. Paris: Belin.

Dale, V. H., O'Neil, R. V., Pedlowski, M., and Southworth, F. 1993. Causes and Effects of Land Use Change in Central Rondônia, Brazil. *Photogrammetric Engineering & Remote Sensing* 59:997-1005.

Eden, M. J. 1996. "Environmental Degradation and Forest Renewability in Amazonia," in *Land Degradation in the Tropics. Environment and Policy Issues*, *Global Development and the Environment Series*. Edited by M. J. Eden and Parry, J. T., pp. 48-60. London: Pinter.

ENGREF, Silvolab, and LASAT. 1997. *Analyses de dynamiques d'exploitation des ressources naturelles en front pionner amazonien*. Silvolab ENGREF.

Fearnside, P. M. 1980. Os efeitos das pastagens sobre a fertilidade do solo na Amazônia Brasileira. *Acta Amazonica* 10:119-132.

Fearnside, P. M. 1990. "Predominant Land Uses in the Brazilian Amazon," in *Steps Towards the Sustainable Use of the Amazon Rain Forest*. Edited by A. Anderson, pp. 233-251. New York: Columbia University Press.

Fearnside, P. M. 1993. Deforestation in Brazilian Amazonia: The effect of Population and Land Tenure. *Ambio* 22:537-545.

Fujisaka, S., Bell, W., Thomas, N., Hurtado, L., and Crawford, E. 1996. Slash-and-burn agriculture, conversion to pasture, and deforestation in two Brazilian Amazon colonies. *Agriculture, Ecosystems and Environment* 59:115-130.

Hecht, S. 1983. "Cattle Ranching in the Eastern Amazon: Environmental and Social Implications," in *The Dilemma of Amazonian Development*, *Westview Special Series on Latin America and Caribbean*. Edited by E. F. Moran, pp. 155-188. Boulder: Westview Press.

Hecht, S. 1985. Environment, development and politics: Capital accumulation and livestock sector in eastern Amazonia. *World Development* 13:662-684.

Hecht, S., and Cockburn, A. 1989. *The fate of the forest : developers, destroyers and defenders of the Amazon*. London: Penguin Books.

Hecht, S. B. 1989. The Sacred Cow in the Green Hell: Livestock and Forest Conversion in the Brazilian Amazonia. *The Ecologist* 19:229-234.

Hecht, S. B. 1992. "Logics of Livestock and Deforestation: the case of Amazonia," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 7-26. Boulder: Westview Press.

Hecht, S. 1993. "Land Speculation and Pasture-Led Deforestation in Brazil," in *The Struggle for Land and the Fate of the Forests*. Edited by M. Colchester and Lohmann, L., pp. 164-178. London: Zed Books.

Lavelle, P., and Pashanasi, B. 1989. Soil macrofauna and land management in Peruvian Amazonia (Yurimaguas, Loreto). *Pedobiologia* 33:283-291.

Ledec, G. 1992. "New Direction in Livestock Policy: an Environmental Perspective," in *Development or Destruction. The Conversion of Tropical Forest to Pasture in Latin America*, *Westview Special Studies in Social, Political and Economic Development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 26-66. Boulder: Westview Press.

Mearns, R. 1996. *When Livestock are Good for the Environment*. *IDS Working Paper 45*. Brighton: IDS.

Parsons, J. J. 1993. "The Scourge of Cows," in *Tropical Rainforests. Latin American Nature and Society and Transition*. Edited by S. E. Place, pp. 36-48. Wilmington: Jaguar Books.

Shane, D. R. 1986. *Hoofprints on the Forest. Cattle Ranching and the Destruction of Latin America's Tropical Forests*. Philadelphia, PA: ISHI.

Toledo, V. M. 1992. "Bio-economic costs," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 67-94. Boulder: Westview Press.

Uhl, C., and Parker, G. 1986. Is a Quarter-pound of Hamburger Worth Half a Ton of Rainforest? *Interciencia* 11.

9 Livestock Production: Social Issues

Documents below report some of the social issues related to livestock production in the Amazonia region. Generally they focus on very negative social consequences of cattle ranching to rural population. Analyses of positive aspects of livestock production by smallholders are generally absent from the literature.

Barkin, D. 1992. "Rural Development Effects," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 235-248. Boulder: Westview Press.

Collins, J. L. 1986. Smallholder Settlement of Tropical South America: The Social Causes of Ecological Destruction. *Human Organization* 45:1-10.

Hecht, S. 1983. "Cattle Ranching in the Eastern Amazon: Environmental and Social Implications," in *The Dilemma of Amazonian Development*, *Westview Special Series on Latin America and Caribbean*. Edited by E. F. Moran, pp. 155-188. Boulder: Westview Press.

Hecht, S. 1985. Environement, development and politics: Capital accumulation and livestock sector in eastern Amazonia. *World Development* 13:662-684.

Hecht, S., and Cockburn, A. 1989. *The Fate of the Forest : Developers, Destroyers and Defenders of the Amazon*. London: Penguin Books.

Ledec, G. 1992. "New Direction in Livestock Policy: an Environmental Perspective," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 26-66. Boulder: Westview Press.

MacDonald, T. 1992. "From Reaction to Planning: An Indigenous Response to Deforestation and Cattle Ranching," in *Development or Destruction. The conversion of Tropical Forest to Pasture in Latin America*, *Westview special studies in social, political and economic development*. Edited by T. E. Downing, Hecht, S. B., Pearson, H. A., and Garcia-Downing, C., pp. 213-234. Boulder: Westview Press.

Painter, M. Editor. 1995. *The social causes of environmental destruction in Latin America*. *Linking Levels of Analysis*. Ann Arbor: The University of Michigan Press.

10 Nutrient Cycling

This section lists papers that discuss aspects of nutrient cycling in natural vegetation and farming systems in different parts of Amazonia, with special focus on nutrient cycles in pastures. Included are some references concerning how some groups in Amazonia manage soil fertility and methodologies to access nutrient flow analysis.

Budelman, A. 1997. "The nutrient flow analysis in local learning and adaptive research," Natural Resources Research Group Seminar Paper pp16, University of East Anglia School of Development Studies

Buschbacher, R., Uhl, C., and Serrão, E. A. S. 1989. Abandoned Pastures in Eastern Amazonia. II Nutrients Stocks in the Soil and Vegetation. *Journal of Ecology* 76:682-699.

Correa, J. C., and Reichardt, K. 1995. Efeito do Tempo de Uso das Pastagens Sobre as Propriedades de um Latossolo Amarelo da Amazônia Central. *Pesquisa Agropecuária Brasileira* 30:107-114.

Defoer, T., Kanté, S., Hilhorst, T., and Groote, H. de 1996. Towards more sustainable soil fertility management. *ODI Agriculture Research & Extension Network* :26.

Falesi, I. 1976. *Ecosistema de Pastagem Cultivada na Amazônia Brasileira*. *Boletim Técnico 1*. Belém: EMBRAPA

Fearnside, P. M. 1980. Os efeitos das pastagens sobre a fertilidade do solo na Amazônia Brasileira. *Acta Amazonica* 10:119-132.

Hecht, S. 1983. "Cattle Ranching in the Eastern Amazon: Environmental and Social Implications," in *The Dilemma of Amazonian Development*, *Westview Special Series on Latin America and Caribbean*. Edited by E. F. Moran, pp. 155-188. Boulder: Westview Press.

Hecht, S. B. 1989. "Indigenous Soil Management in the Amazon Basin: Some Implications for Development," in *Fragile Lands of Latin America*. Edited by J. O. Browder, pp. 166-181.

Kleinman, P. J., Pimentel, D., and Bryant, R. B. 1995. The ecological sustainability of slash-and-burn agriculture. *Agriculture, Ecosystems and Environement* :235-249.

Moraes, J. F. L. de, Volkfoff, B., Cerri, C. C., and Bernoux, M. 1996. Soil Properties under Amazon forest and changes due to pasture installation in Rondônia, Brazil. *Geoderma* 70:63-81.

Nepstad, D. C., Uhl, C., and Serrão, E. A. S. 1991. Recuperation of a Degraded Amazonia Landscape: Forest Recovery and Agricultural Restoration. *Ambio* 30:248-255.

Teixeira, L. B. 1987. Dinâmica do Ecossistema de Pastagem Cultivada em Área de Floresta na Amazonia Central. PhD, Universidade do Amazonas.

Teixeira, L. B., and Bastos, J. B. 1989. *Nutrientes nos Solos de Floresta Primária e Pastagem de Brachiaria humidicola na Amazônia Central*. *Boletim de Pesquisa, 98*. Belém: EMBRAPA-CPATU.

Teixeira, L. B., and Bastos, J. B. 1989. *Matéria Orgânica nos Ecossistemas de Floresta Primária e Pastagens na Amazônia Central*. *Boletim de Pesquisa, 99*. Belém: EMBRAPA-CPATU

11. Livestock systems in tropical America (outside Amazonia)

Given the similarity of livestock production patterns in other parts of tropical America, especially Central America, some papers that raise interesting issues for comparison and that help to understand cattle production in Amazonia have been listed below.

Edelman, M. 1995. "Rethinking the Hamburger Thesis: Deforestation and the Crisis of Central America's Beef," in *The social causes of environmental destruction in Latin America*: *Linking Levels of Analysis*. Edited by M. Painter, pp. 25-62. Ann Arbor: The University of Michigan Press.

Nicholson, C. F., Blake, R. W., and Lee, D. R. 1995. Livestock, Deforestation, and Policy Making: Intensification of Cattle Production Systems in Central America Revisited. *Journal of Dairy Science* 78:719-734.

Schelhas, J. 1996. Land Use choice and Change: Intensification and Diversification in the Lowland Tropics of Costa Rica. *Human Organization* 55:298-306.

Simpson, J. R., and Conrad, J. H. 1993. Intensification of Cattle Production Systems in Central America: Why and When. *Journal of Dairy Science* 76:1744-1752.

Simpson, J. R., and Conrad, J. 1994. Central America Animal Agriculture in Relation to Natural Resources. *Agricultural Systems* 44:143-161.

Sunderlin, W. D., and Rodríguez, J. A. 1996. *Cattle, Broadleaf Forests and the Agricultural Modernization Law of Honduras. The Case of Olancho*. *Occasional Paper nº 7*. Bogor: CIFOR.

12-Methodology

This includes texts about methodological issues focusing on the study of livestock systems, farmers' practices and participatory nutrient flow analysis. General articles about farmer participatory research have been deliberated excluded from this selection. An extensive bibliographic review of this topic can instead be found in Sleeght Stewart et al. 1995. *Participatory Rural Appraisal: an annotated bibliography*. Brighton:IDS.

Bonnemaire, J. 1994. "Sistemas Ganaderos: Conceptos, Metodos e Interess para el Desarollo." *Seminario INTA-INRA de Resultados de enfoques sistémicos aplicados al estudio de la diversidad agropecuaria, Mar del Plata, 1994*.

Budelman, A. 1997. "*The nutrient flow analysis in local learning and adaptive research*." Natural Resources Research Group Seminar Paper pp16, University of East Anglia School of Development Studies.

Darre, J.-P. 1985. *La parole et la technique. L'univers de pensee des eleveurs du ternois*. *Collection Alternatives Paysannes*. Paris: L'Harmattan.

Gibon, A., Matheon, G., Vissac, B., Flamant, J.-C., Revilla, R., and Sibbald, A. R. 1994. "Systèmes d'élevage en ferme: le zootechniciens européens à la recherche de concepts et d'outils." *Systems-Oriented Research in Agriculture and Rural Development International Symposium, Montpellier, 1994*, pp. 34-38.

Landais, E. 1987. *Recherches sur les systemes d'elevage*. *Document de travail*. Versailles-Dijon-Mirecourt: INRA.

Lhoste, P., Doube, V., Rosseau, J., and Soliner, D. *Zonage des regions chaudes: Des Systemes d'Elevage*: CIRAD

Lightfoot, C., Dalsgaard, J. P., Bimbao, M. A., and Fermin, F. 1993. Farmer Participatory Procedures for Managing and Monitoring Sustainable Farming Systems. *Journal of Asian Farming Systems Association* :67-87.

Perrot, C., and Landais, E. 1992. "Un system d'information construit a dire d'experts pour le conseil technico-economique aux eleveurs bovins," . Paris: INRA-EMVT.