APPENDIX 6

Colonist farmers' perceptions of fertility and the frontier environment: Opportunities for the development of more sustainable farming systems in Amazonia

Short title: farmers' perceptions of the frontier environment

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Introduction

In recent years there has been increasing interest in the incorporation of indigenous or local knowledge (see Blaikie et al., 1997; Agarwal, 1995 for discussion of these definitions) into agricultural research and development programmes (Brokensha et al., 1980; Richards, 1985; Scoones and Thompson, 1994). According to proponents of this view, and appreciation of local peoples' knowledge and perceptions can go some way to inform *why* and *how* they act and specifically may aid understanding current practice and future options for the management of natural resources. Furthermore, incorporating this knowledge into the research and development process is likely to enhance the effectiveness of technological and institutional innovations (Blaikie et al. 1997; Okali et al., 1994). It is also claimed that facilitating and recognising local knowledge encourages empowerment and enhances livelihood opportunities for rural people in developing countries (Thompson, 1996; Warren et al., 1996). However many studies of local knowledge have focused on groups such as indigenous people, and communities which have developed ties to local environments over long periods. Until now few studies have focused on the knowledge and perceptions of for example youth (see Richards, 1997) and displaced, migrant and colonist people (Amanor, 1994). In conventional writings such groups are assumed to not have detailed knowledge of the natural environment. However, as Blaikie et al. (1997) underline, local knowledge is not static; it continually evolved and it is often at the interface with outsiders' knowledge or in the context of development initiatives that most productive innovation can take place.

This paper discusses investigations into colonist farmers' perceptions and knowledge of sustainability and natural resource systems. It examines how farmers in a frontier region of Amazonia understand nutrient cycling and the links between different components in their farming systems. In this rapidly evolving and very dynamic situation, the search for more sustainable systems of land use which provide farming families with secure livelihoods and the opportunity to put down roots, build communities and invest in physical and social infrastructure, and thus stem the movement of the frontier further into the Amazon forest, is a focus of research efforts. If locally appropriate and feasible innovations and practices are to be identified, it must be on the basis of farmers' current practices and knowledge. This paper explores some of these opportunities. It is divided into five sections. The following section describes the context of the research in Maraba in Eastern Para state in Brazil and introduces a simplified typology of farming systems. In the subsequent section, diagrammatic representations of farmers' perceptions of these systems and the way they explain nutrient and materials cycling in their systems are presented. The results of participatory exercises conducted to gather knowledge of about soil properties in the region are presented. The paper then discusses how farmers' perceptions of soil productivity relate to how they understand the sustainability of farming systems. Particular issues concern the use and management of forest, fallow, pasture and fire. The concluding section discusses the implications of these findings and farmers' perceptions of sustainability can link natural resource conservation to improvements in livelihoods for colonist families.

The sustainability of frontier farming

In the search for suitable indicators to assess the sustainability of farming systems soil productivity is often identified as one of the most important indicators. According to this perspective, the agricultural systems practised by the majority of colonist farmers in the Amazon are considered highly unsustainable. The slash and burn system, when carried out in more densely populated areas, and frequently followed by pasture establishment, is not only destroying rich forest cover but is also mining nutrient reserves in soils which are naturally poor to start with.

For some authors the rapid rate of turnover and movement of families in colonist areas is evidence of the unsuitability of the land in the Amazon for agricultural production, at least using the technology available at the region (Fearnside, 1990; Moran,1979; Mueller, 1997). However, we can identify some signs of peasant agriculture stabilisation in some areas of 'old' frontier (20 to 25 years of colonisation). For example, this has been observed in the Amazonian Brazilian states of Rondonia, Mato Grosso and Para. Here, farmers struggle to remain on their plots, seek to make their livelihoods more sustainable, and to cope with a dynamic natural environment in transformation.

As agronomists or ecologists, farmers also have perceptions of the ecological sustainability of the agro-ecosystems they manage. This paper examines farmers' knowledge and perceptions of matters conventionally so important for scientists; namely soil, soil productivity and nutrient cycling and their relation to agricultural sustainability. The objective here is not to record farmers' knowledge and produce another typology or classification, as some studies about 'native' knowledge in many parts of the world have done. Rather the study aims to understand farmers' views and perceptions, as well as the conditions by which this knowledge can become part of a development strategy (Peet and Watts, 1996). The fact that colonists retain important knowledge about the natural world they deal with is hardly evidenced in either the academic literature or in development programmes. Colonists are often regarded as having less sophisticated knowledge about the natural environment (Morán, 1981) and as such are assumed responsible for less sustainable natural resource management practices compared to other Amazonian populations (Hecht, 1989b). However earlier research in Maraba has demonstrated that colonists have detailed knowledge of aspects of the natural world, for example forest ecology (Muchagata, 1996). Even if it were the case that colonist knowledge leads to inefficient resource management, then the search for alternatives to decrease forest conversion by this most numerous group of Amazonian dwellers demands that we develop a dialogue with them. This dialogue should seek not just to identify gaps in their knowledge, but to build upon their existing knowledge through encounters with other actors in the search not for an ideal sustainable system, but for one that can fit in with colonists' own definitions of sustainability.

Colonists' views about sustainability, as anyone's perceptions, are socially constructed, and so depend on their social and natural environment, objectives, values and strategies. The frontier environment is very diversified (Muchagata, 1996), and as communities and farming systems evolve, perceptions of the environment will evolve too. Even within the same community, people have different perceptions and can disagree on many points. When analysing environmental change, some will see change as degradation, whilst others can perceive it as improvement. Consequently, farmers' perceptions have to be contextualised in order to understand their position and to link their perception or models to the way they actually behave.

Researchers' modelling of frontier farming systems

The research site, Marabá Region, is one of the most dynamic pioneer frontiers in Brazilian Amazonia (see Figure 1). In the late 1960s the region, covering 29 000 km^2, was very isolated, almost completely covered by forest, with very low human population, and with an economy dependent on the extraction of Brazil-nuts. In the 1990s Marabá saw the development of important infrastructure, including a major road network, mining projects, and one the world's largest dams. These activities stimulated the migration of families from different parts of the country, many of whom are now involved in agricultural activities in the region. The smallholder population consists of approximately 20 000 families, scattered in more than 150 localities, occupying one third of a territory shared with large ranches and Indian reserves.

Since this is a frontier region, the length of settlement is one of main determinants of the agricultural systems adopted by farmers. In newly settled areas farms still have a comparatively large amount of forest and thus the nutrient reserve needed to establish new crop areas, the *roças*. As the system evolves forest gives way to crops and pasture. A combination of factors contribute to increase or slow the speed of farm evolution: a key element is the availability of capital to invest in agricultural and livestock activities. Other factors, however, can also be very important, such as the natural resource endowment (especially the type of soil), the economic setting, and access to roads and markets. A 'standard' evolution sequence of the farming systems for the Marabá region has been described by de Reynal et al.(1995) and Muchagata (1997) as being characterised by these phases, installation, diversification and specialisation, outlined in Box 1.

Box 1: Evolution of farming systems in Maraba

First phase - installation:
A farmer (sometimes alone with the rest of the family following one or two years later) occupies a plot or *lote* completely covered by forest, in a recently opened locality, which has no infrastructure or services. There, the farmers 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 farm household is very dependent on the forest resources: almost everything in the house is made by members of the household, and timber and non-timber products are important source of income. Another important cash source can be labour, sold to neighbour *fazendeiros.* Given the instability of land tenure, the *lote* boundaries are not clearly defined and need to be protected. Moreover, many farmers are not sure whether they will stay in the area in the 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 *lote* changes significantly. The family have improved their house and built structures to produce cassava flour; they also produce beans and maize, mainly for household consumption but they 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 *lotes* have some pasture around the house and, depending on the farmers' strategy, there will be also some fallow land. Farmers who have more capital initially may have acquired cattle, but generally having not more than 10 or 15 animals.

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

It is important to note that Box 1 shows a very general evolutionary model that applies to most of the 'successful' or positive trajectories. The lack of capital, health problems or, less frequently, environmental constraints can lead the stagnation of farms or very negative outcomes. There are also cases where farmers decide not to follow the cattle ranching option, and continue to cultivate only annual crops, and there are also cases where farmers choose to diversify production systems perennial crops. This option is currently only possible for a small number of farms located close to main towns with ready markets for products.

Farmers' models of farming systems and nutrient flows

The participatory modelling of farming systems and nutrient flows with farmers was undertaken through drawing maps and diagrams with farmers in selected localities. Farmers involved in these modelling exercises are farmers who are taking part in a larger participatory research project aiming to evaluate options for better integration between livestock and crop-forest activities. Farms in three localities of Marabá region were selected in workshops by farmers and researchers to be monitored and to essay technical innovations. This monitoring consisted of collecting information on farm and family activities (production, labour, cash flows, etc.). The localities where this research is taking place were selected together in collaboration with farmers' unions and cover part of the farming systems evolution sequence described earlier. Since the work is targeting cattle producers this sample carries this bias. Some of the characteristics of these localities and the farms studied are summarised in Table 1.

Table 1 Characteristics of the localities and farms studied

locality	Length settled – years	Number of farms monitored	Average age of farms (yrs)	Farm size ha	%forest cover	%pasture	%fallow	Herd size
Nova Canaã	24	9	14	20-215	14	44	18	3-45
Murumuru	23	9	7	55-225	10	81	4	20-200
Macaranduba	11	5	9	50-100	51	15	13	6-10

The modelling was undertaken in two phases. Firstly, farmers drew maps of their farm, displaying land use and natural resources present (forest, river, soil). In the second phase farmers were asked about the flows of material between the different components of the farming system. In order to discuss their perception of nutrient flows within the farms, farmers were asked what they think cultivated and non-cultivated plants use from soil and what happens to nutrients after cultivation and harvest. Figures 1 to 3 illustrate some of the results of this work. Figure 1 presents a farm from Murumuru, which specialises in cattle production. Figure 2 represents a relatively small farm from Nova Canaã, where forest cover has been cleared but where the farmer is still trying to practice a diversified farming system. Figure 3 shows a more diversified farm with more forest remaining Maçaranduba.

The diagrams show the main flows between the components of the farming systems. Here material and nutrient flows are emphasised, and labour and cash flows are absent. For this reason part of the material flow, such as goods for family use coming from the town are not included. Even the more specialised (and in some respects simpler) farming systems of Murumuru are quite complex, and very often not all the elements of farming systems where remembered or acknowledged by farmers. The resulting pictures are generally not too different from the more formal surveys which have been conducted with these farmers (Machado et al, 1998). Of course the more diversified the system, the more complex the diagrams drawn by farmers are. However through drawing the diagrams together with farmers it is possible to identify what is important for them. In the more diversified farming systems (Nova Canaã and Maçaranduba) minor components were always mentioned. For example, minor crops such as watermelons, sugar cane or cotton are cited in these instances. Elements of the farming system components that do not interact with others were more rarely mentioned. For example this is true for horses which are enumerated only in instances where horses were essential (when the farmer has to cover long distances or in extensive ranching). The same can be said about fallow. From farmers' perspectives fallow is hardly contributing to other components of farming systems. Fallow and forests were often represented as a closed unit, i.e., providing material to soil and using it, but not interacting with other farming systems components. Of course in areas where forests interact, in terms of production of timber and fruits, this was clearly pointed out, and this was especially prevalent in the case of Maçaranduba farmers.

Very often the diagrams drawn represent a model rather than what is actually happening on the farm at the time of the interview. In this sense farmers represented in their diagrams some of the normalised practices, and not necessarily those that they routinely do or were doing at that particular time of that particular year. The most common example is related to the interactions between crop-livestock sub-systems or forest-livestock sub-systems. Many farmers represented the use of crops, forest and even fallow products for feeding cattle. These included cassava, crop residues, *babaçu* (*Orbignya martiana*) leaves and orchard fruits. One farmer even cited the use of *Cecropia* leaves although this is a very uncommon practice in the region. Others normalised infrequent practices such as feeding pigs and poultry crop residues, or the common but frequently overlooked practice of feeding them orchard fruits. In monthly monitoring or in interviews with farmers seeking information on three years of practices related to livestock husbandry, these elements never appeared. Likewise, some forest products were shown by farmers on their diagrams although subsequent interviews and on-farm monitoring have shown these products not to be routinely collected.

The diagrams in general show very diversified farming systems. The interactions between the different sub-systems (crops-livestock-forest) are important but the nutrient cycling is poor. Few farmers cited the contribution of nutrients from forest burning, a crucial factor in nutrient conversion within these systems. This might be a problem of the interview technique, but this seems unlikely. However it is apparent that there are generally very few opportunities for nutrient cycling within the systems. There is practically no use of manure (with only one farmer using it for the establishment of a perennial crop). External inputs of nutrients come exclusively from the use of mineral salt for cattle. Only in Murumuru are there some farmers using fertiliser for perennial crops, and this is because they are part of a heavily subsidised government project.

It is important to stress that the knowledge about nutrient cycling is very uneven, even between farmers of the same locality. For example, while some farmers highlighted the contribution of manure or leaf nutrients to soil, and then to plants, and linking this with nutrients to their families or off the farm and to markets, there were cases where farmers could hardly identify any link between soil and plant growth. For this reason it is important to adopt a more holistic approach, linking farmers' perceptions of material and nutrient flows with their knowledge of soil properties to analyse how they are related to and influence soil management practices. An earlier study carried out in Maraba by de Reynal and others (for more details see Menezes et al, 1990, and Muchagata and de Reynal 1992) was very helpful in elucidating this issue. The analysis below builds on this earlier work in the light of our recent study.

Farmers' knowledge of soil properties

With the support of farmers' unions working in the area, three workshops were organised in four municipalities, and three or four farmers from every locality in the municipality were invited. In all 30 localities took part on these workshops with a total of 95 farmers participating. Farmers were asked to provide information about the natural environment of their localities through the use of prepared forms. Great care was taken to include at least one literate person in each group. The forms asked for a description of the soil itself, the topography and position where the soil was found, the number and size of layers, soil texture, presence of stones, biological activity and presence of roots. It also sought information on the crops associated with each type of soil, which crops are more suitable for each soil, the normal crop yields, best time for sowing, how long the soil retains moisture, and ease of weeding. Information about natural vegetation and weeds appearing in each soil type were collected. To be sure that farmers understood the organisers' objectives and terminology before each workshop session a soil profile was jointly observed and terminology and queries clarified.

At the end of the workshops 143 different 'soil units' were identified. Here a soil unit means a difference in soil characteristics identified by farmers in each locality. This large figure represents an aggregation of units identified in all localities. For each locality a minimum of three and a maximum of ten soil units were specified. For each one farmers identified between two and five soil layers and described them. The comparison between farmers' descriptions and those of agronomists highlights five issues.

First, farmers recognise differences in soil types not only as a function of their surface characteristics or crop yields. They have also acknowledge sub-surface features. For the majority of situations they highlighted characteristics such as layers, depth, texture, and presence of stones which were very similar to those found by agronomists' field work. Box 2 shows an example from the locality Consulta (an locality which had been settled for eight years at the time of the appraisal) and compares farmers' and scientists' descriptions of one soil profile.

Box 2 Descriptions of a soil profile in Consulta

Pedological profile Scientific description	**Soil description by Farmers***
Plinthic Tropaquult High part of the landscape 0-25cm-Yellowish brown(10 YR 5/6);silt loan; granular; sparse iron nodules; abundant roots. 25-45cm-Reddish yellow(7,5 YR 6/6); silt loam; blocky, many nodules; quartz pieces of different sizes; many roots. 45-80+cm-Red(2,5 YR 5/6) with brownish yellow mottles (10 YR 6/8), silt clay, blocky; few nodules; common roots	**High Clay Yellow (Barro amarelo do alto)** 10 cm Yellowish red, ++clay 0 sand, +++ gravel, ++stone, +++biological activity,+++root 100cm-yellow,+++clay O sand,++ gravel,++root 50 cm-yellowish,++clay 0 sand,+++ gravel, ++stone, +root unknown size, Yellowish brown red , +clay,0 gravel, 0 stone, 0 root
Plinthic Tropaquult mid-low part of the landscape 0-40 cm-Yellow (10 YR 7/6), silt loan; granular and blocky; abundant roots. 40-80cm-Brownish yellow (10 YR 6/6), silty clay loam; blocky; sparse small iron nodules; many roots. 80-180cm- Strong brown (7,5 YR 5/8); silt clay blocky; small nodules;common roots. 180-200+cm- Reddish brown (5YR 5/4) with red, yellow and grey mottles; silty clay; blocky; few roots. .	**Low Clay Yellow (Barro amarelo do baixo)** 100cm-yellowish, +++clay + sand,+stone, +++biological activity, +++root* 100-cm-whitish, ++clay, +++gravel, + stone, + root* 100cm- Purplish yellow, +++clay, + stone 200cm-Purple, + clay + sand, + stone *these two layers can exit or not
Tropaquent 0-30 cm- Brownish yellow (10 YR 6/6); sand; subangular blocks; abundant roots. 30-80cm- Reddish yellow (7,5 YR 6/8) with many red, yellow and grey mottles; silt loan; unstructured; with small greyish nodules and small quartz pieces; many roots. 80-110+cm- Yellowish red (5 YR 5/8) with mottles like above; silt; greyish nodules, quartz pieces bigger than above; few roots.	**Low sand land (Terra arenosa do baixo)** 30cm-white, ++clay ++sand, +gravel, ++stone, +++biological activity;+++root 100cm-yellow, +++clay + sand, +gravel, +stone, + biological activity, ++root size unknown, yellowish, +clay ++sand, + stone
Tropaquent 0-10cm- Light brownish grey (10 YR 6/2); sandy; granular and subangular blocky; abundant roots. 10-90cm-Reddish yellow(7,5 YR 6/8); with darker yellow mottles; silt loam; unstructured; many roots 90-190cm- Light red (2,5 YR 6/8) with yellow mottles; silt loam: small; common roots 190-200+cm- Light red (2,5 YR 6/8) with yellow and grey mottles; silt; iron grey nodules; quartz pieces; few roots.	**High sandy land (Terra arenosa do alto)** 20cm-white, ++ clay ++ sand, ++ gravel ++stone, +++biological activity, +++root 100 cm-yellow, ++clay +sand, ++root 100cm- purplish, ++clay +sand, + stone

* Key for farmers' descriptions:

0	absence
+	little or few
++	much or many
+++	very abundant

Secondly, farmers have a good notion of soil distribution in their localities, and the sketch maps drawn by them revealed soil characteristics with distribution very similar to soil maps in two localities where detailed soil surveys were conducted.

Thirdly, farmers perceive more subtle changes and variations in soil than the scientific classification captures. Where pedological classification found only one soil type, farmers can distinguish up to three soil units. On average in the localities involved farmers identified the presence of five soil units (6.5 soil unit in hilly landscapes and 2.8 in more flatter areas), whereas the scientific classification identified only a mean of 2.8 different soil types per locality. Farmers detect landscape changes using characteristics such as the presence of stones or gravel, or changes in colour and texture of soil, always relating them to crop growth and development. That is, they value some differences and think that they have consequences for their production systems. This vision is closer to more recent soil science approaches that acknowledge soil as 'pedological cover', that is a continuum, instead of privileging vertical soil profile units, as the soil classifications do.

Fourthly, the quality of information provided by farmers varies as a function of the type and extent of contact they have with different soil types. Information was more detailed where farmers had been settled for longer periods or when farmers taking part in the workshops were more mobile within the locality so got to know it better. Also soils that farmers use more often are better discerned. For example, every locality related the presence of soils later classified as hydromorphic (24% of soil unit cited), describing their characteristics very well, although generally these soils occur only in small areas. These soils are relatively more fertile and more moisture-retentive than others, so they enable the cultivation of some types of crops that do not grow well in other areas, such as beans, and also make earlier sowing possible.

Fifthly, the comparison between farmer's perception of soil types and respective crop yields has to be made with caution. A perception is related to personal experience, and parameters such as clay content, soil colour or yields are relative and should be contextualised. Depending on soil types available, a farmer able to harvest 2000 kg/ha of rice in a particular soil rich area can find this figure low, whereas farmers in other place would evaluate this figure as a very positive indeed. Furthermore, yields are dependent not exclusively on soil types, but on farmers' practices as well. Practices change in relation to knowledge, technology available and the importance a crop has within the farming system. For example, there are some localities where the main crop is cassava, instead of rice. This is due to the dominant soil type in these zones, a quartpsament, inadequate for rice production. In order to maximise profits farmers will engage more efforts to increase cassava yields in these places than in areas where cassava is a secondary crop. When comparing two localities, one where the quartsapsament is dominant and other where this soil covers only a small area, yields at the former will be reported as much higher than at the latter.

Farmers perceptions of environmental change and sustainability

How farmers perceive change in soil and soil fertility

As expected the perception of change in soil fertility is related to the length of settlement. Farmers' perceptions of fertility is very closely linked to the presence of forest, and especially in newly settled communities where there are still some 'virgin' soils (i.e. uncultivated) to exploit. Deforested areas have been cropped not more than three times, so this tends to be where there was more pressure on natural resources in general and where those changes were more clearly perceived by farmers. Consequently, in Maçaranduba none of the interviews reported changes in soils, whereas in Nova Canaã the changes were more evident to farmers. There, they found soil drier than it used to be and also 'weaker', that is, less fertile. But soils are not only becoming degraded. Farmers with low lands at Nova Canaã could perceive that fertility improved, thanks to sediment derived from erosion further up slopes and on higher land.

When highlighting the causes of changes in soil fertility few farmers attribute them to run off or erosive processes. Many believe that it is exposure to the sun ('the sun heats the soil') that degrades soil, and sometimes this is related to a general perception that the dry season is becoming harder i.e. hotter and drier. In other words, farmers link climatic change to changes in soil productivity. Some farmers also comment that poaching during the wet season, especially under high stocking rates, can cause compaction of soils.

The main indicator to farmers that soil has become less fertile is not the decline of soil productivity as such, but the presence of weeds. This means farmers stress the decrease in their work productivity, which declines when more labour is required for weeding. For farmers this represents a more important fertility indicator than soil productivity itself. But they also perceive some physical characteristics of soil indicating fertility decrease, as for example the presence of sand layers in the top soil.

How farmers' practices affect soil fertility

Overcropping is the main reason identified by farmers as contributing to the decline in soil fertility in all three localities. Here overcropping can represent up to three years of continuous cropping. However, it is very rare to find plots that have been cultivated more than twice. A small number of farmers identify certain crop and grass species as being intrinsically harmful to soil. High stocking rates are also blamed for deterioration of soil conditions.

Interestingly, farmers often cited fallow as a practice with negative effects on fertility. Even if the majority of farmers have 'practical consciousness' (what actors know but can not express discursively, Giddens, 1984) that fallow is a way of replacing soil fertility (fallow burning drastically reduces weed contamination), fallow is always associated with weeds and sometimes also with pests. Farmers living in older areas declared they would like to have less land in fallow, as this would result in less work associated with weeding. To these farmers forest is preferable, or pasture. Only in more recently colonised areas is leaving the land in fallow an effective fertility management strategy, since a first cycle fallow will not be so infested with weeds and pests and can represent an alternative to the heavy burden of forest clearing. But the use of second cycle fallow for crop growing is the last option for many farmers with no forest remaining on their farms.

Fire: a controversial practice

Many farmers believe that fire is a beneficial practice. This is most clearly articulated by those who consider growing crops without burning as impossible, and that pasture managed with fire is vastly superior to unburnt pasture. In the opinion of these farmers, fire combats harmful organisms and brings ‘strength’ to soil. On the other hand, many farmers perceive fire as a detrimental practice. The main reason they give is that burning increases weed invasion, and makes soil drier and harder. It is also contributes to a loss of soil ‘strength’, and it destroys soil ‘richness’. A small proportion of farmers think that the use of fire can be positive and negative at the same time; it is beneficial for land under pasture, but harmful when used for the preparation of crop land, or that fire is a good practice to improve plant development (through killing weeds), but is not good for the soil itself. The use of fire represents different things to different farmers. For the first group of farmers fire is a way of ‘amansar a terra’, a current expression in the region meaning a good way to make land less wild; to tame the land. They however recognise that uncontrolled fire can be dangerous and accidents are frequent, leading to the destruction of houses, perennial crops and forest. Nevertheless, even for those who are aware of all the negative impacts of fire, there is no way to avoid its use.

Farmers perceive a number of strategies to improve soil conditions, but few of these are feasible given their current economic circumstances. The most common ‘solution’ for loss of soil fertility cited by farmers is ploughing with a tractor and using chemical fertilisation. This shows that although farmers’ knowledge about soil properties may be relatively detailed and sophisticated they do not have or have not had the opportunity to develop endogenous strategies to cope with soil degradation. They are aware of alternatives, but these are only suitable for large producers and do not fit into their current farming systems. Agroforestry options which are potentially better adapted for smallholders in the area, were only mentioned by one farmer. The alternatives farmers perceive and recognise are shaped not by their local conditions, but by contacts with actors from other spheres, like local ranchers or farmers from other regions.

A comparison of the results coming from the participatory exercises on soil properties with the diagrams modelling the material flows and colonists’ perceptions of environmental change reveal that farmers’ knowledge of soil characteristics is less uneven than knowledge of nutrient cycling. Apparently it has been easier for farmers to observe the visible characteristics of a new environment than to understand processes that lead to soil change. This appears a paradox, since one could expect that the nature of knowledge on soil properties is of a kind that could not be transferred from one area to another (for example, from the semi-arid northeastern Brazil, homeland of most farmers interviewed, to Amazonia), while knowledge of processes such as material cycling or the effect of certain practices on soil are more easily transferable and can be applied to different situations. Probably this is due to the fact that is easier to identify visible or touchable characteristics (such as colour or texture) during daily work than reasoning about processes that must be observed and analysed throughout the years. But this does not explain why farmers could not transfer their knowledge of some processes to other regions. Were they not aware of such process before migration? Or perhaps frequent migration, or migration to an environment so different, imposes too many barriers to compare even similar processes? Another explanation could be that as landless people, as the majority was before leaving their original places (Goncalves and Topall, 1991), these farmers have never had the opportunity to practice a sedentary or intensive agriculture. Understanding this apparent paradox could help to explain how farmers adapt, or do not adapt, certain technologies and practices when they move to Amazonia.

Farming systems and sustainability

When discussing the future of their farming systems under current management conditions, the majority of farmers think that they will not be able to sustain cropping in the near future. Many of them, particularly those from Nova Canaã, believe that the area will become a 'sertão', that is a savannah type vegetation. This illustrates that in many respects they already perceive the process of succession of species under constant fire management. This process slowly eliminates many of the tress and thus severely undermines the ability of forest to regenerate. As this continues the most feasible option for them will be to move to other areas.

In contrast some farmers, mainly in Murumuru where pasture dominates land use, think that pasture has the potential to be a sustainable system, and that the key for that is to be able to control weeds. If they were able to do this then they can continue to sustain their livelihoods based on the livestock specialised farming systems they are practising. This vision is in line with recent studies evaluating the process of pasture degradation in Amazonia that demonstrate that fertility is not a problem, as was earlier discussed. The main issue lies in weed control, either for long term pasture maintenance (Correa and Riechardt, 1995: Moraes et al. 1996) or forest recovery (Nepstad et al. 1991, Uhl et al. 1989a, Uhl et al. 1991, Uhl et al. 1989b, Buschbacher et al, 1988, Vieira et al. 1996).

The perception of sustainability of farming systems is influenced by a number of factors. If livestock systems can prove to be a more stable alternative for farmers at Murumuru, this is not necessarily the case for Nova Canaã. This reflects more than individual farmers' practices or strategies, but rather the fact that the proximity to urban area allows farmers to sell milk, representing a significant source of income. This is not feasible in Nova Canaã. Therefore the relative lack of forest is more important for Nova Canaã farmers than for those in Murumuru, and this may well prove a problem in the future for the recently settled plots in Maçaranduba.

Implications of farmers' perceptions of sustainability for technology development

According to farmers' views then, the longterm sustainability of their farms depends on finding effective alternatives for weed control, fire management and control, and pasture management.

Weeds are a problem that severely affect all forms of agriculture in the region, and constitute the most serious constraint to long term cultivation. For this reason pasture is well adapted to these farming systems: even though pasture still requires weeding, the labour needed is less than weeding other crops. Apart from some research conduced with agroforestry systems, where green cover has been promoted, few studies have investigated alternatives for weed control for either annual cropping systems or pasture.

Fire management is another key issue. The control of fire has become increasingly important in the last decade. Widespread fires have caused severe damage in Amazonia; for example, in the State of Roraima 3% of forest cover was destroyed by fire in 1998. In response, government programs such as the Prevfogo, have been created in order to promote community based action on fire management. However, although these initiatives are important, they fail to address the underlying causes and the central issue remains the absence of alternatives to fire use, and this is directly linked with the problem of weed control.

The role and effect of fire on soil and vegetation need to be clarified for both researchers and farmers, given that there is much controversy about this matter. Since the removal of fire from these farming systems is inconceivable at present, there is a need to create alternatives that can make the systems less vulnerable to it. Protection strategies for perennial crops and homesteads or use of fire resistant species in silvopastoral systems deserve investigation. Innovations promoted to improve livestock production, such as live poles and fodder trees have to take into account the inevitable presence of fire. Such innovations are clearly not appropriate for smallholders in fire risk prone areas.

From the perspective of farmers and scientists, pasture has the potential to become a more sustainable system, and further research in this area is central to any strategy to improve the sustainability of colonist farming systems. Different measures or techniques, such as better establishment of pasture area; adoption of species that provide good soil cover; and planned rotational grazing need to be promoted. Some of these techniques are already practised by farmers on some farms in Murumuru. They could potentially have a significant impact on the durability of pasture without demanding too much capital or labour investments.

As the farmers' diagrams show, although links between crops, livestock and forest exist, they are still weak. Considerable opportunity lies in greater integration of these sub-components. For example the greater use of crop residues or forest products would enhance animal diets and increase nutrient flows on farms. Less use of fire would enhance the benefits of such integration, giving greater potential for perennial crops, and would not impact on forest productivity.

Conclusions

This study set out to understand farmers' perceptions of environmental change. It has shown that farmers practise diversified farming systems in a dynamic physical and social context. As these systems evolve they can tend either to degradation, as forest disappears and problems with weeds are increased; or to a fairly sustainable system, based on pasture and cattle production. In each of the localities and farms studied there is low integration of sub-components of the farming system, and low nutrient cycling. However, there is no dependence on external inputs. This potentially gives room to manoeuvre to find feasible options within the system itself to improve sustainability of farms. Although farmers' perceived solutions to environmental deterioration are shaped outside their own reality focusing on technological developments such as highly mechanised techniques, we believe that collaboration between farmers and researchers can identify feasible options. Our findings have demonstrated that farmers' knowledge of aspects of the environment, such as soil, is very detailed, indicated that in collaborative work both farmers and researchers could benefit.

Our findings also highlight that local knowledge at the frontier is diverse both within and between different localities in the region. This may be related to farmers' origins, their length of settlement, the means by which colonisation took place, and other factors. This demonstrates that any long-term development options will require a high degree of information sharing not only between farmers and scientists but also between farmers themselves. Some of the priority areas have been identified, including weed control, fire management and improvement of pasture conditions.

Most current development projects at the frontier aim to slow or constrain the movement of farmers further into the frontier. The assumption underlining these initiatives is that sustainability needs to be achieved in already occupied areas, on farmers' current *lotes*. Farmers with specialised cattle ranching systems perceive that they can achieve sustainable farming on their current plots. However, for other groups of farmers, who are more dependant on crops and forest resources, the forested border of the frontier is still a space that can be used to achieve a sustainable livelihood, not necessarily a sustainable farm. Thus the causes of migration should be understood as a strategy to improve livelihoods. More realistic policies which offer support for farmers such as health care, education and land-tenure services are needed in addition to the technological innovations for farmers we suggest to enhance more sustainable management of natural resources at the forest frontier.

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