Modelling the sustainability of frontier farming at the forest fringe

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Modelling the sustainability of frontier farming at the forest fringe: A study which includes the linking role of livestock in the development of more sustainable farming systems.

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List of Acronyms

CAP	Centro Agropecuário
CFCH	Centro de Filosofia e Ciências Humanas
CPATU	Centro de Pesquisa Agroflorestal da Amazônia Oriental
DEV	School of Development Studies
EMATER	Empresa Estadual de Assistência Técnica e Extensão Rural
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
FATA	Fundacão Agrária do Tocantins Araguaia
IMAZON	Instituto do Homem e do Meio Ambiente da Amazônia
INPA	Instituto Nacional de Pesquisas da Amazônia
LAET	Laboratório Agroecológico da Transamazônica
LASAT	Laboratório Sócio-Agronômico do Tocantins
LUMIAR	Serviço Descentralizado de Apoio Técnico às Famílias de Agricultores Assentados
MPEG	Museu Paraense Emílio Göeldi
NAEA	Núcleo de Altos Estudos da Amazônia
NEAF	Núcleo de Estudos Integrados sobre Agricultura Familiar
ODG	Overseas Development Group
ORSTOM	Institut Français de Recherche Scientifique pour le Développement
UEA	University Of East Anglia
UFPa	Universidade Federal do Pará

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Modelling the sustainability of frontier farming at the forest fringe: A study which includes the linking role of livestock in the development of more sustainable farming systems

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Executive summary

International attention has identified the Amazonian forest frontier as a region of critical importance for the conservation of biodiversity. However the area is also vital to the livelihoods of a range of different rural communities whose welfare and survival depend on maintaining the ecological integrity and agricultural productivity of the environment. This research aimed to contribute to understanding the sustainability of frontier farming systems of family farmers, and particularly to examine the role of livestock in these systems. This was identified as a gap in current knowledge and also vital to the development and support of more environmentally sustainable land use strategies and poverty alleviation in Amazonia.

Research and policy often overlook smallholder family farms, yet the sustainability of these enterprises is critical to stabilising the advance of the agricultural frontier in Amazonia. Other land users, particularly cattle ranchers, indigenous groups and loggers, are often the focus of conservation and development efforts. However colonist farmers make up a large proportion of the population in many parts of the region. They tend to be economically and socially marginalised, living close to subsistence and dependent on natural resources.

The research grew out of a collaboration between the University of East Anglia and the LASAT at the Laboratório Sócio-Agronômico do Tocantins of the Universidade Federal do Pará. Research centred on the region around Marabá in Pará State. This region in eastern Amazonia has communities, or localities, which have been settled for up to 25 years. Although characterised as 'aging frontier' settlements and localities exhibit a diversity of environmental, social and economic conditions. By monitoring farms in three localities our research was able to capture a range of different aspects of localities of different 'ages' within the region.

The research involved a close collaboration and working relationship with Brazilian researchers and with small farmers and their organisation in Marabá. We sought specifically to investigate farmers' own knowledge and perceptions of the environment, the changes as the frontier evolved, and their strategies of coping in this dynamic situation. The approach to research was participatory in nature and involved building partnerships with farmers and farmers organisations, through a series of workshops and meetings and continuous process of feedback of findings and information to farmers.

Livestock are important components of smallholder farming systems. The profitability depends on a number of factors, but their contribution to family income depends critically on the access to markets for dairy products in addition to meat. In areas where farmers can sell fresh milk there is an incentive to specialise the farming systems and intensify livestock production. Depending on pasture management strategies, this may have positive or negative impacts on sustainability.

Our study identifies indicators of sustainability at farm level and at locality level. The four key indicators at the farm level are:

- **Forest cover:** forest acts as a nutrient bank; maintains ecological functions and biodiversity; a source of food and income; a natural buffer against fire or diseases.
- **Income:** a good indicator of family wellbeing, particularly when comparing farms within the same locality.
- **Agrodiversity:** represents different sources of food, income, flexible labour demand and safeguard to oscillations in prices and productions levels
- **Pasture quality:** an indicator of longterm productivity.

Of these pasture quality is the critical component of system sustainability. We identified three different models of pasture management employed by farmers in the region, and their implications for longterm productivity. Contrary to received wisdom a major problem with pasture management is *under utilisation*; low stocking rates result in accumulation of dry matter and increased weeds, which then make use of fire necessary. Pasture becomes less productive under these regimes. With more intensive management; improved forage, better planned rotations, farmers could save labour and land.

In order to facilitate the adoption of improved husbandry and pasture management, further research, and more effective dissemination of information to farmers is necessary. Innovations have already begun as a result of our research, including use of mineral supplements and health practices.

From our findings we are able to make recommendations for further work on developing specific indicators of changes in pasture quality which could be usefully adopted by farmers. Ultimately the use of such indicators could enable farmers to intensify livestock production (given external factors) without rapid conversion of forest cover on farms. This is potentially a significant contribution to household welfare and environmental management at the forest agriculture interface.

Background to the study

In smallholder forest/agriculture interface areas the maintenance of diversity and the enhancement of flows of nutrients and energy between forest and farm are considered to be important for the medium and longer term sustainability of food production and of rural livelihoods. Much agricultural research in the forest/agriculture region has been concerned with attempts to reverse the perceived problem of resource degradation and systems instability associated with forest and fallow burning and brief initial periods of annual cropping. It has also been to search for more diverse and integrated options to extensive pasture/ livestock based systems. As yet there has been little work examining the integration of livestock and their role in sustainable smallholder systems; most research in the past has concentrated on other aspects of these systems, such as agroforestry.

Research on livestock in smallholder systems at the agricultural frontier has frequently focused on narrow, technocratic studies of performance potential in isolation from the broader context. Such studies often fail to consider and measure the implications of changing physical and biological inter-relationships and the impact on the rest of the farming and livelihood system. In the development of our understanding of these changes, this indicates that we need to focus much more on the management of nutrient flows in systems; and this is therefore an aim of the current project.

Furthermore, although the knowledge of resource users is frequently considerable, it is often not sufficiently taken into account in the pursuit of productivity enhancing options by researchers. Such knowledge, and the participation of resource users in the on-going analysis of change would seem to be vital if we are to understand the nature and potential of these systems adequately. The underlying causes of change within and between systems are quite complex and it is therefore necessary to examine them in some detail in order to discover possible common elements in the change processes. It will also be important to know whether the pressures of an emphasis on productivity gains are pushing systems into a de-integration path and are leading to inherently less sustainable systems than those which maintain diversity of elements and retain livestock as key integrators.

Most studies indicate that dominant forms of land use in the Amazon are pasture and short cycle agriculture, both apparently notorious for their lack of sustainability and low rates of economic return (Serrão and Homma, 1993). A number of writers emphasise the need to steer the research agenda for agriculture and environmental management in Latin America towards increasing land and labour productivity and minimising environmental degradation in ways which enable smallholders and migrants to secure means of livelihoods (Altieri and Masera, 1994, NRC, 1993, Uhl et al., 1994). Increasing agricultural productivity through promoting environmentally sound intensification of crop and livestock production has been suggested as one way to mitigate so-called ‘nutrient mining’ of frontier clearing in Amazonia (Schneider et al 1990; Barbier et al, 1994). The search for sustainable systems of resource use and agriculture for these frontier regions is therefore of paramount importance, both for needs of food production, poverty alleviation, and environmental conservation, but also needs to be considered within a wider definition of sustainability which necessitates an interdisciplinary approach.

A number of problems arise in defining and measuring sustainability and particularly providing operational applications of the concept to real life situations. For example, a range of definitions of sustainability have been offered with regard to agricultural systems and land use (notable examples include Conway, 1987; Altieri and Anderson, 1986; Kleinman et al, 1995; Pretty, 1995; National Research Council, 1987), and approaches to the measurement of sustainability are now being developed (Munasinghe and Shearer, 1995, Bell and Morse, 1999). Most of these studies stress the need to examine different dimensions of sustainability of land use systems, and to take into account both ecological and biophysical, and social and economic aspects. Pretty (1995:11) describes sustainability as a 'complex and contested' concept which requires the integration of approaches to produce more efficient and effective use of resources; thus he characterises the challenge of sustainable agriculture as the ability to make better use of internal resources. Different studies have stressed various aspects of sustainability: for example, soil management (Hecht, 1989); pest management (Altieri, 1993); agroforestry (Schultz et al. 1994); agrodiversity or biodiversity and its relation to ecosystem functions (Brookfield and Padoch, 1994). Altieri (1991) provides a framework which conceptualises the integration of resource, components and functions for multiple use farming systems, and identifies the sorts of interventions or actions which might enhance these functions. Most authors also stress the use of an interdisciplinary analysis which utilises both indigenous knowledge or ethnoscience, and modern scientific knowledge, incorporating the best of both epistemological systems, or perhaps using indigenous knowledge as a 'springboard' (Smith and Pluckett, 1995). These findings support a methodology which develops a participatory approach to modelling the inter-related physical and economic flows within these systems.

Few studies have focused on the role of livestock in these multiple use systems at the frontier. The studies which have addressed livestock have tended to examine extensive ranching enterprises, widely described as one of the least sustainable land uses (Hecht, 1985 and 1992; Fearnside, 1990; Simão, 1992). However, livestock are possibly critical components of sustainable farming systems, and there is a need to understand resource flows through integrated systems of multiple land use. But this is a much under-researched area and most previous work has concentrated on crop diversity or agroforestry and few studies to date have incorporated a meaningful analysis of smallholder livestock.

Two general requirements emerge from the literature; sustainability implies on the one hand, an ability to address near-term human needs, while on the other and ability to account for long term social, economic and ecological limits. In applying sustainability to agriculture, a specific set of requirements can be defined. For example, Altieri and Anderson (1986) defined sustainability in agriculture as 'the ability of an agroecosystem to maintain production through time, in face of long term ecological constraints and socio-economic pressures'. Most studies of sustainable agriculture have stresses the ecological sustainability of land use, and many have done this by using specific indicators.

However, if we acknowledge that different sources of knowledge are also part of the sustainable land use formula, as discussed above, then other definitions and indicators and methods are suggested. This explicitly involves local resource users and acknowledges their contributions to learning, and their experience in research and

experimentation. This approach has been well documented as Participatory Rural Appraisal. The approach taken in our research builds upon the methods adopted by Lightfoot et al. (1993), and Pretty et al. (1995). Lightfoot et al. have assessed the sustainability of farming systems by examining indicators for economic efficiency, bioresource recycling, species diversity and natural resource capacity. This approach captures a greater share of the sustainability equation than more simplistic models adopted by other researchers. The method also allows resource managers themselves to define the terms and parameters.

In addition, we sought to gain insight into how systems of land use are changing over time, and thus by looking at case studies at different stages of frontier colonisation, approximate to historic analysis. We therefore explicitly acknowledge that these systems are co-evolving in response to a range of stimuli, ecological and social or economic, or as new knowledge is gain, exogenous or endogenous (see Norgaard's work on agricultural development in the Amazon, Norgaard, 1994).

In summary then, there is a growing body of work which examines the conceptual basis of sustainability in terms of land use and agriculture, and studies are now emerging offering operational definitions of sustainability. However, the interdisciplinary nature of the concept, the need to examine changes over time and for different groups in society, and the difficulties in applying notions and experience from one case study to another, results in a range of different approaches to its analysis. Most research into sustainable agriculture has taken a more narrow ecological approach and often focus on soil productivity as sole indicator of sustainability. In addition, the literature also recognises that sustainable land use often involves a fusion of indigenous and modern scientific knowledge. Although some studies in different Amazonian region have highlighted the evolutionary pattern of farming systems on frontier regions (Pichón, 1997a and b, 1996; Richards, 1997; Thiele 1993, Moran, 1989), fewer of these have examined the contribution of livestock to smallholder diverse enterprises. We undertook an extensive literature review, and present this and an annotated bibliography in Appendix 8.

Participatory methodologies which recognise knowledge of local resource managers are slowly being applied to issues of sustainability but to date no such study has addressed these issues in the context of frontier farming in Brazil. Most of the current systems of resource use at the forest frontier are not integrated and exploit reserves of energy and nutrients held in vegetation and soil. Experience over the past 20 years has indicated that small family based farming systems at the forest frontier are not sustainable and after a few years farming in one area, people are forced to move on with the frontier. Ranchers often move into the vacated areas and degrade the resource base still further. Such systems cannot be sustained in the longer term on social, economic, political and biological grounds. The project sought to support the actions of a number of research and farmer organisations that are working towards the development of more sustainable models of resource use and livelihood systems. The research involved harnessing the knowledge, energy and ideas of small farmers in this process. Farmers' perceptions and views were integrated into the methodology (see Sections on Activities below) and explicitly investigated (see Appendix 6). Findings were continuously fed-back to farmers and farmer organisations (see Workshops in Activities below, and Appendix 7).

Geographical focus of the research

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 contributes 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. These patterns of land use are also further discussed in Appendices 3 and 9.

Box 1 Evolution of farming systems in Maraba

First phase - installation:

A farmer occupies a plot or *lote* completely covered by forest, in a recently opened locality, which has no infrastructure or services. The farmer 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 will be very dependent on the forest resources: almost everything in the house will be 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.

Three localities, representing different stages in frontier development were selected, and within them case study farms chosen (see Research Activities) for further study. Table 1 summarises the key features of the three localities and the farms studied by the project.

Table 1 Characteristics of the three study areas and farms

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	6	7	55-225	10	81	4	20-200
Macaranduba	11	6	9	50-100	51	15	13	6-10

Figure 1: Location of the study area

Project Purpose

The purpose of the project was to analyse and model forest, crop and livestock resource interactions within smallholder production systems and farmer perceptions of these systems, and to identify key indicators that determine the long-term viability of enterprises. This will assist in the understanding of processes that lead to both environmental degradation (including deforestation and soil fertility decline) and countervailing processes that encourage greater systems sustainability.

Research Activities

Table 2 summarises the activities specified in the project LogFrame and indicates whether these are successfully completed and where further details can be found. There is a brief outline of the four activities and sub-components in the text below.

Table 2 Activities specified in the project LogFrame

1. Assemble and analyse secondary materials from past and on-going research	Complete; literature review and bibliography attached as Appendix 8.
2. Undertake primary data collection from a sample of farming households to include: • Participatory mapping of resource types • Participatory modelling by farmers of resource flows and interactions between crop/livestock/forest • Gathering and diagramming information on resource flows between system sub-components • Data analysis and synthesis and presentation	Activities complete: farmers and farms from three localities selected and data collected and analysed. Activities summarised below, and findings discussed and presented in Outputs sections and in Appendices 1,2,3,5,6.
3. Convene a series of farmers workshops throughout the research period to obtain feedback on methods, findings and test feasibility of more sustainable resource management strategies	Complete; summarised below and final workshop proceedings presented as Appendix 7.
4. Disseminate findings and recommendations and proposals for action to research and development agencies, in Brazil, regionally (with particular reference to CIAT, Bolivia) and in the UK	Ongoing: see dissemination under Outputs and material in Appendices 1,2,3,4,5,6,7.

Activity 1 Literature review

A review of the literature on livestock production in Amazonia and frontier farming systems was produced and is enclosed as separate Appendix 8. Special emphasis is given to diversity of production and its environmental, social and economic consequences. An annotated bibliography is attached to it, with nearly 180 references in English, Portuguese, French and Spanish, divided in twelve sections.

Activity 2 Primary data collection

i. Monitoring

Monitoring took place in three localities over a period of 15 months (Nova Canaã and Murumuru) and 13 months (Maçaranduba). Pre-monitoring interviews were interested in family history, farm structure and practices related to pasture management and herd control. The monitoring consisted of interviews with questionnaires, direct observations and some measurements (for example milk and cheese production, time spent on certain tasks, etc.). Researchers visited the farms on a monthly basis, at approximately the same date each month. Monitoring was concerned with the different components of farming systems: yields, cash flows and consumption, labour, herd events and management, and pasture management. Evaluation of pasture conditions was conducted on a quarterly basis, with visual observations and estimate of biomass, soil cover, weed invasion (type and percentage of cover) for every paddock. All data collected were regularly inserted into a database. Twenty-one farmers were studied but analyses for one year round data were collected for only 18 farms, as some families moved or circumstances changed.

These activities were primarily implemented by UEA Research Associate, Marcia Muchagata and LASAT Researcher Waldiléia Rendeiro, with support of LASAT Researcher Rosinaldo Machado and LASAT technicians Josivalto Paixão and Claudionísio Araujo. Further details are outlined in Research Findings sections, and in Appendices 1 and 2.

ii. Complementary studies

Complementary studies were undertaken in order to collect data on particular issues and to allow in-depth investigation of specific topics not covered during the monitoring activities. They comprised:

a) Farmers perceptions of nutrient flows and fertility

The participatory modelling of farming systems and nutrient flows with farmers was undertaken by drawing maps and diagrams with farmers at the three localities. This activity was carried out in two phases: firstly farmers drew a map of their farm, displaying land use and natural resources available (forest, river, soil). Secondly, farmers were asked about how they perceived the flow of materials between the components, drawing links using the maps produced in the first phase. An interview guide was also used to clarify their view about nutrient flows and perceptions of sustainability on their farms. Interviews were carried out by UEA Research Associate,

Marcia Muchagata and LASAT Researcher Waldiléia Rendeiro. The findings from this research component are explored in Appendix 6 and discussed in the Research Findings section of this report.

b) Use of forest and fallow products and knowledge of useful forest and fallow species, with emphasis on fodder trees and fire resistant species

The study was conducted at the three localities and used an open-ended questionnaire on use and knowledge of useful plant species. Interviews where complemented by visits to some fallow and forest areas for plant examination, and were carried out by UEA Research Associate, Marcia Muchagata and LASAT Researcher Waldiléia Rendeiro. Findings are presented in Section I.3 of Research Findings.

c) Gender analysis of frontier farming systems

A detailed study of the gender divisions of labour and women's participation in community life and community organisations was conducted in Maçaraduba and Nova Canaã, using guided interviews. An open-ended questionnaire was also applied at the three localities about access and control of resources, and women's labour and life cycle. The study was complemented by interviews with women's group leaders in Maraba and Belém, and was a collaboration between LASAT researcher, Waldiléia Rendeiro and UEA MSc student, Natasha Grist. Appendix 5 presents the findings of this study which are summarised in section II.7.

d) Milk and Meat Markets

A survey of milk and meat markets was conducted in Maraba using interviews with people involved in the marketing chains of meat and dairy products. They were asked about local, regional and national markets; processing technology and capacity; prices; role of other trades in the chain. ODG Research Associate Marcia Muchagata undertook this activity and the findings are reported in section II.6 and in Appendix 1.

e) Ethonoveterinary practices

An open-ended questionnaire was applied to all monitored farms on farmers' practices by UEA Research Associate, Marcia Muchagata and LASAT Researcher Waldiléia Rendeiro. Findings are incorporated into analysis presented in Appendices 1 and 2.

f) Farming Systems in Nova Canaã

This activity was a result of the collaboration Between ODG and LASAT and the MSc course on Family Farm, Environment and Development in Amazonia, developed by the Núcleo de Estudos da Agricutura Familiar, Centro Agropecuário, University of Pará (NEAF-CAP-UFPa). Five students conducted a detail study of farming systems in five selected farms in Nova Canaã, of which three were taking part in the project's monthly monitoring. Students lived with farmers during four periods of two-three weeks and studied a range issues, from soil morphology to social networks. In their final period around 30 farmers were interviewed to build a typology of farming systems in the region. The activities were supervised by LASAT researchers William de Assis and Rosinaldo Machado.

Activity 3 Farmer Workshops

Two initial workshops were convened in each of the three selected localities. The first workshop in each locality discussed project activities with farmers and undertook participatory resource mapping. General issues related to farming in the area were also explored. The second set of workshops discussed farming systems in more detail, with an emphasis on livestock production and livestock related problems. Researchers and farmers discussed selection criteria, and selected the farms to be monitored throughout the year.

A mid-project 3-day workshop was organised in Maraba, bringing together farmers from the three localities (not necessarily those involved in monitoring). It was the first feed-back from research activities and also served to clarify and discuss issues related to pasture and fire management with farmers. With support from livestock specialists linked to the University of Pará (Laura Ferreira and Soraya Carvalho) it was possible to organise two sessions on health treatments and mineral supplements. They organised and presented information perceived to be a gap in farmers' knowledge.

In Nova Canaã a workshop was organised to present the results of MSc students research to farmers. Some issues related to livestock production were also discussed.

A final 3-day workshop was held in Marabá with farmers from eight different localities, researchers and collaborators (ODG, LASAT and University of Pará, ORSTOM-INPA) as well as development organisations (FATA, EMATER, LUMIAR). The workshop presented research results on animal performance, costs of livestock production, pasture management and gender. Information on pasture management was complemented by presentations about pasture recovery with *Andropogon guianensis* by Danielle Mitja (ORSTOM-INPA). The final session identified areas for further research and discussed project continuity (with funds coming from University of Pará), mainly through on-farm trials. Summary of the workshop proceedings is presented in Appendix 7.

Activity 4 Dissemination

Dissemination of findings has taken place from an early stage in the project and through a range of different media including:

- Feedback was continuously provided to farmers participating in the monitoring and to other farmers in the region (for example, Appendix 7)
- Meetings were held with target institutions at early stages in the research
- Papers have been presented at various workshops and conferences in Amazonia (e.g. Appendix 2, 4)
- Press and media interest has been generated by the research
- Various reports and an NRSP Research Insight has been widely distributed internationally (see Appendices 3, 5,8)
- The Bibliography has been made freely available to target institutions and academic and research institutes (Appendix 8)

- Posters in Portuguese and English are being prepared to further disseminate research findings to target institutions
- Papers in English are ready for submission to scientific journals (Appendices 1, 6)

Further details of dissemination activities are given in Contribution of Outputs.

Project Outputs

Table 3 summarises the outputs from the project as specified in the LogFrame. The Analysis of the research findings is presented below and discussion in various Appendices, indicated in the table.

Table 3 Outputs specified by the Project Logframe

Output 1**:** Review of literature from Portuguese, Francophone and Anglophone research on role of livestock in frontier farming systems in Amazonia	Attached as Appendix 8
Output 2**:** A set of indicators of sustainability based on farmers' perceptions of farming systems, resource flows and crop/livestock/forest interaction.	Analysis presented in Research Findings, indicators outlined in Section 9
Output 3**:** A set of techniques acceptable to farmers to enhance resource flows and productivity with special attention to role of livestock and sustainable use forest resources and strategies to decrease pressure on forest resources	Analysis presented in Research Findings, discussion of application in 'Contribution of Outputs'
Output 4**:** Strengthened collaborative links between Brazilian research institutions, including LASAT, and regional and UK based institutions	See Activities and Dissemination sections and suggestions for further research and action

SUMMARY OF RESEARCH FINDINGS

The research findings are summarised in three sections that focus on the role and management of livestock and pasture; the household economy of frontier farms; and the sustainability of frontier farming.

Section I The role and management of livestock and pasture

1. Livestock Performance

Herd constitution in each locality is a reflection of farmers' dual purpose objectives for meat and cheese production, and also of their links with the *fazendas*. For this reason the herds have *zebu* cattle, which are preferred by the *fazendeiros* for meat production, mixed with milk specialised breeds. Herd composition reveals farmers' strategy to increase herd size. The smaller the herd, stronger this trend (Table 1.1).

Herd management is quite simple as feeding is based exclusively on pasture. As the systems become more intensive, vaccination and other health treatments are more frequently and consistently applied. This reflects not only the willingness of farmers to look after the animals more carefully, but it is also a consequence of changes in the local environment. Table 1.2 presents the occurrence of diseases and ectoparasites during monitoring and in recent years.

The most serious health problem is related to mineral deficiency. This is related to the limits of exclusive pasture feeding coupled with the lack of use of adapted mineral salts. Most farmers provide salt for their animals, but only a few mix mineral concentrates with it.

In contract to farmers' perceptions, many herds are not yielding a calf/cow/year as they state (Table 1.1). This production is only found in Maçaranduba. The interval between births and the fertility of the herd are related to environmental health and farmers' practices. Where pasture is still in good condition and herds are quite small, they are managed more intensively, thus the interval between births is low and fertility high, as in the case of Maçaranduba.

There is generally no active management or intervention to control the breeding season, and therefore births are concentrated at the beginning of the dry season. Although dairy products are the main sources of cash for these farmers, milk production is highly variable throughout the year, revealing the lack of control of production cycles. This is illustrated by Figures 1.1 and 1.2 which present milk production and births for two farms. Generally cows produce less than 500 kg of milk per year (less than two litres of milk per day during the lactation period), a very low figure (see Table 1.2). The indicators of calf and meat production are better. Weight gains are around 110kg per year and in the first year the gain is up to 240 kg by the sale age of most of the male animals.

More detailed information on livestock performance can be found on Appendices 1 and 2

Table 1.1 Animal performance indicators

	Maçaranduba	Nova Canaã	Murumuru
Fertility	100.00%	69.93%	92.50%
Fecundity	100.00%	69.50%	92.00%
Still-born	0.00%	0.33%	0.50%
Mortality	3.50%	8.86%	1.42%
Mortality-calves	4.50%	12.00%	2.58%
Mortality-adults	0.00%	3.29%	0.67%
Culling rate	4.75%	18.57%	17.83%
Exploitation rate	6.00%	22.43%	29.17%
Growing rate	57.50%	11.14%	14.67%
Age of first conception (years)	3.00	2.25	3.00
Interval between births (months)	11.37	13.91	14.18
Average weight gain/year	n.a.	108.67	127.33
Weight gain for the first year	n.a.	186.20	221.67
Milk production			
Farm monthly production-dry season	81.50	682.83	2077.25
Farm monthly production-rainy season	99.68	690.80	1963.80
liters/cow/day dry season	0.58	1.42	1.86
liters/cow/day rainy season	0.74	1.41	1.67

Table 1.2 Diseases and parasites in monitored herds

	Maçaranduba		Nova Canaã		Murumuru	
Disease	96-97	97-98	96-97	97-98	96-97	97-98
Foot and Mouth	0	0	2	0	3	0
Brucelosis	0	0	0	0	2	0
Rabies	0	0	1	0	0	0
Carbunculo	n.a	0	n.a	0	n.a	4
Babesiose	0	0	0	0	0	0
Diarrhoea in youngster	3	1	6	5	2	4
Diarrhoea in adults	0	0	0	1	1	2
Mastitis	1	1	4	2	1	4
Parasites[a]						
Worms	4	2	4	7	3	5
horn fly	5	0	5	0	6	4
carrapato	6	0	6	0	5	2
bicheira	n.a	1	n.a	1	n.a	3
Deaths[b]						
adults death	0	0	2	6	2	2
youngsters deaths	1	4	5	11	1	9
miscarriages	n.a	0	n.a	1	n.a	0
stillborn	0	0	1	1	2	2

a-Diseases and Parasites in number of farms that presented the problem

b-Deaths in number of total cases

Figure 1.1: Seasonal production on a farm in Nova Canaã

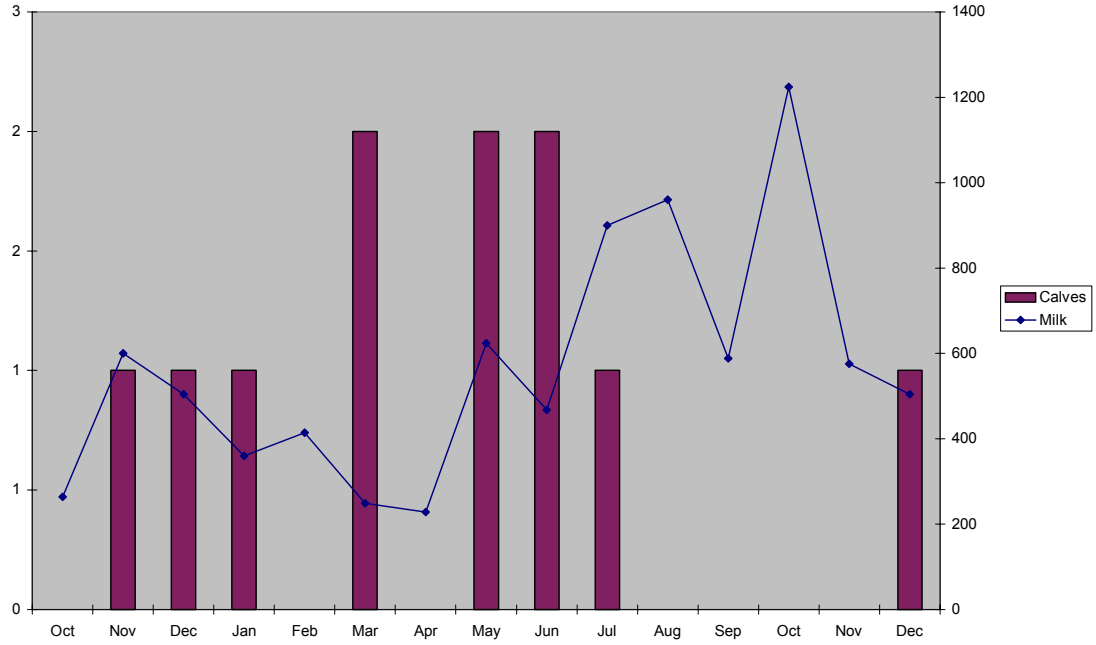
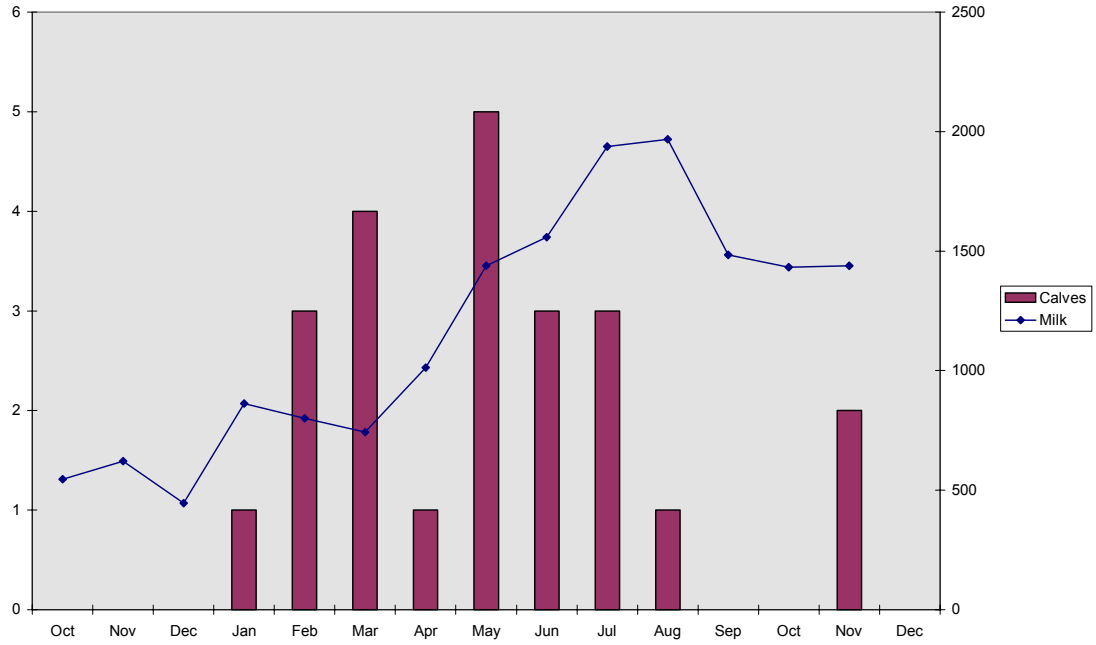


Figure 1.2: Seasonal production on a farm in Murumuru



2 Pasture Management and Degradation

Pasture management is the key to improving the sustainability of colonist farming systems and intensifying livestock production. Farmers' conventionally see the need to increase the area of pasture areas as herds increase in size, and this threatens forest areas. Figure 2.1 presents the expansion of pasture areas at the localities studied.

Figure 2.1 Pasture development in the three study localities

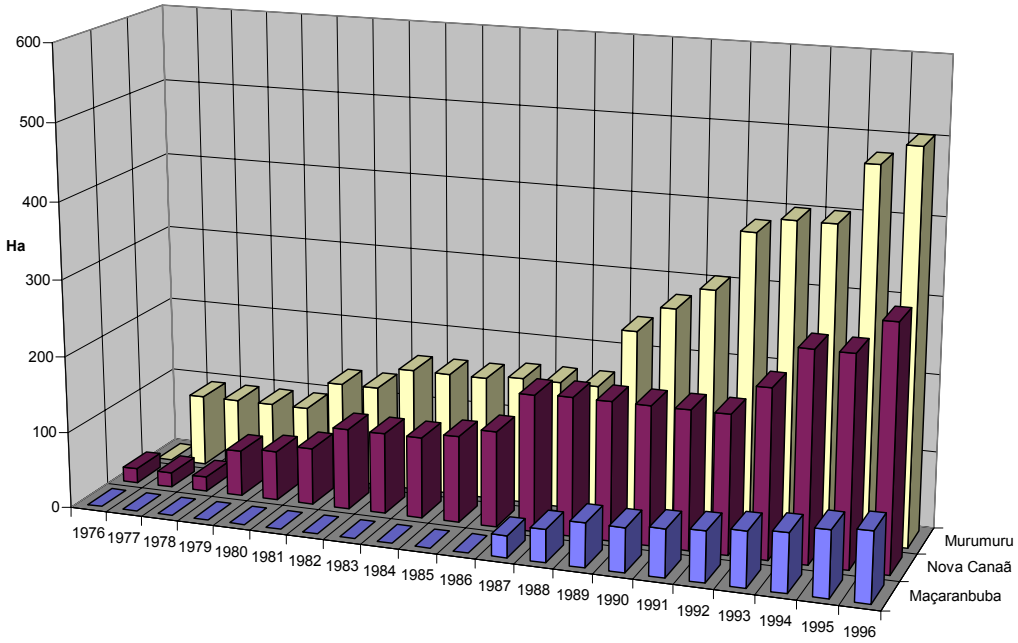


Table 2.1 presents the main grass species. The importance of each species depends on the length of settlement in the locality. *P. maximum* was a popular species during the1980s. However, the growth of *P. maximum* in tussocks can lead to erosion and degradation, and other species such as *B.brizantha* are required for more intensive and durable pastures. Farmers' strategies are to have paddocks of different pasture types. The method of pasture planting depends greatly on farmers' strategies of fertility management of their farms. Figure 2.2 presents the possible options to pasture establishment.

Farmers try to adopt a rotational system for pasture grazing. The more specialised the system, the greater the number of paddocks (Table 2.1). The rotation system and stocking rates throughout the year are very complex, as farmers often send animals to and/or receive animals from neighbours or relatives, and their decisions are related to pasture conditions, water availability, animals particular needs and their own workload. Decisions related to rotational grazing are tactical than strategic, that is, more conditioned by limits and opportunities experienced by farmers each year rather than a result of overall planning about pasture and other land use resources.

Table 2.2 Paddock characteristics in the localities

	Maçaranduba	Nova Canaã	Murumuru
nº of farms	5	8	6
nº of paddocks	11	19	30
paddocks per farm-average	2.2	2.4	5
paddocks per farm-min-max	1 and 4	1 and 3	3 and 12
average paddock size	8.2	16.54	16.77
paddock size-min-mas	3.6-19.2	2.4-38.4	2.4-43.2
total area of paddock	90.2	314.4	503.2
main species	*B. brizantha*	*P.maximum*	*B. brizantha*
introduction of *B. decumbens*	1987	1986	1990

	Maçaranduba		Nova Canaã		Murumuru	
	main	secondary	main	secondary	main	secondary
Panicum maximum	0	4	**10**	3	6	8
Brachiaria brizanhta	**6**	0	3	5	**20**	3
Brachiaria mutica	0	1	**5**	2	0	2
Brachiaria decumbens	**5**	0	1	0	0	0
Brachiaria humidicola	0	5	0	0	2	5
Brachiaria ruziziensis	0	0	0	0	1	1
Paspalum notatum	0	0	0	0	1	1
Hyparrheira rufa	0	0	0	0	0	1
Pernambuco grass	0	0	0	0	0	1
Total paddocks with more than 1 species	11		19		30	
Paddocks with only 1 species	3		7		12	

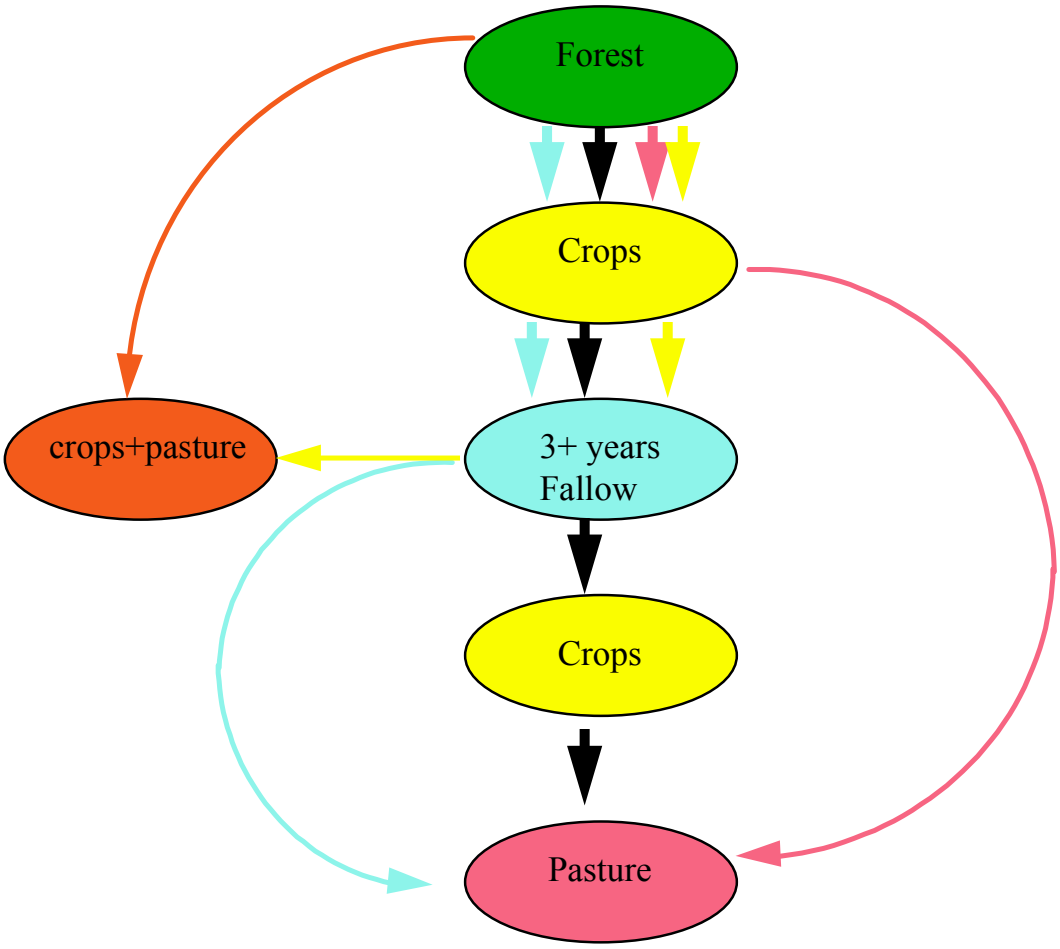


Figure 2.1 Options for pasture establishment

After detailed monitoring of pasture rotations and visual evaluation of forage quality, it was possible to identify 3 models of pasture use (Figure 2.2).

Model 1- *Lotes* with few paddocks, with minimum rotation or used as if they were just one. Low stocking rates. Much biomass is produced but little is consumed. Very common at Maçaranduba and Nova Canaã.

Model 2- Farms have 3 to 4 paddocks. The most heavily used is the one close to the house. Other paddocks are used less frequently. The property produces more forage than is needed. Less frequently grazed areas are rarely weeded and so weeds have more chance to seed and spread. Farmers rely on fire more often, thus speeding the process of pasture degradation. Better pastures are the ones found close to houses. This is a common model at Nova Canaã and Murumuru.

Model 3- Found on one farm in Murumuru and one in Nova Canaã. This is the only model characterised by high stocking rates. Consumption of grass is high and pasture quality is a result of a number of practices (pasture establishment, weeding, fire management). At Murumuru this model presents pasture in excellent conditions, while in Nova Canaã grass cover is poor and weed invasion high.

There are the less specialised areas of pasture that use fire every year, as this is necessary under low stocking rates (Table 2.3). Most farmers prefer to set fire before the rains, when the burn is more efficient, and they can have new pasture which can be grazed early in the season. For the long term sustainability of grazing, a burn after the first rains would be preferred, as this will have a lower temperature, kill a smaller number of grass plants, and have less damaging impacts on soil and soil biology.

Table 2.3 Fire use in pasture management

Year	Burns	Maçaranduba		Nova Canaã		Murumuru	
1997	Burnt paddocks	9	82%	15	79%	9	30%
	Non-burnt paddocks	2	18%	4	21%	21	70%
	Burnt before rain	5	56%	11	73%	2	22%
	Burnt after rain	4	44%	4	27%	7	88%
1996	Burnt paddocks	9	82%	11	58%	21	70%
	Non-burnt paddocks	2	18%	8	42%	9	30%
	Burnt before rain	5	56%	9	82%	15	71%
	Burnt after rain	4	44%	2	18%	6	29%
1995	Burnt paddocks	8	73%	11	58%	22	73%
	Non-burnt paddocks	3	27%	8	42%	8	27%
	Burnt before rain	8	100%	11	100%	16	73%
	Burnt after rain	0	0%	0	0%	6	27%
	Paddocks burnt every year	7	64%	6	32%	6	20%

We can also model how farmers consciously or unconsciously manage their pasture to deal with degradation processes. There are three options that could be applied to a single paddock. In the *first* weed invasion and grass vegetation is controlled by constant weeding or use of herbicide, higher stocking rates (above 1.5 A.U./ha) and limited use of fire. If it is needed there is constant sowing of grass in areas where the density of plants is decreasing. This keeps pasture free of weeds and productive for very long periods. The *second option* is the opposite: poor weeding, frequent use of fire and uncontrolled or very poorly controlled grazing, with either low or high stocking rates. This leads to degradation. In a *third option* farmers use pasture while it is new and abundant. With an increase in weeds and shortage of labour, farmer will allow forest regrowth. The herd can still graze the area for a period, but will be selective and often feed from fallow plants. Fire will not be set for a few years, allowing biomass to grow. The burn of this area has the same effect as a traditional fallow, killing weeds and fertilising the soil. Grass regrows quickly, and frequently there will be sowing of new grass.

These options can be simultaneously observed on the same farm. For example, farmers in Mumurumu who adopt the grazing pattern model 1, would apply the option 1 to the paddock close to the house and the option 3 to another paddock that is not very frequently used. As this decision is often a tactical rather than a strategic, it can happen that the farmers adopt the route 3 without being aware to that. They will try to keep the paddock weeded, but will suddenly perceive that is too late for that, opting for fallow regeneration.

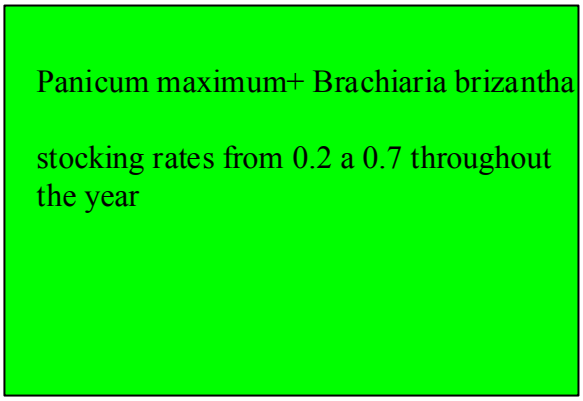
It is important to stress the current lack of information to support informed decisions for farmers and development agents on stocking rates. Even without having specific parameters with which to compare the effects of grazing pressure on pastures we hypothesise that, in contrast to the common view, the processes of decreasing productivity in pasture in the region are more frequently associated with low stocking rates rather than with over-grazing. This is in line with recent studies that show that decrease of fertility generally is not a constraint for the long term viability of pasture areas in Amazonia (see for example Correa and Riechardt, 1995 or Moraes et al. 1996) and that management is the key factor inducing the process of degradation. It has been pointed out the low or sub-optimal stocking rates are partially responsible for low grass cover, since animals do not consume enough to stimulate grass sprouting (Duru, 1994; Topal 1995). The low intensity of grazing results in an accumulation of dry matter, making the use of fire necessary to stimulate grass sprouting. When pasture is completely dominated by fire resistant weeds pasture recuperation (without the use of machines) or natural forest recovery becomes very difficult. It is only at this level that changes in pasture vegetation can be called degradation under current defintions of degradation (see Abel and Blaike, 1993) not before that, as it is most frequent in the region.

In summary, high stocking rates are not common amongst the farms studied and the opposite – low rates - is more frequent. With less pasture area, but better maintained and managed, and with improved forage and better planned rotations, farmers could save labour and liberate areas for other land uses.

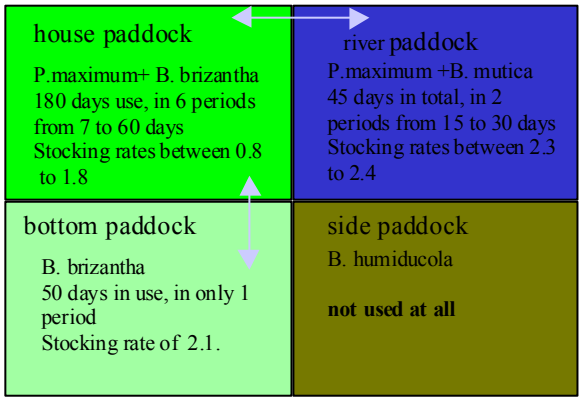
Detailed information on pasture management and its importance to the sustainability of farming systems can be found in Appendix 1.

Figure 2.2 Models of pasture and rotation management

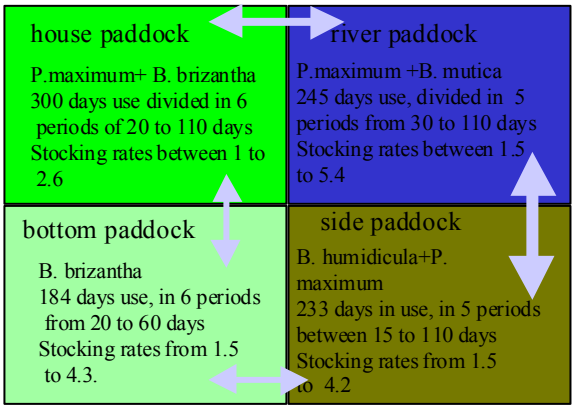
Model 1: Paddocks without divisions, low stocking rates



Model 2: Various paddocks, under-used



Model 3: Various paddocks, overused



3 Fodder trees

The adoption of fodder trees represents a way to improve nutritive value of livestock feeds and a strategy to better integrate crops and forest with livestock. In Eastern Amazonia, however, the constant presence of fire is a severe constraint to the widespread use of fodder trees. The identification of fire resistant species is one option, and these could potentially play a significant role take part as multiple use species in agrosilvopastoral systems.

When asked about fodder fallow and forest plants, farmers identified 17 species (Table 3.1). However, at present there is little opportunity to incorporate such plants into current farming systems. There is some potential with the yet unclassified plant-*corindiba*- which is probably from the family *Borraginacea*. The next step should be to send a sample for identification and laboratory analysis.

There are opportunities in terms of identifying fire resistant trees. There are two types of fire resistance:

- *Species that survive fire* (Table 3.2) Thirty-one plants were identified, from which at least 17 present potential, as they are used for timber. Four of them are good for fencing, and they could be tested as live poles.

- *Species whose development is stimulated by fire* (Table 3.3) Amongst these are tree legume species, including a type of *Cassia* (other *Cassia* were incorporated in agroforestry trials elsewhere). The use of palms could also be further investigated.

Five species are in both lists: they survive fire and have their development stimulated by burn.

Farmers often retain some useful trees, and these will remain in pastures for future use. This demonstrates that roots for silvopastoral systems are already in place. Next steps would include bibliographical search on ecology of the potential species, to analyse possible adaptation to farming systems (for example evaluate seed dispersal to check aggressiveness and risk of becoming a weed); consult farmers about their perception of the use of selected plants in silvopastoral trials; and establishment of on-farm trials.

Detailed analysis of smallholder use and knowledge of forests in presented in separate Appendix 9.

Table 3.1 Fodder trees identified by farmers

Plant		type of plant				type of vegetation		locality where it was cited			Obs.
Brazilian Name	**latin name**	**tree**	**grass**	**srub**	**palm**	**Forest**	**Fallow**	**Maçaranduba**	**Nova Canaã**	**Murumuru**	
Babaçu	*Orbignya martiana*				x	x			x	x	
Bananeira da Mata	*Calathea sp*			x		x			x		
Cafezão	*Cordia sp*			x					x		
Capim Cega Jumento	*Solanum rugosum*		x				x	x			good for chicken
Capim Beira Estrada	*Paspalum sp*		x				x	x			
Capim duro	*Paspalum virgatum*										
Capim Pacoã	*Panicum laxun*		x				x	x			
Capim Pampuã	*Panicum ?*		x				x		x		
Corindiba	*Borraginacea*	x				x			x		
Embauba	*Cecropia sp*	x				x	x	x	x	x	
Feijão Bravo	*Calopogonium muconoides*			x			x			x	
Mandioca de Caboclo	*Manihot brachiloba*			x		x			x		
Marua	*?*			x					x		
Najá	*Maximiliana martiana*				x	x				x	
Orelha de burro	*?*					x	x			x	
Taboca	*Lasiacis sp*		+-			x		x	x	x	good for donkeys
Uxi	*Endoplera uxi*	x							x		good for pigs

Table 3.2 Fire tolerant species identified by farmers

Plant		type of plant				type of vegetation		locality where it was cited		
Brazilian Name	**latin name**	**tree**	**grass**	**srub**	**palm**	**Forest**	**Fallow**	**Maçaranduba**	**Nova Canaã**	**Murumuru**
Amarelão	*Euxyphora paraensis* Hub.	x				x			x	
Angico	*Piptadenia sp.*	x				x			x	
Assa-peixe	*Vernonia brasiliana*			x			x			x
Axixa	*Sterculia sp*	x				x		x		
Babaçu	*Orbignya martiana*				x	x	x		x	x
Bacaba	*Oenocarpus bacaba*				x	x	x			x
Barriguda	*?*	x				x		x		
Barrote	*Trattinickia burseraefolia* Sw.	x				x				
Beiju de Coco	*Diallium guianensis*	x				x		x		
Canafista	*Cassia sp.*	x					x		x	
Capim Cega Jumento	*Solunum rugosum*		x				x	x		
Castanha	*Bertholletia excelsa* H.B.K.	x							x	
Cedrarana	*Cedrelinga catanaeformis* Ducke	x				x		x		
Corindiba	*Borraginacea?*						x			
Embaúba	*Cecropia sp.*	x				x	x	x	x	
Estopeiro	*Cariniana strellensis (Raddi)* O. Ktze.	x								
Ingá	*Inga spp*	x					x		x	
Ipê	*Tabebuia spp*	x								
Jambo	*Eugenia sp*	x					x		x	
Maçaranduba	*Manilkara sp*	x				x				x
Macauva	*Palmae*				x	x			x	
Mamuí	*?*	x					x	x	x	
Melancieiro	*Alexa grandiflora* Ducke	x				x		x	x	x
Najá	*Maximiliana martiana*				x	x	x			x
Pequi	*Caryocar villosum* (Aubl.) Pers	x				x			x	
Quariquara	*Minquartia sp.*	x				x			x	
Sapucaia	*Lecythis usitata* Miers.	x				x			x	
Tamboril	*Enterolobium sp.*	x				x		x		
Taúba	*Mezalaurus itauba* (Meissn.) Taub.	x								
Tucum	*Palmae*				x	x			x	
Vassoura de botão	*Sida rhombifolia*					x			x	

Table 3.3 Species stimulated by fire identified by farmers

Plant		locality where it was cited			type of plant			
Brazilian Name	***latin name***	**Maçaranduba**	**Nova Canaã**	**Murumuru**	**tree**	**grass**	**srub**	**palm**
Braúna	*Melanoxylon brunia*		x		x			
Caiçara	*?*		x					
Canafista	*Cassia sp*	x	x		x			
Cobi	*?*		x					
Corundiba	*Borraginacea ?*	x			x			
Embauba	*Cecropia sp*	x	x	x	x			
Fava de Paca	*Leguminosae*	x			x			
Ipê	*Tabebuia sp*		x		x			
Jitirana	*?*		x		x			
Jurubeba	*Solanum subinerme*	x		x			x	
Lacre	*Vismea sp*			x				
Laquiri	*?*		x					
Limãozinho	*?*	x						
Maminha de porca	*?*	x						
Melancieiro	*Alexa grandiflora* Ducke	x			x			
Sapucaia	*Lecythis usitata* Miers			x	x			

4 Costs of livestock production

Costs and profits increase with herd size. Table 4.1 and Figure 4.1 show that, apart from the *lotes* where livestock production is still at an early stage (the case of most of Maçaranduba farmers), the activity is always profitable. At Maçaranduba most farmers are still in a phase of investment, where the cost of infrastructure is large and herd size small, and markets for milk are almost absent. In Figure 4.2, the main source of income from livestock is sale of animals, except in Maçaranduba, where in order to increase herd size, farmers avoid selling stock (except in emergencies). However, the importance of dairy production (milk and cheese) increases with the degree of specialisation of farming systems, and is higher at Murumuru than in other areas.

Generally there is little cash expenditure, with the most important cost being associated with labour, this constituting more than 60% of total costs in all instances. The figure is divided between daily activities that are unavoidable (such as milking, health treatments); and pasture management, related mainly to weed control. Changes in pasture management would potentially lower these costs. Labour expenses are not generally recognised by the small farmers, since most farm work is done by family members. Likewise, although they know that the cost for infrastructure development are very high, and often this is the main constraint to launching the activity, farmers rarely take this cost into account on an annual basis. Hence, according to farmers, livestock production is very profitable and the major costs are related to inputs for animal production. As shown in Table 4.1, in Murumuru the expenditures on inputs are higher, reflecting the degree of intensification.

Further details of livestock costs are presented in Appendix 1.

Figure 4.1: Costs, revenues and net income from livestock production at the three localities

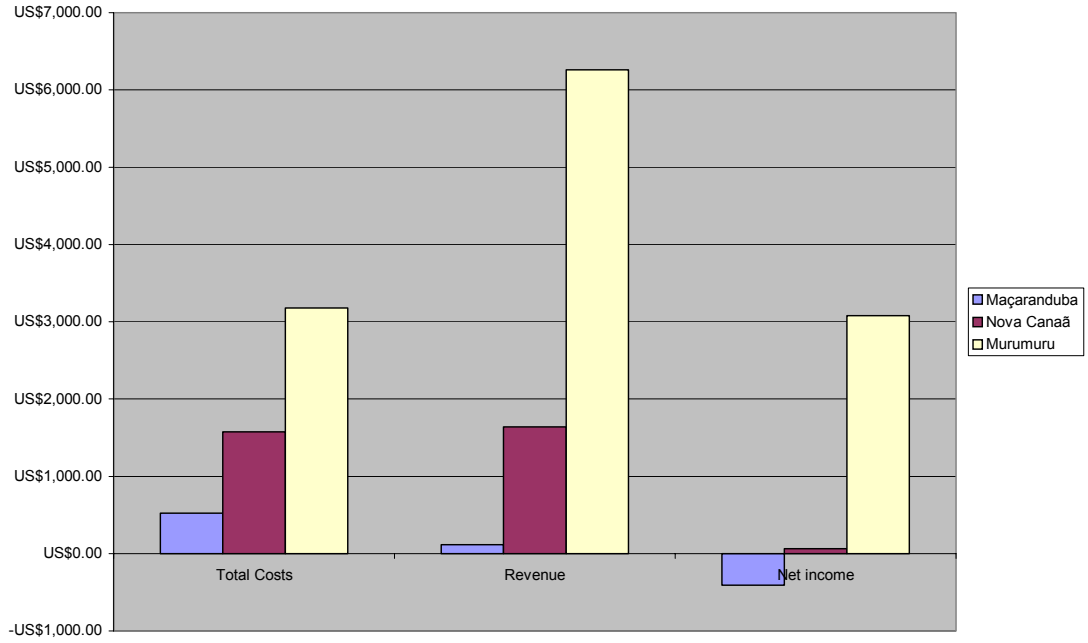


Table 4.1: Costs for livestock production at the three localities

	Maçaranduba	Nova Canaã	Murumuru
Herd husbandry			
mineral suplement	US$20.67	US$64.84	US$161.13
vaccines	US$2.17	US$20.75	US$53.33
other medicine	US$12.83	US$47.52	US$120.97
animals (horses and donkeys)	US$22.63	US$109.20	US$72.14
diet suplement	US$0.00	US$3.73	US$43.09
Pasture maintenance			
seeds	US$33.70	US$150.83	US$185.07
herbicide	US$0.00	US$0.00	US$8.26
Other			
whey-bacteria	US$0.00	US$10.37	US$0.00
Labour			
daily activities	US$168.37	US$610.27	US$1,134.24
other health treatments	US$6.52	US$1.86	US$18.84
pasture maintenance	US$167.39	US$446.58	US$864.86
Infrastructure depreciation			
fences	US$52.38	US$63.04	US$352.72
corral	US$4.93	US$5.30	US$20.62
trencher	US$1.81	US$1.03	US$2.16
tools	US$29.04	US$36.02	US$35.78
cattle crush	US$0.00	US$0.00	US$15.94
pasture rents	US$0.00	US$37.14	US$102.32
tax	US$0.00	US$23.83	US$3.62
Total costs	**US$522.43**	**US$1,572.71**	**US$3,179.16**

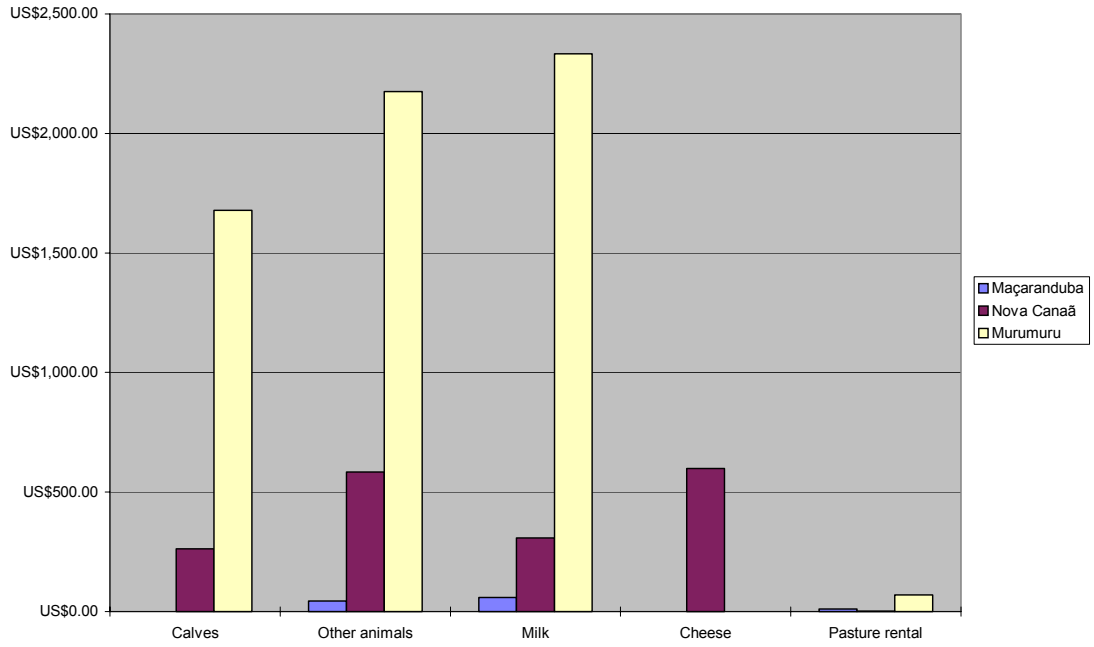


Figure 4.2: Sources of revenue from livestock production

Section II The household economy of frontier farms

5 Income

Although farmers who keep cattle would be expected to be the better off in the region, many of the livestock producers are still very poor. In our sample four of the farms monitored presented family monthly income lower than the Brazilian minimal wage per worker (US$ 138 per month). The highest revenues were found for the more specialised systems in Murumuru, where family income was up to US$13370 annually (US$ 1114 per month).

Contribution of different enterprises to household income is in line with the evolutionary patterns of farming systems in each locality: in Maçaranduba forest and crops contribution to income are relatively higher than at Nova Canaã or Murumuru, while in Murumuru most of the revenue is related to livestock production. Some families also have non-agricultural earnings, either from pensions or paid work, normally performed by older sons or wives.

Families with lower income spend most of their cash on household needs, leaving only the minimum necessary to invest in productive activities. Better-off families are able to make greater investments, thus increasing their productivity year after year. Their expenses on household items also reflect their wellbeing, with money being spent not almost exclusively on food, as in the case for the poorest families, but on durable goods. Expenses on transport and medicine are important for almost all households, reflecting the poor infrastructure throughout the region. Figures 5.1, 5.2 and 5.3 present examples of sources of income, expenditure and detailed family expenses respectively for one farm in Maçaranduba, Nova Canaã and Murumuru.

Figure 5.1: Sources of income, expenditure and family expenses for one *lote* in Maçaranduba

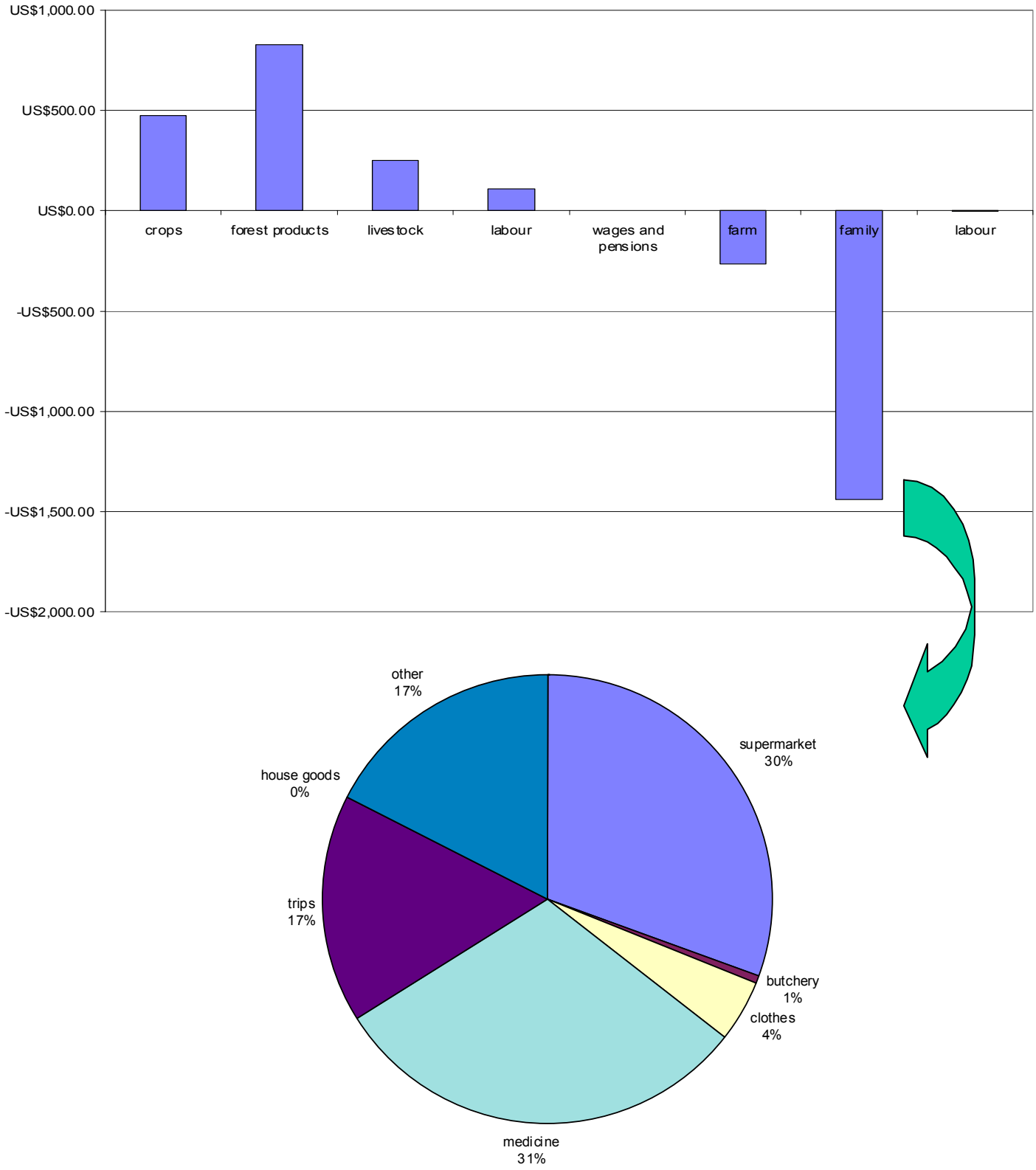


Figure 5.2: Sources of income, expenditure and family expenses for one *lote* in Nova Canaã

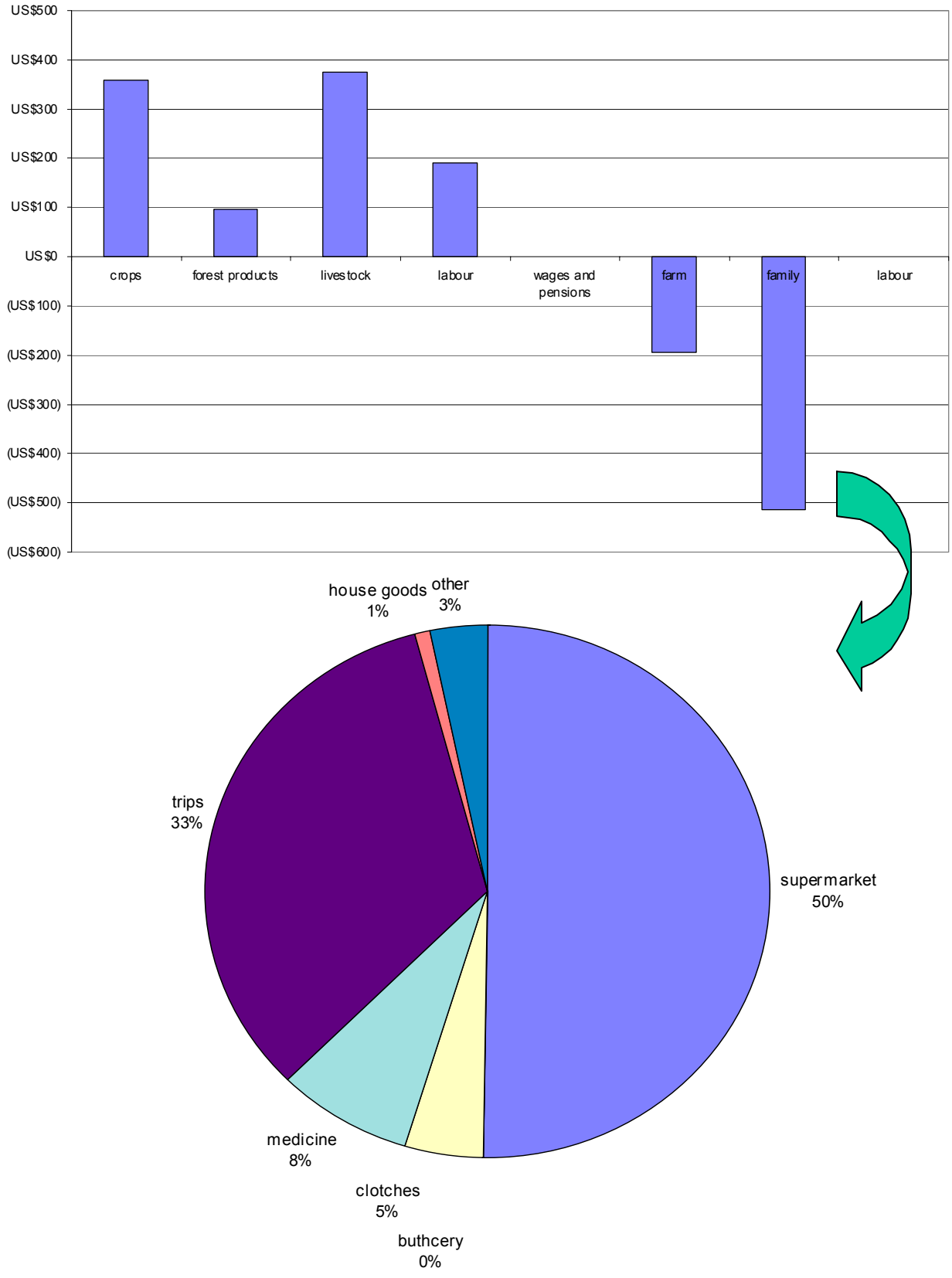
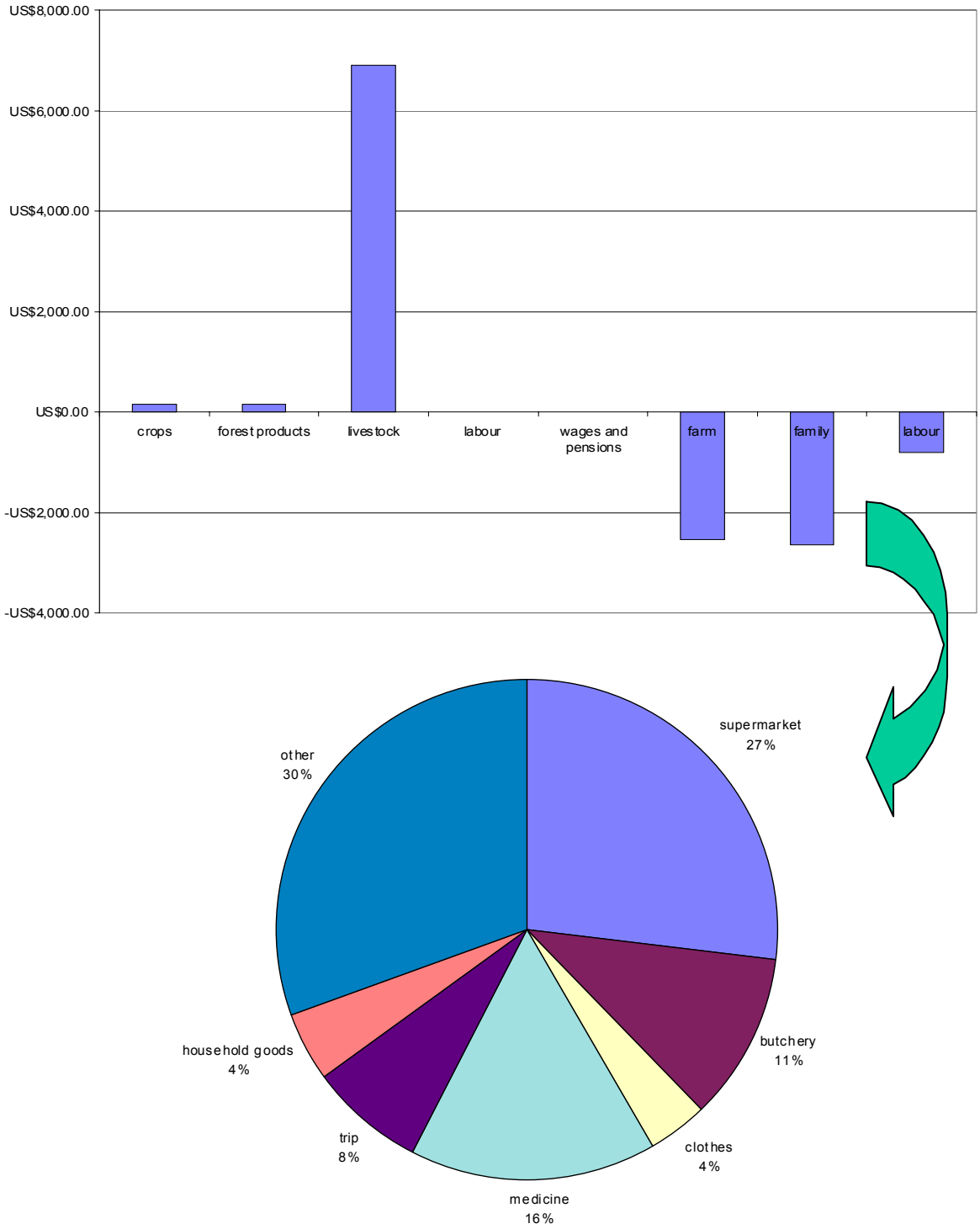


Figure 5.3: Sources of income, expenditure and family expenses for one *lote* in Murumuru



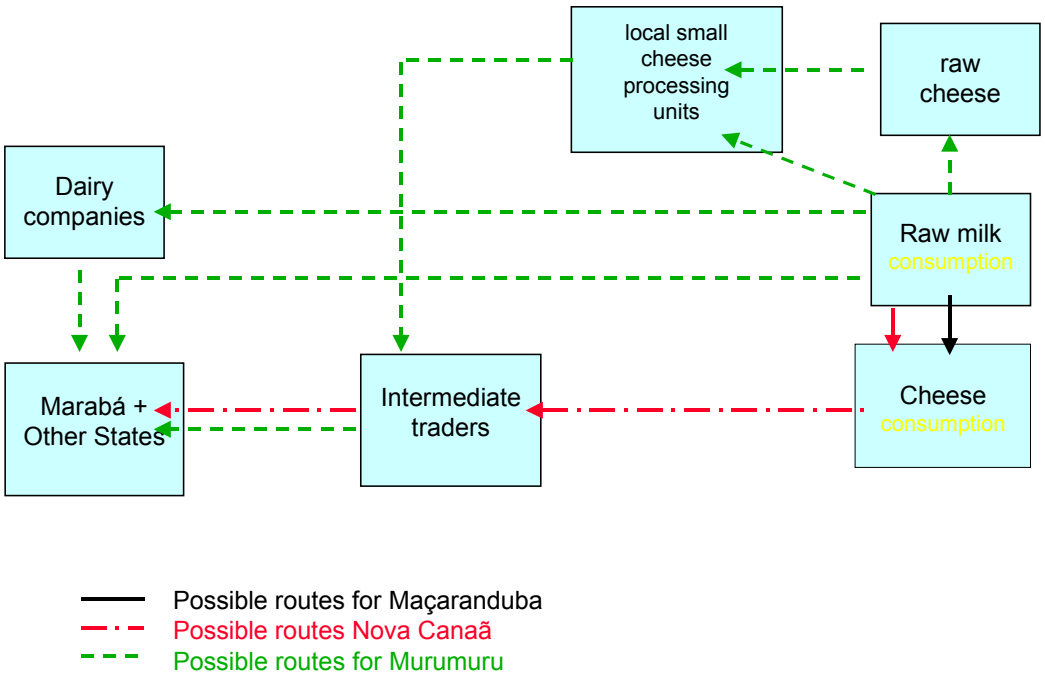
6 Markets

Increase of revenue is very dependent on access to markets, and this is the key factor motivating farmers to intensify production in general. As distance from markets increases, farmers receive lower prices, with difference in prices paid at the farmgate at those paid at the urban centres reaching up to 1600%; and have less opportunities to sell their products. In Maçaranduba, for example, the forest is rich in fruits such as cupuaçu, but its perishability means that only a small proportion of potential production can be actually sold. Lack of market is the key constraint to improvement in the contribution of forest to livelihoods. However, as different forest products (perishable fruits, nuts, timber, medicinal plants) demand different marketing structures and market chains, it is seems unlikely that improvements can be made in the short term.

Distance and access to urban centres are particularly important in determining prices and markets for milk as well, while these factors are of much less importance for the sale of live animals. In distant regions, when the herd starts to increase in number there is a need to commercialise milk production, but it is impossible to sell fresh milk. This is the case of Maçaranduba. This makes cheese production the main option, and cheese has become a source of income for many farmers in Nova Canaã. However, the income is not regular; prices change dramatically according to the season. Cheese can be sold to middlemen locally or at urban centres, and it is then exported to other regions. Another option is to sell it to small shops or weekly markets at urban centres, at better prices.

Selling fresh milk however, is a privilege of farmers living close to urban centres, where dairies are established and organise milk collection daily. This happens only where there are all-weather roads. Although farmers receive low prices per litre of milk - currently something between US$0.10 and US$ 0.17 - this represents a better price than cheese, particularly given the extra labour and investment necessary for cheese production. For this reason in Murumuru none of the farmers are involved in milk processing at the farm level. However a dense network of milk processing units exists. The main unit is a dairy company based about 10 km way, which has a processing capacity of 50 000 litres per day. This dairy sells pasteurised milk to Marabá and exports cheese and butter to other regions. There are also five small processing units, rustic family-based businesses, located at the village, with a capacity to process around 1000 litres per day each. Figure 6.1 illustrates the commercialisation network for milk and cheese.

Figure 6.1 Commercialisation of dairy products



7 Gender aspects of frontier households

Gender division of labour

Activities within the farming systems are strongly segregated by gender. The percentage of women participating in most agricultural activities in the communities is low in comparison with male participation (see Figures 7.1 and 7.2). The most common activity for female participation is harvesting. Men's farming activities typically include the heavier tasks of land clearance. Strong gender segregation is apparent in livestock care: men look after cattle (only one female respondent had this responsibility), whilst women manage small livestock (pigs, chickens and guinea-fowl). However, tasks which require foraging or collection outside the house (fuel, water, forest products and hunting) have a more diverse gender allocation.

The "help" of children is significant in the farm system. Both sexes collect wood and water, and girls tend to help more in the house with cooking, cleaning, washing and child care, whilst boys, particularly as they grew older, help their fathers in the fields. In Nova Canaã there are several households where adult males remain on the farm helping their parents in agriculture. Females who have finished school (aged 12 years and over) remain working on their parents' farm until marriage.

Research results suggest that women's participation in agriculture has always been limited, even in their areas of origin, but that they become more involved at the beginning of the colonist phase due to the critical need for their labour, and in relation to the stage in the family life-cycle. Thus a decline in women's involvement in agricultural activities over time in colonist settlements is not indicative of a "housewifisation" process, but a shift back to a "normal" state of affairs where women largely perform domestic work within the agricultural system.

Gendered ownership and decision-making

Within the communities studied all significant decisions concerning migration and the household are made by men. They make the decision to migrate in the families. Whilst presumably the wives were consulted at some point, the current situation is that several of the women are unhappy living in these communities, and wish to return to either their city of origin or to their family 'back home'. They said they only stay because of their husbands wishes, or because he has family there. All intra-household decisions about agricultural strategy, market purchases and livestock marketing are made by the men. Women make decisions about household food consumption. They often have no access to cash, nor need for it: cash is generally controlled by the men.

Further details of this study are presented as Appendix 5.

Figure 7.1 Farming activities by gender in Nova Canãa

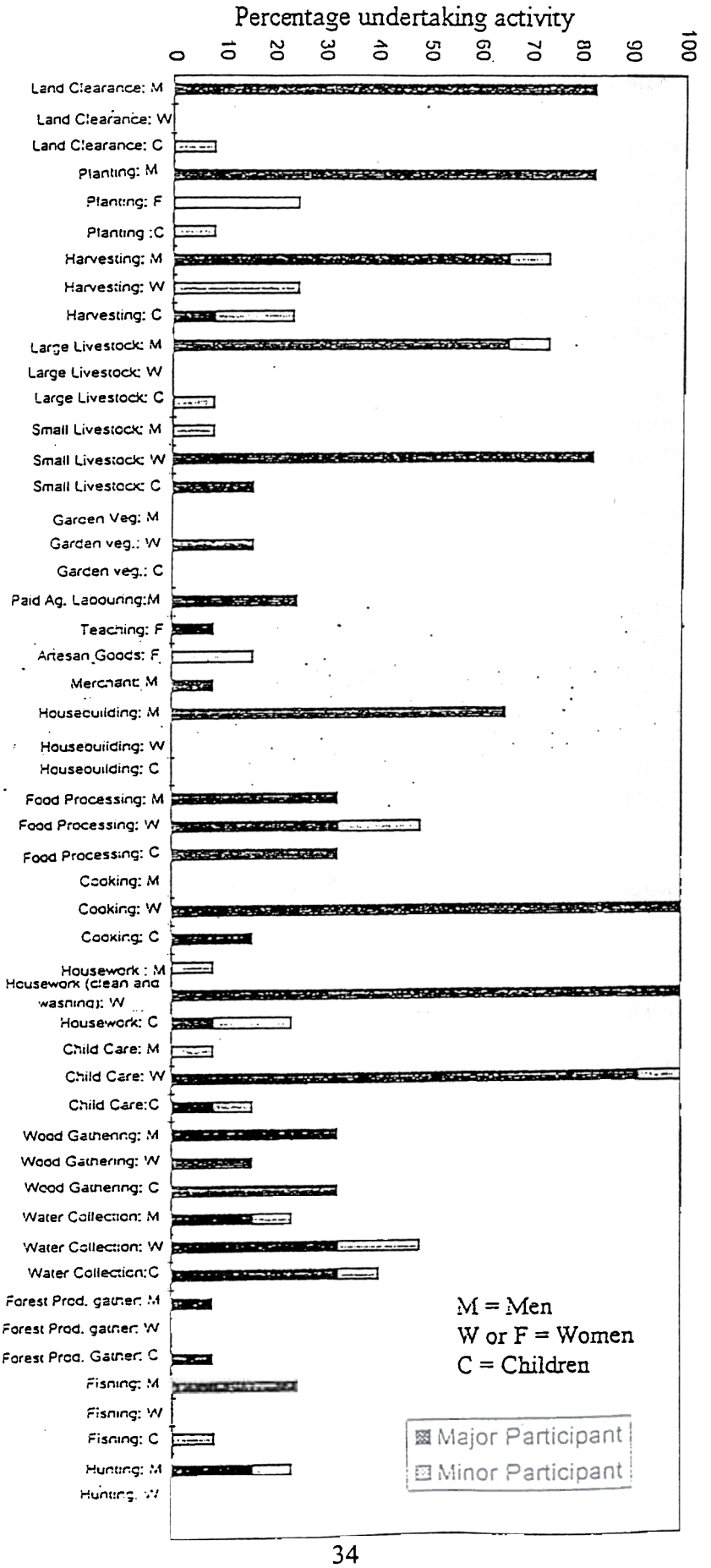
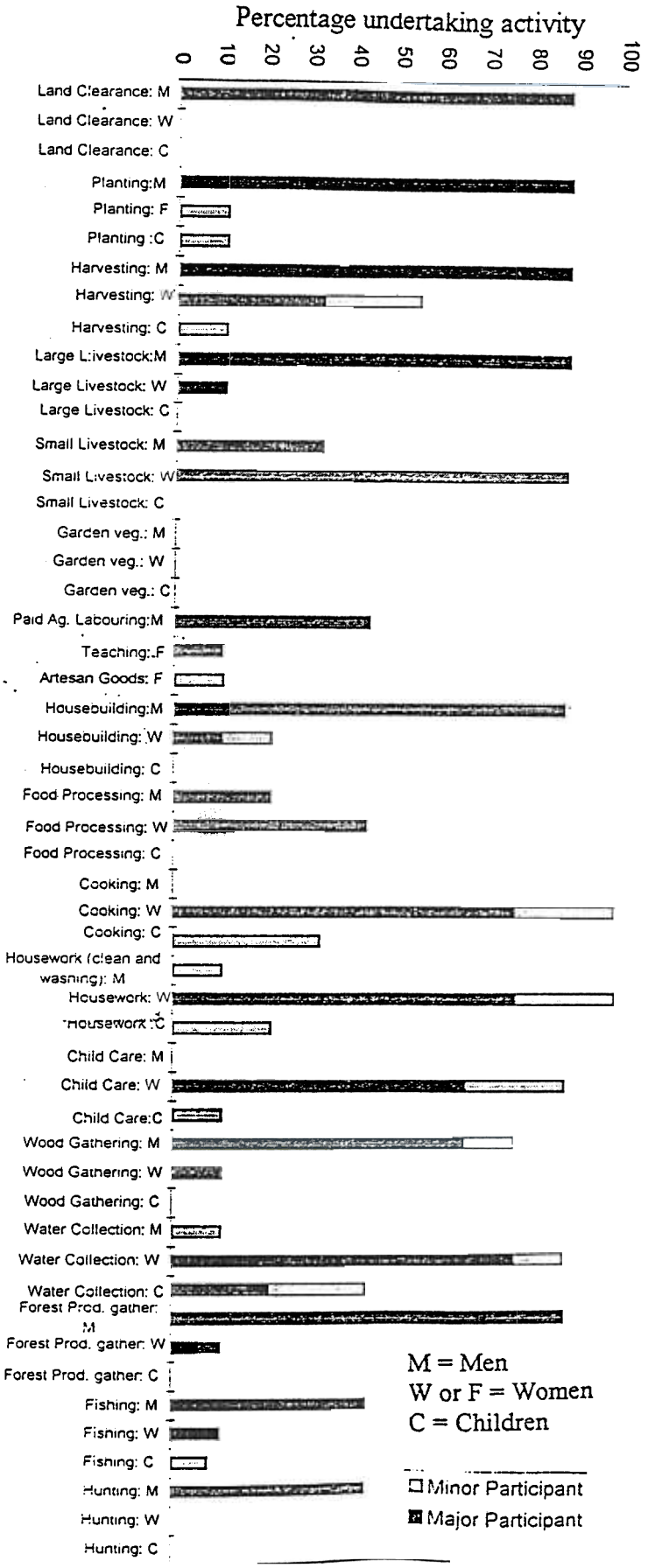


Figure 7.2 Farming activities by gender in Maçaranduba



Section III Sustainability of frontier farming

8 Farmers' perceptions of sustainability and nutrient flows

Nutrient flows

The participatory modelling of farming systems and nutrient flows was undertaken in a series of meetings and workshops and by drawing maps and diagrams with farmers. The resulting diagrams (some examples are shown in Figures 8.1, 8.2 and 8.3) show the main flows between the components of the farming systems. By drawing the diagrams together with farmers it was possible to identify what components of farming systems and which linkages and flows are important for them. Components that do not interact with others were rarely mentioned, as for example fallow. From farmers' perspectives fallow is hardly contributing to other components of farming systems. Fallow and forests were often represented as closed units, i.e., providing material to soil and using it, but not interacting with other components of the farming system. In areas where forests interact, in terms of production of timber and fruits, this was clearly pointed out.

The diagrams in general show very diversified farming systems. The interactions between the different sub-systems (crops-livestock-forest) are important but could be strengthened, and nutrient cycling is generally poor. Hardly any farmer cited the contribution of nutrients from forest burning, a crucial factor in nutrient conversion within these systems. There is practically no use of manure and external inputs of nutrients come exclusively from the use of mineral salt for cattle.

Knowledge about nutrient cycling was very uneven, even between farmers from the same locality. While some farmers highlighted the contribution of manure or leaf nutrients to soil, and then to plants, and linked these nutrients to family consumption, or off the farm and to markets, there were cases where farmers could hardly identify any link between soil and plant growth.

Perceptions of fertility and environmental change

The perceptions of change in soil fertility are related to the length of settlement. Farmers' perceptions of fertility are closely linked to the presence of forest, especially in newly settled communities where there are still some 'virgin' soils (i.e. uncultivated) to exploit. 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. Overcropping is the main reason identified by farmers for the decline in soil fertility in all three localities. High stocking rates are also blamed for deterioration of soil conditions. Interestingly, farmers often cited fallow as a practice with negative effects on fertility, being associated with a source of weeds and sometimes also with pests.

The use of fire was found to be a controversial practice. For one group of farmers fire is beneficial, as growing crops without burning seems impossible, and pasture managed with fire is vastly superior to unburnt pasture. For them fire combats harmful organisms and brings 'strength' to soil. Another set of farmers perceive fire as a detrimental practice because burning increases weed invasion, and makes soil drier and harder. It also contributes to a loss of soil 'strength', and it destroys soil

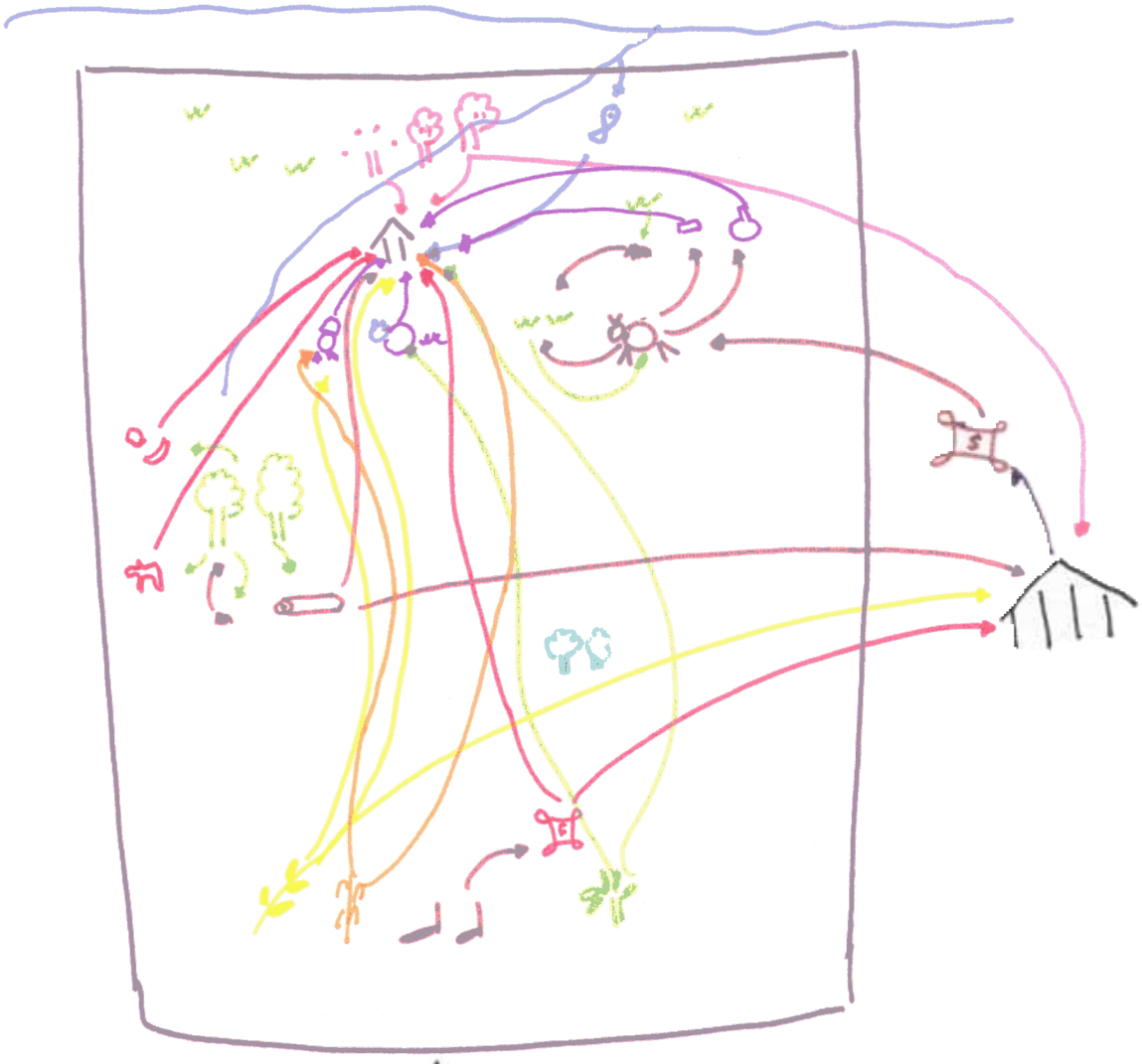
'richness'. Nevertheless, even for those farmers who are aware of all the negative impacts of fire, there is no way to avoid its use.

The majority of farmers think that they will not be able to sustain cropping in the near future. As forest and fallow are becoming scarce 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 is to be able to control weeds. If they were able to do this then they can continue to subsist in the place as long as they want with 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 core problem (see for example Correa and Riechardt, 1995 or Moraes et al., 1996).

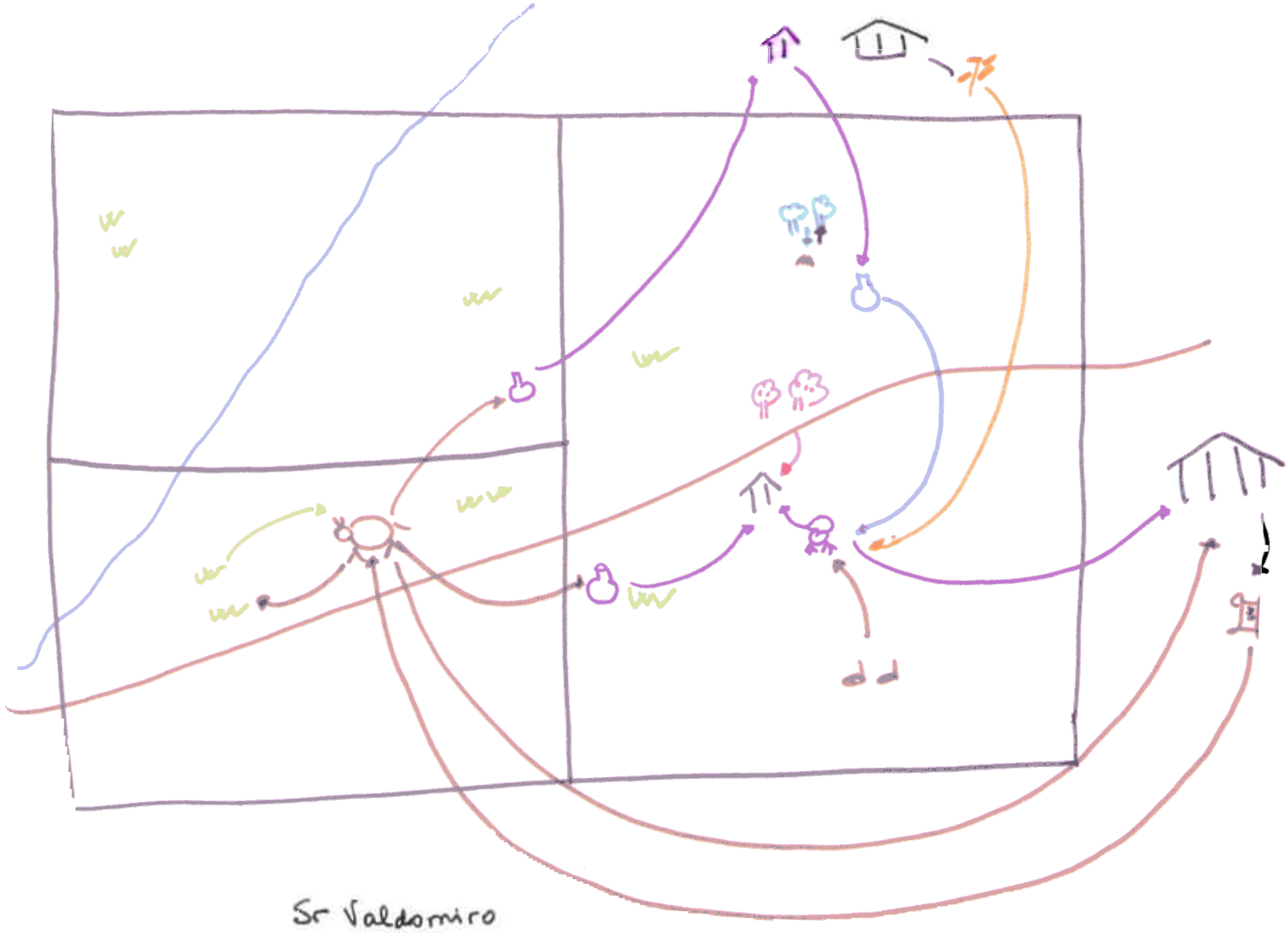
Farmers' perceived solutions for environmental deterioration were shaped outside their own reality, focusing on use of high-tech machinery, while agroforestry practices which are potentially better adapted for smallholders in the area, were mentioned by only one farmer.

Appendix 6 discusses the findings on farmers' perceptions of resource flows and soil types.

Figures 8.1 – 8.3 Farmers' diagrams of nutrient and material flows on their farms



Sr Luizinho
Maparanduba
96 ha total
60 ha forest
6 ha fallow

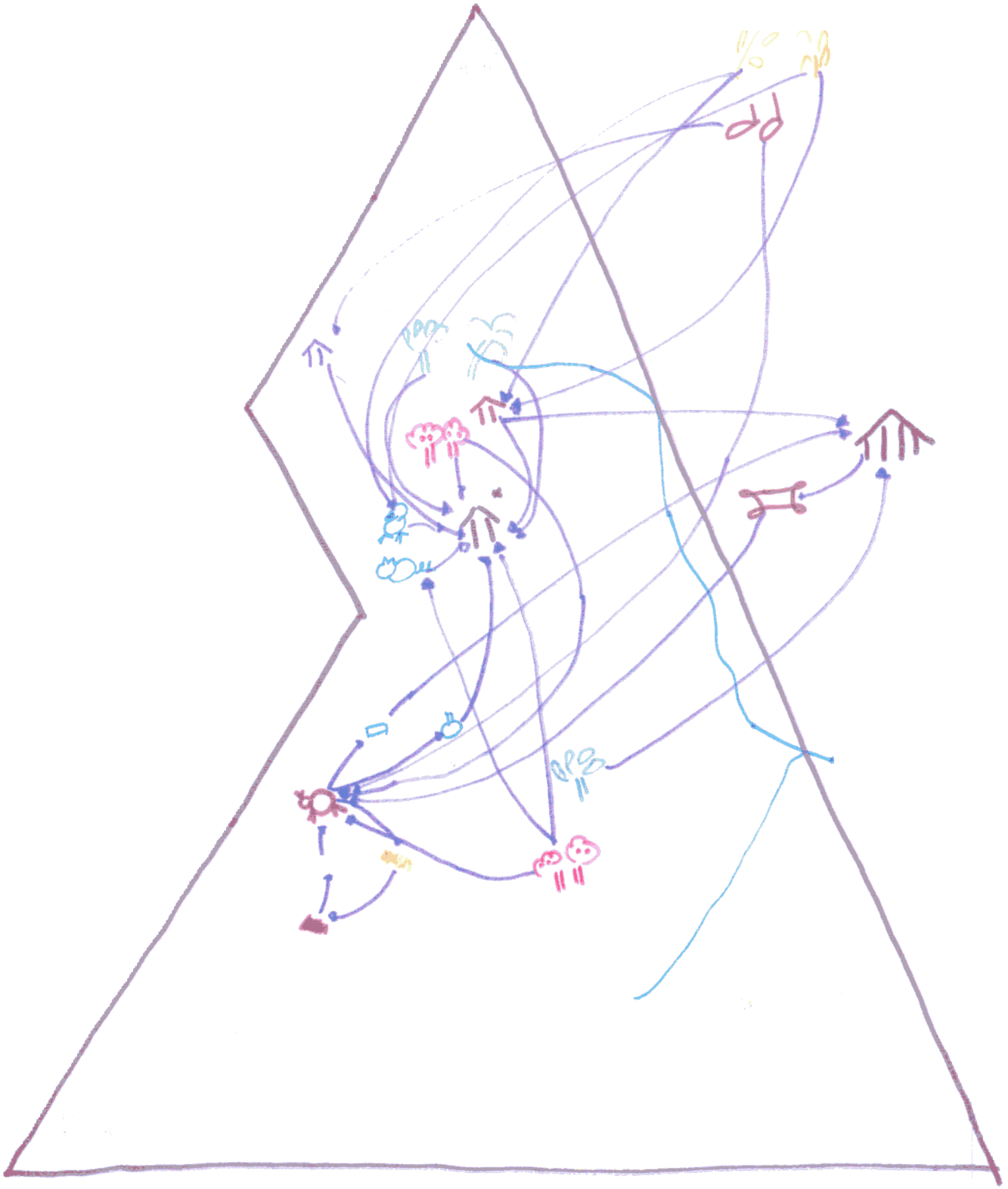


Sr Valdomiro

56 ha total

no forest

Murumuru - milk route



Sr Osvaldo (B de)

20 ha 4 hours the same land

0 forest

0 fallow

using other farmers land to grow crops

9 Sustainability Indicators

The selection of appropriate indicators to assess sustainability of a given system is difficult, given their complexity and that sustainability incorporates many dimensions. Potentially there are a large number of possible indicators from which to select only a few.

Table 9.1 presents our selected farm-level indicators of sustainability. They are the result of a process that incorporated farmers' perceptions on sustainability and some of the indicators that make sense for them (Section 8) coupled with careful analysis of data collected throughout the year. As these indicators are still too numerous, four of them were selected that we believe can present the richest picture of the degree of sustainability of a single farm, and allow assessment or comparison between farms. Some of them aggregate or summarise information on other possible indicators as well (for example, forest cover is related to conversion to pasture or intensity of forest use). The four indicators are:

- **Forest cover:** an important indicator for both farmers and researchers. For farmers remaining forests represent the possibility of having a crop field free from weeds, a source of food and income, and a buffer zone, to protect from fire or spread of diseases. For researchers it represents conservation of biodiversity and maintenance of number of environmental functions. On the graphics it is presented in percentage of forest cover.
- **Income:** Presented as total gross income in US$. As there is little cash expenditure and most of the costs are represented by labour, the total gross income figure gives a good idea of family wellbeing, particularly when comparing farms within the same locality.
- **Agrodiversity:** Presented as number of crop and animal species produced for food or cash. It represents the possibility of having different sources of food, income, flexible labour demand and safeguard to oscillations in prices and productions levels. In order to compare their importance for food security the number presented on the graphics do not include orchard species or riding animals. If they were included the variation between farms will not be so easily perceived, as even the most specialised farms can present orchards with more than 20 species.
- **Pasture quality:** It indicates the possibility of having a productive pasture in the long run. It is presented by an index that reflects the level of weed invasion and soil cover by forage species (1 for pasture in worst conditions to 5 to good cover and well-weeded pastures).

The assessment of sustainability using these indicators for some farms are presented in Figure 9.1, 9.2 and 9.3. The larger the kite, the higher are the levels of sustainability. None of the farms studied can maximise all the sustainability criteria at the same time. From all the farms analysed the two which show the most sustainable profiles are one in Maçaranduba (Figure 9.1) and another in Murumuru (Figure 9.3, *lote* 15). *Lote* 15 has good pasture conditions, is practising a relatively diversified system and has some forest remaining. One of the farms in Maçaranduba is close to this, but income is too low, and this is likely to drive the farmer to less long term sustainable but more profitable land use practices. Such is the case on most of the farms in Murumuru, such as *lote* 13 (Figure 9.3), where forest has completely disappeared. Farms in the worst positions are those with pasture in very bad

conditions as shown in Figure 9.2, *lote* 1, in Nova Canaã. There, although the systems are still diversified, environmental degradation is high and income remains low, as it is also the case of *lote* 4.

These indicators, however, show only a snapshot or static picture, the current state of the farms. They do not show the dynamics over time, nor the driving forces of change (Morse and Bell, 1999). For example, farms in Murumuru presented a more sustainable pattern of enterprises some years ago than today. In addition, trends in sustainability on individual farms are not exclusively guided by individual farmer's management, but are also the result of evolution and change in the localities. Table 9.2 presents indicators selected that could apply to assess sustainability levels of a locality, all of them with important implications for farm development. These are thus the locality level factors that will influence individual farm sustainability and the evolution of the locality itself. Rate of turnover of farm families or households was not selected as an indicator, as locality stability is the ultimate appraisal of farm level and locality levels of sustainability.

Table 9.1 Farm level indicators of sustainability

Where	Indicator	Sustainability objective	Observations
Farming system-general	Agrodiversity	increase	measures the level of diversity of cultivated and non- cultivated plant species and animal species present and used by families
	Degree of integration of different components	increase	evaluates the exchanges in terms of nutrient and material between sub-systems (ex. crops and small livestock)
	Farm planning	increase	evaluates farmers' adoption of medium-long term plans for land use.
	Fire control and management	increase	evaluates action to limit use of fire and prevent accidents
	Water management	keep natural availability constant	evaluates action to manage surface water in order to conserve natural supplies
	Conversion to pasture	slow/minimise	measures area converted to pasture over time
Livestock systems	Animal performances	optimise	measures different animal performance indicators (average milk production per cow, interval between births, mortality rate, growing and culling rates)
	Pasture quality	increase	evaluates the degree of pasture soil cover and weed invasion
Crop Systems	Role of annual crops	increase or stabilise	evaluates the presence of annual crops, considering diversity, production and contribution to income
	Role of perennial crops	increase	evaluates the role of perennial crops-considering area extension and use (consumption or cash)
	Length of cropping in a single plot	increase	measures the number of seasons or years a cleared plot remains used for crop production
Forest system	Forest cover	stabilise	measures forest cover
	Intensity of forest use	increase or stabilize	evaluates the importance of different forest products for livelihoods
	Forest richness	stabilise or increase	evaluates forest natural or induced richness in useful species
Family	Overall household income	increase	measures total family income
	Income proportion used for other than food	decrease	measures proportion of total income used for food. Indicates surplus to invest in production and investment in family well-being
	Labour fluctuations	stabilise	evaluates if labour is well distributed throughout the year or if there are shortages or surplus
	Children attending school	increase	measures number of children attending school and for how long, if there are children at school age on farm

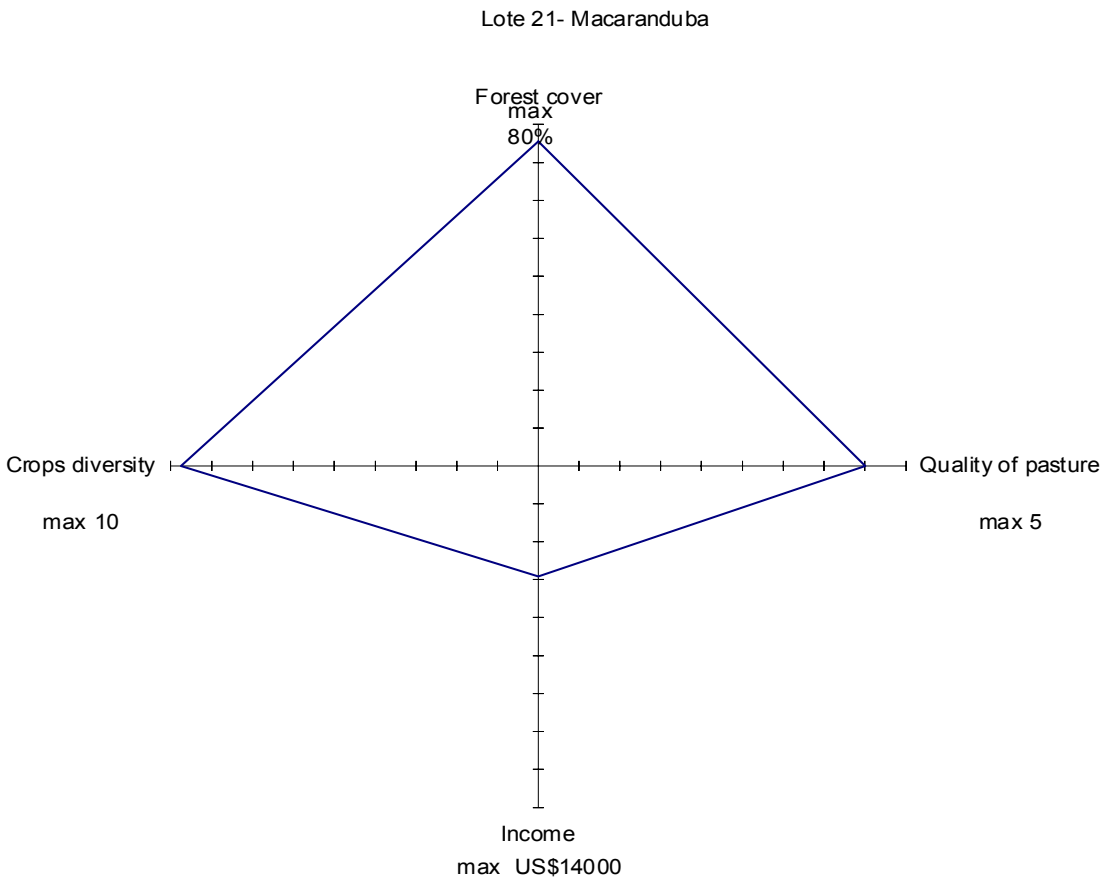
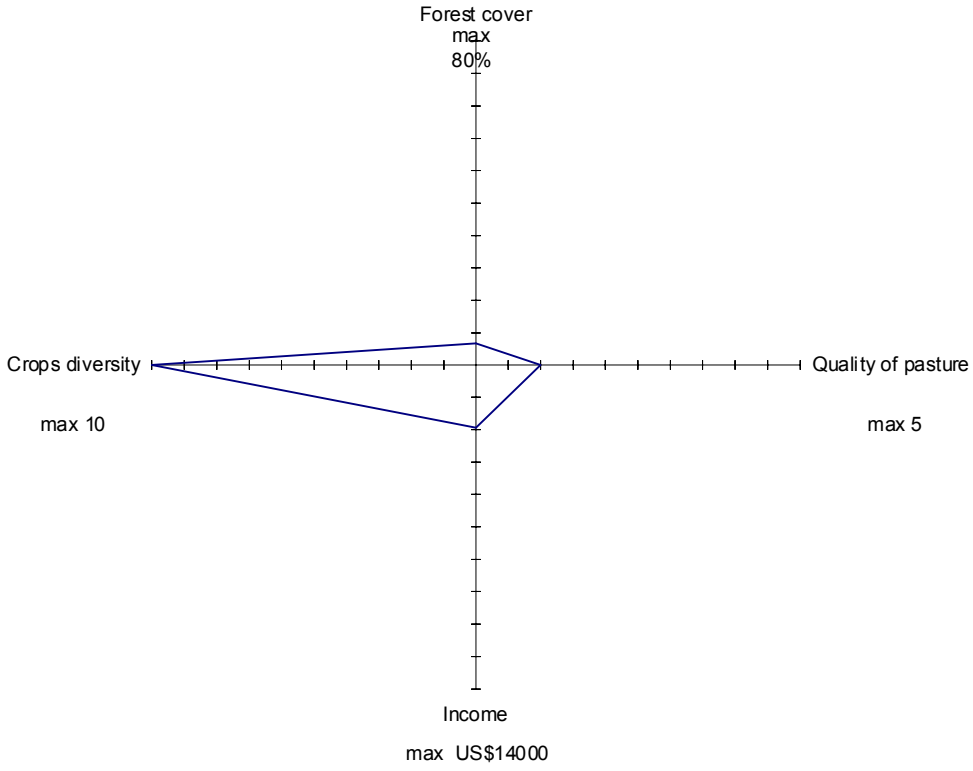


Figure 9.1: Patterns of sustainability of a farm in Macaranduba



Lote 4- Nova Canana

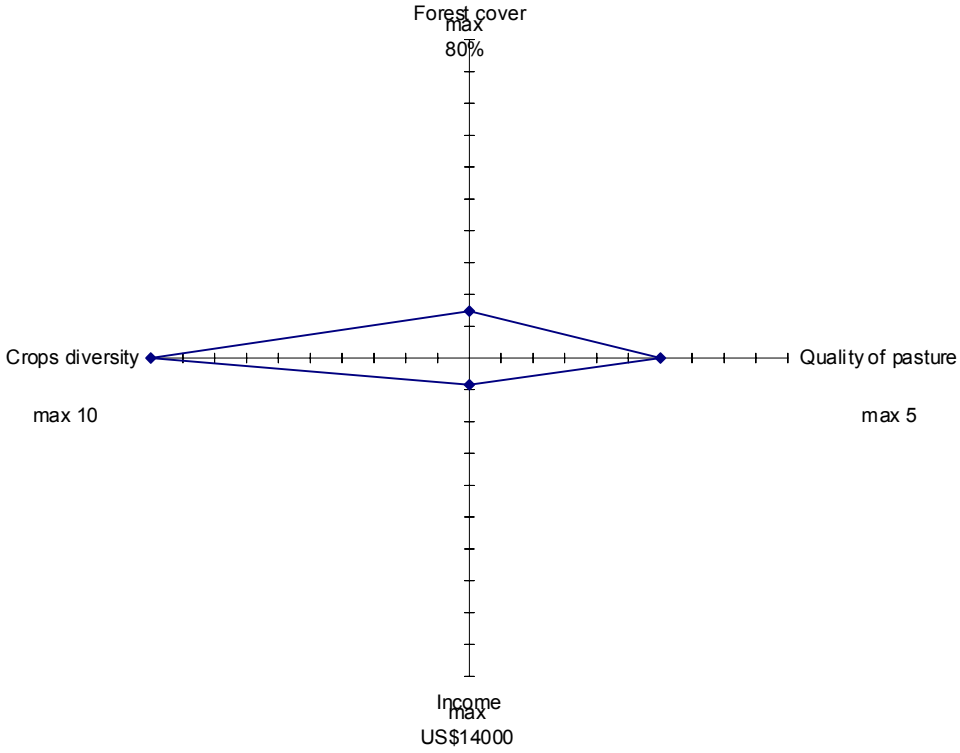


Figure 9.2: Patterns of sustainability of farms in Nova Canaa

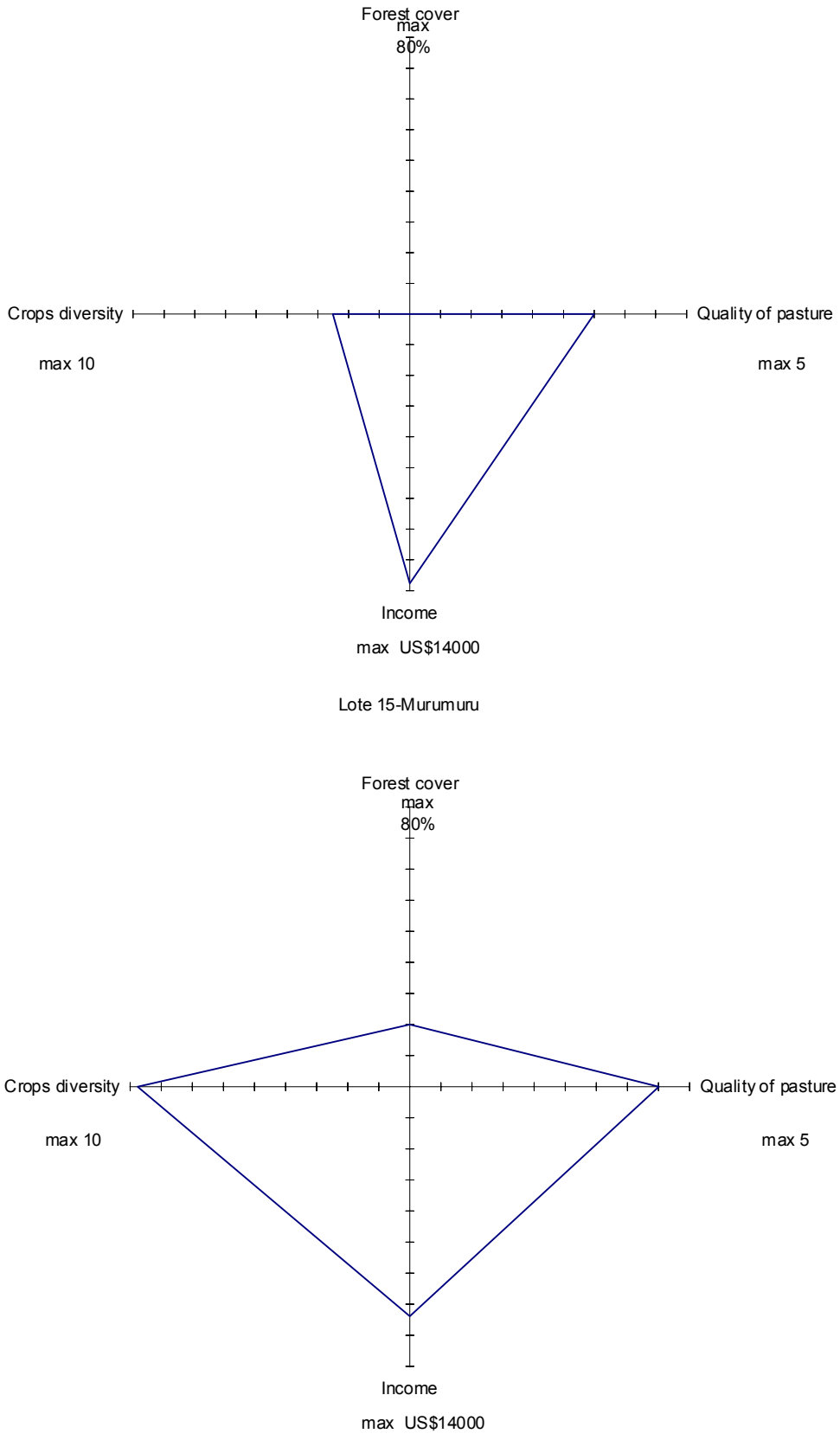


Figure 9.3: Patterns of sustainability of farms in Murumuru

Table 9.2 Locality indicators of sustainability

Indicator	Sustainability objective	Observations
Forest cover	Stabilise	Measure forest cover
Agrodiversity	Increase	Measures the level of diversity of cultivated and non- cultivated plant species and animal species present and used by families
Environment related diseases	Decrease number of cases	Evaluates existence of diseases related to environment and sanitation conditions, specially malaria
Access to markets	Increase	Evaluates access to market considering prices, presence of traders and structures facilitating sales
Access to other services	Increase	Evaluates access to roads, health, shops, electricity and other infra-structure
Institutions working in the area, mainly farmers' organisations	Increase	Evaluates governmental and non-government institutions providing services and support to family well-being and farm production

Contribution of Outputs

Research findings and dissemination of information to farmers by the project team has already had some impacts on livestock production systems. After the mid-term project workshop farmers started to adopt some of the changes proposed. For example, some farmers in Murumuru have built new structures, with cover, to provide mineral salt to the animals. They also reorganised the timing of their vaccination, and have changed the supplier of mineral salt to one who sells better quality products. One farmer decided to significantly reduce the use of fire in his farm.

In Nova Canaã a group of farmers bought vaccines and mineral salt together and negotiated better prices in town. Some of them have given up the common but useless practice of using 'benzeocreol', a disinfectant erroneously applied for the control of worms. They have also adopted a more effective and less expensive product for application to calves' umbilical cords.

At the final workshop farmers and development agents identified their priorities for research and action and which are immediately being implemented. They are:

- **Development of mineral salt adapted to the region.** After work conducted by researchers, farmers' groups will have technical support and will be able buy the ingredients separately and mix them to make up locally-adapted mineral supplements.

- **Experimentation with new forms of pasture management.** This will include control of grazing and stocking rates; use of other forage species, including legumes; and fire management. As adoption of more efficient rotation strategies is considerably enhanced when farmers are able to observe and monitor these activities, the project has already contributed to better management, as most farmers in Murumuru and half of those in Nova Canaã are keeping detailed records of herd events, production, costs and grazing.

Other research and development proposals discussed at the workshop and identified by our current research are presented in Box 2.

The collaboration between ODG at UEA, LASAT from the UFPa and farmers organisations worked very well and brought a number of benefits. The partners involved perceived the need to continue work together in the area. LASAT has been awarded funding from the Para Government for a small project to continue to support the two activities above, and also experiments with 'forage banks', involving the use of separated plots with napier grass and sugar-cane to supplement feeds during the dry season. This project will involve collaboration with development agent partners, mainly the LUMIAR project. So far, the funding will cover this work in two localities.

The research methods and questionnaires were discussed with researchers and lecturers from the University of Para and the methods developed in our project are being adopted by some of them. The research group, LAET, based in Altarmira, is about to start a similar work in Altamira region, another colonist area in Western Para State. This will help to build up data on farming systems and livestock production and allow comparative analysis across a broader area of the Amazonian frontier.

The research has successfully identified sustainability indicators. These were developed in close collaboration with smallholders themselves, building on farmers' own perceptions and knowledge. They are relatively simple to measure and can rapidly inform the sustainability of farms and localities.

Our findings confirm that livestock production is a preferred land use option for smallholders. The better integration of this activity with other land uses, such as forest use and conservation, is dependent on the support colonists can receive. Intensification so far has been a spontaneous process, but it can be facilitated and encouraged if services such as technical assistance and infrastructure are developed. The continuity or future repetition of similar studies in Marabá or other frontier regions would be able to track the progress of pasture and animal production performance indicators, as well as the evolution of farming systems. By doing this it would be possible to confirm whether or not the detected process of intensification is a durable one and if this intensification can really support the stabilisation of frontier farming, as envisaged.

Box 2 Proposals for further research and development

Research:

- Identification of appropriate techniques of weed control, specially for the assa-peixe (*Vernonia brasiliana*)
- Effectiveness of locality adapted strategies for herd improvement with a special emphasis on milk production
- Further investigation of local knowledge and use of local remedies for veterinarian purposes
- Development of simple farm-level and paddock indicators of pasture quality and change appropriate for use by farmers to enhance management of pasture rotations

Development:

- Work with farmers and farmers groups to encourage the adoption of appropriate vaccination calendars
- Production of booklets about animal health
- Better technical support for purchase of high quality pasture seeds
- Training at local level on practices related to livestock management
- Collaboration with farmers on the control of parasites
- Extend action-research strategies on livestock production to other localities in the region.

Dissemination

The following target institutions have been visited, included in workshops and sent relevant publications:

- Centro de Pesquisas da Amazônia Oriental- Empresa Brasileira de Pesquisa Agropecuária (CPATU- EMBRAPA): Forestry, and Livestock Production departaments- Belém, Pará- Brazil
- Universidade Federal do Pará : Núcleo de Estudos Integrados da Agricultura Familiar, Centro Agropecuário; Núcleo de Altos Estudos da Amazônia (NAEA); Centro de Filosofia e Ciências Humanas (CFCH). Belém, Pará- Brazil
- Museu Paraense Emílio Göeldi (MPEG)- Departament of Social Sciences. Belém, Pará- Brazil
- Instituto do Homem e Meio Ambiente da Amazônia (IMAZON). Belém, Pará- Brazil
- Empresa Estadual de Assitência Técnica e Extensão Rural do Pará (EMATER-PA) .Marabá, Pará- Brazil
- Laboratório Agro-ecológico da Transamazônica (LAET). Altamira, Pará- Brazil
- Fundação Agrária do Tocantins Araguaia. Marabá, Pará- Brazil

Publications

a) Scientific publications and presentations

Brown, K. and Muchagata, M. 1998. "Forests and livelihoods of colonist farmers in Eastern Amazonia," in *World Forests, Society and Environment*, vol. 1. Edited by M. Palo and Uusivuori, J., pp. 262-263. Dordrecht: Kluwer Academic Publishers.

Brown, K, and Muchagata, M. 1999. *The evolution of colonist farming systems at the Forest Frontier. Is there hope for sustainable land use in Amazonia*. *NRSP Research Advances no. 7*: DFID, London (Appendix 3)

Grist, N. 1999. *The role of women in colonist settlement in eastern Amazonia*. ODG Research Working Paper, University of East Anglia (Appendix 5)

Grist, N. and Rendeiro, W. (in preparation) *Gender in Colonist Settlement in Eastern Amazonia: the shifting roles of men, women and children in response to the dynamics of colonist farming systems and the family life cycle.*

Machado, R. C., Muchagata, M.G. and Silva, W. R.1998. Pecuária Leiteira na Região de Marabá: Perspectivas para o estabelecimento de uma produção familiar sustentável numa região de fronteira antiga in *Produção Leiteira na Amazônia Oriental: situação atual e perspectivas*. EMBRAPA and Universidade Federal do Pará, 26 a 27 de Agosto de 1998, Belém (Appendix 2) (in Portuguese)

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 (Appendix 9)

Muchagata, M., 1998. *Livestock Production and Sustainability on an Amazonian Frontier: Farmers' Views*, Natural Resources Research Group, University of East Anglia, October 1998

Muchagata, M.G, and Amaral, M., 1998. Tem barulho na mata. Perspectivas para manejo comunitário de florestas em uma região de fronteira in *Métodos e Experiências de Pesquisa-Formação-Desenvolvimento em Agricultura Familiar.* NEAF-CAP-UFPa: Belém (in Portuguese)

Muchagata, M.G. and Brown, K. 1997. *Smallholders Farming Systems in Amazonia: Livestock Production and Sustainability. A Literature Review, Research Framework and Annotated Bibliography.* University of East Anglia, ODG.Mimeo (Appendix 8).

Muchagata, M. and Brown, K. 1999. Colonists perceptions of fertility and the frontier environment: Opportunities for the development of more sustainable farming systems in Amazonian frontier regions. To be submitted to *Agriculture and Human Values* (Appendix 6)

Muchagata, M. and Brown, K. 1999. Cows, colonists and trees. Rethinking the role of cattle on environmental degradation in Brazilian Amazonia. *To be submitted to Agricultural Systems* (Appendix 1)

Muchagata, M. G., de Reynal, V., Figueiredo, R. B. 1998. Perspectivas e potencial econômico da agricultura familiar numa região de fronteira amazônica: o caso da região de Marabá in *Simposio Internacional Amazonia XXI. Agenda e Estratégias de Sustentabilidade*.NAEA-UFPa: Belém (Appendix 4) (in Portuguese)

Rendeiro, W. (in preparation) *Agricultura Familiar e Gênero Participação da mulher nas diferentes fases dos sistemas de Produção em três localidades no Sudeste do Pará* (in Portuguese)

Salgado, I., Muchagata, M.G. and Amaral, M. 1999/on press. Manejo Florestal y Manejo Florestal Comunitario. Perspectivas y limites para la Conservacion Productiva de Recursos Madereros en la Amazonia Brasilena. *Ciencias Ambientales* Vol 16. (in Spanish)

b) For Farmers

Muchagata, M. Rendeiro, W. and Machado, R. 1999. *Sustentatabilidade da Atividade Pecuária. Relatório do Encontro entre Agricultores e Pesquisadores para Discussão dos Resultados de Pesquisa*. March 1999 (Annex 7) (in Portuguese)

A poster in Portuguese is in preparation.

All farmers taking part in monitoring received folders with summaries of all the information collected at their farms

c) General Public

A poster in English in under preparation

M. Muchagata interview with *Correio do Tocantins* (Regional Newspaper) on Forest Conservation and Management in Maraba region-June 1997

M. Muchagata interview with the *Jornal Nacional* - *Globo TV* on Social and Ecological causes and consequences of Burns in Eastern Amazonia- August 1997

M. Muchagata interview with the *Gazeta Mercatil* (National Newspaper) about Sustainability of Farming Systems and Farmers' groups initiatives in Eastern Amazonia. November 1997

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