SOIL FERTILITY AND BIOMASS FLOW MANAGEMENT PRACTICES BY SMALLHOLDERS IN THE AGRESTE REGION OF PARAIBA (BRAZIL)

Eric Sabourin, Jean Philippe Tonneau, Luciano Marçal da Silveira; Pablo Sidersky

Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CIRAD Tera - BP 5035 - 34 032 Montpellier Cedex - France

Tel/fax 33 4 67 61 57 60
E-mail: eric.sabourin@cirad.fr -

Correspondance: Cirad tera, 73, Rue JF Breton 34 398 Montpellier Cedex 5 , France

Abstract:

This paper presents the main results from an appraisal of biomass flows and soil fertility management practices used by smallholders in the Agreste region of Paraíba (Brazil). The study was conducted in different agro-ecological conditions in the municipalities of Remígio and Solânea. The participative appraisal of fertility management is based on the development of a model of biomass flows at a farm level. The validation of this model meant that it was possible to construct a common representation of biomass management, which enabled real dialogue between researchers, technicians and smallholders. Diagnostic conclusions have evidenced a competition between livestock intensification process and soils conservation. As a result of this study, technicians have reviewed their approach to soil fertility management.

Key words: family agriculture, soil fertility management, biomass flows, mixed farming, Brazil.

Introduction

The study of soil fertility management is part of the AS-PTA programme (Support and Services for Alternative Agricultural Projects) to support sustainable family agriculture in the Agreste region of Paraíba State. The project was carried out in partnership with farmer organizations from the Solânea and Remígio municipalities (Map 1). This paper describes the results of the study and how it was presented to farmers. It is divided into three parts: background and methodology; soil fertility management practices and the conditions for their implementation; development and validation of a model of organic matter flows on a farm level.

1. Background

1.1. The region and the farming systems

In Nordeste, the Agreste region is known for its diverse agro-ecological conditions (Andrade,1980). Average rainfall in the eastern part of the Remígio and Solânea districts is around 1000 mm/year, whereas 40 km to the west it is 400 mm/year. This gradient is reflected by the range of natural vegetation and farming practices in the region.

The region was classified into different agro-ecological zones based on the appraisals of its farming systems. There are three main landscape units: Brejo, Agreste and Curimataú. Each area is made up of different agro-ecological zones whose rainfall, soils, relief and farming systems differ (Map 1). Brejo is situated in the east at a higher altitude. It was formerly a sugarcane-producing area, but sugarcane has now been replaced by fruit (bananas, mangoes, etc.), beans (*Phaseolus vulgaris* and *Vigna unguiculata*), yam (*Dioscorrea sp.),*

cassava (*Manilhot esculenta*) and livestock production. Agreste is an area of traditional mixed cropping, the choice of which depends on soil type. Crops include maize (*Zea mais*), beans, cassava and field beans (*Phaseolus lunatus*) or potatoes (*Solanum tuberosum*) which are grown in association with aniseed *(Foeniculum vulgare*), the two most recent commercial crops in the region. Curimataú is a semiarid region where livestock production predominates. Mixed cropping of maize and beans is also common. Most small farms and the majority of the population are concentrated in Brejo and Agreste.

The importance of family agriculture in the two districts is confirmed by data on land ownership which shows that 77% of farms are smaller than 5 ha. Farms of less than 10 ha (90% of holdings) only represent 30% of total farm land, whereas holdings of more than 200 ha represent over 50% of land (FIBGE, 1986).

All of the family farming systems are based on mixed cropping and livestock production. For years, production has been partially or completely market-oriented with a succession of cash crop cycles (tobacco, cotton, sisal, castor beans, potatoes, aniseed, etc.). Although six production subsystems were identified, the landscape is dominated by annual crops, pasture and orchards. Virtually all smallholder families raise a few animals, which are generally tethered. Cattle production is the most common form of livestock production. The proportion of small ruminants is higher in areas with less rainfall.

The producer typology indicates that the majority of producers are either "*roçado* cultivators" or "landless". The next most important categories are "mixed farmers" and "specialist farmers" (fruits and potatoes) (AS-PTA, 1997).

1.2. An appraisal of soil fertility

The aim of the participatory appraisal of soil fertility management was threefold:

- analyse the soil fertility management practices in order to understand how farmers manage their production systems (rationale and strategies);
- evaluate proposals that have already been tested or diffused;
- encourage farmers to consider and discuss their soil fertility management practices with the help of the (graphic) representation.

The action-research methodology involved the following five steps:

- the description of the different practices used by farmers to manage biomass flows and the factors that influence them (Pieri, 1989; Dugue, 1998);
- the identification and analysis of farmers' rationale and strategies for adopting particular practices in the different farming systems;
- the presentation of the results to the farmers based on the graphic representation of biomass flows; the validation of the model of organic matter management;
- the collective evaluation -in consultation with the farmers- of the innovations currently being tested or diffused (in terms of their effectiveness and relevance);
- the programming of new research, experimental and development activities.

2. Smallholders biomass management practices

On a farm level, soil fertility management can be described by the flow of biomass between different areas or centres that produce, import or export organic matter. The model is based on these areas and flows which are used to construct a systematic and graphic representation of soil fertility management practices.

2.1. The areas involved in soil fertility management

Several areas can be distinguished: areas where biomass is concentrated (the house, storage areas, cattle pen (*curral*) and the orchard (*quintal)*; areas that export fertility (cultivated fields or *roçados*, grassland and self sown plants); fertilized areas.

2.1.1. Areas where biomass is concentrated

- *The house and the* orchard (quintal):

It is common to find several fruit trees, a vegetable patch, a few hens and even a small pigsty near the house. This area is called the *quintal*. The importance of the fruit trees determines how the *quintal* is organized and how dense it is. Heaps of organic residues known as *monturo* are piled in this area. The quintal is the area used for the most demanding crops in term of fertility (maize, yam, vegetables). In the wetter parts of Brejo, the *quintal* is made up of small plots of different crops: vegetables and fruit, maize and medicinal plants which are sometimes associated with a small cultivated wood or *matinha*.

- The cattle pen or *curral* is an ideal area for collecting organic matter. In the three agro-ecological zones, the *curral* is gradually being developed**,** - with addition of a feeding trough, rack (*cocheira*) and roof (*galpão*) - to make a proper stable. The use of a *curral* reduces food waste and concentrates the residues, excrement and straw that are used for manure.

2.1.2. Areas that export fertility

- The traditional cultivated areas (*roçado*)

The *roçados* are the plots that are cultivated each year. In a traditional *roçado*, several crops - maize, beans, field beans and cassava- are grown together. These areas generally export fertility via the production of crops, eg cereals, tubers and straw. The only regular means of returning fertility to the soil is by grazing livestock after the harvest and ploughing in weeds and crop residues that are left in the field. When livestock graze these plots, most of the biomass that they consume is not returned. Therefore, there is a progressive loss in fertility which can limit the plots' productive potential. The amount of fertility loss varies. For example, it is less pronounced in Curimataú where the soils are naturally more fertile (Leprun & Silva, 1995).

- Fodder crops

Fodder crops, which were only recently introduced, are managed in much the same way as other *roçado* crops. Organic manure is sometimes applied to fodder crops, such as forage cactus (*Opuntia sp*.) and napier grass (*Pennisetum purpureum*). Napier grass is generally

grown on small plots in lowland areas because it can be grown in places prone to flooding or even saline conditions. It is extremely productive giving high yields of biomass.

Plots of spineless cactus (*Opuntia sp.*) provide an unusual example of pluriannual cropping. *Opuntia* is always fenced off from livestock. Farmers have started associating plantations of *Opuntia* with perennial legumes (gliricidia, leucaena, pigeon pea) and planting trees and local cacti in the enclosures.

- Grassland

The term *pasto* refers to natural grassland, grass leys (*Bracchiaria sp.* and pangola grass/*Digitaria decumbens*) and areas where natural vegetation has regrown, known as *capoeira*. Herds move between the different areas on and outside the farm[1]. However, the owner of even a small herd always sets aside an area specifically for grazing. This is essential during the rainy season so that animals can be enclosed and fed while the rest of the land is used for crop production. This area used to merge with fallow land and the areas recolonized by natural vegetation that were periodically cleared and cropped. Now, the small size of farms has meant that fallow and natural and even secondary vegetation have disappeared.

2.1.3 Fertilized areas

The traditional practice of leaving land fallow as a way of improving the fertility of cultivated soils has disappeared. On the largest farms (over 30 ha), the oldest *capoeiras* (15-20 years) can sometimes appear to be vestiges of fallow. However, they are managed like grasslands or forage areas. Soil impoverishment as a result of farm intensification has already

[1] After harvest all the local herds have access to the cultivated plots which are otherwise fenced off.

forced a number of farmers to take action to improve the fertility of their *roçados*. The plots where cash crops (potatoes, yam, banana and vegetables) are grown, receive the biggest applications of organic matter (manure from the *curral* or bought-in) or mineral fertilizer (potatoes and vegetables). The same practices *are used for* plots of spineless cactus and napier grass.

2.2. Management practices used for biomass flows

There are numerous types of biomass and diverse management practices. Biomass can include crop products and residues (fruits, cereals, tubers, straw and chaff), natural grassland and grass leys, self sown vegetation, trees and shrubs. The biomass produced is initially used by the farmer (harvest, fodder) or the livestock. We can differentiate between practices that return biomass to the soil and those that concentrate it.

2.2.1. Returning biomass to cultivated plots

This practice involves returning biomass in-situ, either directly or by grazing animals on the harvest residues. At the start of the rainy season, when the soil is being cultivated, the most woody weeds are pulled up and heaped at the edge of the field so that they can be incorporated the following year. This practice is due to the fact that the woody material is difficult to incorporate and hinders the transit of draught cultivators. Potato farmers clear the land more rigorously. In fact, the high C:N ratio of plant residues at the end of the dry season exacerbates the immobilisation of available nitrogen due to soil micro-organisms (Tiessen et al., 1998).

In the dry season, the *roçado* is used for grazing, except for the plots down to cassava and aniseed/potatoes. Available fodder includes the herbaceous layer (adventitious) and remaining crop residues, particularly dry maize leaves and canes and bean stalks.

Soil fertility can also be replenished by applying manure produced on-farm. In areas of high rainfall, manure is usually spread every 2-3 years on crops of yam, bananas and crops grown in association with cassava. There have also been reports of manure applications to napier grass and spineless cactus. Potato farmers apply manure and also buy in artificial fertilizer. They apply 15-20 t/ha/year of manure and a small amount of nitrogen (urea, ammonium sulphate) to each plant (50-100 kg/ha).

2.2.2. *Concentration practices*

This practice corresponds to the movements that concentrate biomass in the areas next to the house (cattle pen and stocks of fodder), which involves transporting the material from the fields, the grassland and the *capoeira.* Some residues are transported with the harvested crop (*Phaseolus* haulms and leaves, *Vigna* and field bean pods, straw and chaff of maize cobs).

In the dry season, fodder is systematically fed to the animals which are either penned or kept in an enclosed pasture. Cob husks, cob silk and maize straw are stored in the same way as bean haulms and chaff. The maize stalks remain in the field after harvest. They can be left for the livestock to graze. Otherwise they are harvested and stored under a tree or near the house. Sweet potato haulms, cassava leaves, cassava stalks and banana trunks are fed to livestock while they are still green. These residues are the main source of complementary food for livestock in the Brejo areas where they are fed after the harvest. However, in Curimataú and Agreste, crop residues are systematically stored for the dry season. These

practices are a step towards the intensification of livestock production. They mark the integration of crop and livestock production.

In the wet areas (Brejo), green fodder comes from more diverse sources. For example, Gramineae can be sown in the lowlands (napier and *bracchiaria*) and on the edge of plots, cut from the verge or supplied by the neighbours. Grazing animals on land owned by a third party, combined with penning them at night, contributes to both the import and concentration of biomass. In the dryer areas, local plants from the *capoeiras* and the spineless cactus are used, above all.

3. The construction and validation of the biomass management model

3.1. The model's components

The representation of biomass flows was based on a series of observations made on ten farms in the three agro-ecological zones. It is organized around the different spaces and biomass flows (Silveira et al., 1999). The spaces are symbolized in terms of generic category in order to simplify the representation: house, cultivated field, orchard, cattle pen, grasslands, forage store... (Figure 1). The model is built around three main types of biomass flow (exports, transfers, imports), the combination of which determines the centres of loss, accumulation or maintenance of soil fertility[2].

3.1.1. Exports

[2] In Figure 1, the flows are indicated by coloured arrows that correspond to different types of biomass: blue = crops (cereals and tubers); green = fodder and straw (dotted = occasional flow); brown = manure (& artificial fertilizer).

The main exports from the cultivated land (*roçados* and *quintal*) come from crops that are for subsistence or sale. The flows are concentrated towards the house and then the market. The export of biomass from grassland mainly results from the removal of animals. Some biomass is returned in situ (excrement recycling, represented by the cycle of bicoloured arrows). In Curimataú, manure is sometimes sold.

3.1.2. Transfers

Biomass is removed from cultivated or grazed land in the form of straw, crop residues and diverse types of fodder. In reality, it is transferred to the animals. These transfers are partially recovered by recycling excrement or applying manure, depending on how the herds are managed. Manure is generally used to fertilize cultivated land. Straw and crop residues heaped in the fields or near the house are generally for animal consumption. The same applies to the weeds that grow in the fields after harvest.

Most biomass is returned to the soil in the form of applications of dry manure (powder) or crop residues. The priority areas are the *quintal* (vegetables and fruit trees), which is generally near the *curral*, and some fields, particularly where potatoes, yam and cassava are grown and, ultimately, plots of napier grass and spineless cactus. In the case of grassland, biomass recycling in the form of animal waste is limited, except in the case of fenced night paddocks where animals are given supplementary feeding in the dry season.

3.1.3. Imports

- *Fodder imports* can be divided into four groups:

- livestock are grazed off the farm (fields owned by a third party, common land, verges) and return to the *curral* at night;

- fodder (Gramineae, cacti, crop residues) is harvested outside the farm to feed livestock in the dry season;

- rented or borrowed land is cropped outside the property;

- purchase of fodder (spineless cactus, sorghum) or even concentrates;

- *Bought-in manure* is another form of importing fertility. This practice is still limited to potatoes or market garden crops.

There are diverse practices. The challenge is to find a way of classifying different types of fertility management depending on the agro-ecological zone, farm size, the farming system and the type of farmer. The model of biomass flows was built to represent these practices systematically so they could be analysed.

3.2. Soil fertility management and farmer strategies

The farmers discussed and validated the model. Six types of soil fertility management were identified with several local variations. They can be distinguished by the degree of complexity and intensification of both crop and livestock production (Table 1). Farm management practices seem, primarily, to be geared towards the intensification of livestock and crop production; the role of soil fertility seems to be secondary. The basic and simplest form is comprised of the house and one (or two) cultivated fields. As the model evolves, other areas and factors come into play, with increasingly complex combinations of flows which

correspond to different degrees of intensification. The main factors involved in these evolutions are: (1) the presence of the orchard (*quintal)*, (2) livestock, (3), grassland (4) introduction of a cattle pen (followed by a feeding trough and shelter), (5) fodder storage (6) applications of manure and, lastly, (7) the purchase of manure and artificial fertilizer.

The farmers' observations confirm that there is a strong link between the main features of the model and smallholders' strategies. These strategies are largely determined by land and labour availability*,* agro-ecological conditions, the intensification of livestock production and the role of cash crops.

3.2.1. Land and labour availability

The relationship between the size of a smallholding and soil fertility management depends, above all, on the potential to restore fertility in some areas (cultivated fields as well as grassland). When size allows, fallow can still be practised. Land availability depends on the farmer's circumstances at the start of his career (inheritance, initial endowment).

Land availability is also linked to soil diversity and quality which, in turn, determines the degree to which farmers can specialize.

Farmers often set up with a limited amount of land and a few animals. In general, the aim is to develop crop production by increasing the amount of cultivated land. The size of the cropping area is directly linked to labour availability (the number of children, their age and how they help on the farm). The problems of mobilizing a labour force are determining factors for productive capacity and biomass management. In other words, they determine the area cultivated, volumes of produce, type of livestock and how much fodder or manure is stored or transported. The availability of labour is a problem on most farms. It can be linked to the farmer's life cycle. The labour force depends on how much energy the farmer and his wife have. It also depends on the presence of neighbours and mutual help (*mutirão*) or the exchange of days of work as well as on

the potential to employ a worker (temporarily or full-time).

Table 1: **Types of soil fertility management model in Agreste-Paraíba**

Type	**Characteristics**	**Sub-groups**	**Elements**
0	The simplest basic model		House + cultivated fields or *roçado*, very rare
1	Typical smallholding found in Brejo do Roçado de Solânea: presence of an orchard or ***quintal***		House, field, and ***quintal***. Export from *roçado* and limited transfer to the house and *quintal*.
2	Livestock present (farms with small herds, no grassland)	2a	House, field, *quintal* and **livestock**. Animals tethered and/or grazed off-farm.
	Livestock with **grassland** (*pasto*)	2b	House, field, *quintal*, **livestock and grassland**.
3	Typical model in Brejo do Gravatá,Remígio: including ***cattle pen*** (*curral*)	3a	House, field, *quintal,* livestock, grassland and ***cattle pen*** (***curral)***. - Import of fodder from outside the farm - Manure applications to some cultivated fields (yam)
	Ditto 3a, with a **napier grass** plot (*capineira*)	3b	House, field, *quintal,* livestock, grassland, cattle pen and **napier grass** plot (*capineira*)
4	Introduction of **fodder storage** (Gravatá -Remígio)	4a	House, field, *quintal*, livestock, grassland, cattle pen and **fodder storage** (often with fodder imports from outside)
	Ditto with a **napier grass** plot (***capineira***).	4b	House, field, q*uintal*, livestock, grassland, cattle pen, **fodder storage**, and **napier grass** plot (***capineira)***
5	**Model commonly found in Curimataú: cattle pen and straw storage but no** *quintal*		House, field, livestock, cattle pen, grassland, *capoeira*, fodder storage, land cultivated outside the property. Little manure is applied on-farm; some cases of manure sale.
6	**Typical model in Agreste da Batatinha: with more intensive potato production.** Manure bought in	6a	House, field for beans, field for potatoes, livestock, cattle pen, fodder storage. *Quintal* are rare. Fodder imported and manure bought in for the potato crop.
	Ditto with purchase of artificial fertilizer	6b	Ditto + artificial fertilizer

Lastly, the strategy adopted by a farmer at the end of his career depends on the future succession. Elderly farmers on their own only maintain soil fertility on a certain part of the farm (*quintal* or *curral*) or adopt a more extensive system. They may even abandon any attempt to restore fertility through lack of strength, resources or interest. The continuation of

family farms is largely dependent on land accumulation. In general, when land is equally divided between the descendants, there is not enough of it to ensure that each descendant can take over a viable production unit. Thus, each generation has to start a new accumulation cycle, which depends on different conditions (market crisis, diseases, drought) and on the opportunities for diversification. The decision to diversify is voluntary and thought out. In contrast, production crises are unexpected and depend, above all, on external factors: agro-ecological (pests such as *Anthonum grandis* which attacks cotton) or economic factors (drop in sisal prices, competition with potatoes from the south) (Sabourin et al., 1999).

3.2.2. Agro-ecological and geographical diversity

This diversity is due to the decreasing rainfall gradient between Brejo and semi-arid Curimataú. The drought has exacerbated the problem of whether the small amount of available biomass should be used for animal feed or returned directly to the soil. In Brejo, there are few fodder crops other than natural grassland and plots of napier. Storage facilities are almost nonexistent. In Agreste, little is done to improve soil fertility because traditional crops (maize, beans and cassava) are unprofitable. In Agreste and Brejo, where soils are less fertile than in Curimataú, we have already observed applications of manure and incorporation of crop residues and weeds, which could also be fed to livestock.

3.2.3. Diverse but increasingly intensive livestock production

Livestock production is becoming more intensive in all three zones. However, intensification is more marked in Curimataú and the driest parts of Agreste de Remígio where cash crops have not been grown since the cotton crisis.

This is demonstrated by the fact that increasing efforts are being made in terms of animal feed:

- use of grassland, *capoeiras*, crop residues, on and off-farm;
- livestock are tethered to graze (smallholdings of less than 5 ha in Agreste and Brejo);
- harvest of fodder off-farm during the dry season (verges, crop residues);
- fencing grassland (sometimes after the establishment of a grass ley);
- introduction of fodder crops (spineless cactus, sorghum, pigeon pea, napier) grass;
- livestock fed in cattle pen or enclosure;
- construction of cattle pens, feeding troughs and manure stalls;
- build up of fodder storage, first in the cultivated plots and then close to the cattle pen.

The intensification of livestock production offers new possibilities in terms of soil fertility management. However, it uses the same areas and resources as crop intensification. Therefore, livestock and crop production are not just complementary, they are in direct competition for biomass. As Landais and Lhoste (1990) suggest, the presence of cattle pens or manure stables does not always guarantee that manure will be used. This is the case in Agreste de la Paraíba where few farmers have access to a cart or sufficient labour to transport and spread manure. In addition, the aim of intensifying livestock production, unlike more intensive crop production, is not simply to increase productivity and production levels. In the region land is scarce and expensive, livestock production can be a means of saving.

3.2.4. Determination linked to cash crops

The importance of manuring is more obvious when profitable crops are grown (yam, potato, banana). The possibility of obtaining access to credit or a market has encouraged potato

farmers and market gardeners in Remígio to risk buying in several lorry loads of manure each year ($300-500/ha). The alternative of green manure (*crotalaria*) is less expensive but hard to fit into the crop calendar, particularly in dry years. It is also difficult to incorporate using animal traction which is limited to one ox. A number of farmers in the Gravatá de Remígio region buy enough manure each year for a third of their cultivated land. However, when no cash crops are grown, manure use is limited, as in Curimataú where it is even sold.

3.3. The dynamic and diverse evolution of soil fertility management

3.3.1. Diversity and mobility

One important lesson to be drawn from this appraisal is the fact that soil fertility management systems are diverse and relatively unstable. The status of different cultivated areas, with the exception of the *quintal* when it is planted up with trees, is never definitive and can change in a generation. This does not mean that there is nothing but loss of soil fertility, soil depletion or environmental degradation, as claimed by some alarmist publications that suggest that 70% of land in Paraíba is affected by desertification. As we have seen, there are practices, some of which are ancient, that maintain and restore soil fertility. The process involved in the intensification of livestock and crop production is proof enough. In order to understand how fertility flows are managed, we must look beyond the confines of the farm, which can be limited in different ways (farm spread over several sites, family-owned land dispersed, access to common land) (Landais and Lhoste, 1990). The management of livestock feeding during the dry season is marked by the community's solidarity which is very strong during prolonged droughts. Even when there is no common land, farmers open gates and take down fences so that their neighbours' herds can graze the stubble of cultivated fields after harvest. Land use (the organization of space) is not simply set according to soil quality and a

specific function. Farmers have priorities (needs and strategies) which determine the status of fields and how their fertility is managed.

The transfers and mobility of fertility on a farm, in an area or even a small region (valley, catchment area) should be identified. This is important for constructing a more complete and integrated representation that takes into account these different factors and their corresponding productive areas and subsystems. A representation of this kind offers an alternative point of view and new possibilities for action that deal with the competition between the association of crop and livestock production and the role and limitations of fodder break crops (Landais and Lhoste, 1990).

3.3.2. Farmers are increasingly aware of the importance of fertilization

The study confirmed the fact that farmers are aware of the importance of improving fertility and accumulating biomass. Applying manure to crops that respond directly to fertilizer is one example. However, apart from the areas that are always cultivated (*quintal*, bananas and potatoes), these fertility transfers are often arbitrary adjustments as opposed to part of a rational management plan. In fact, different areas are not always used for the same purposes and the practice of using a fodder break crop has only recently been introduced. The transition from simple adjustments to organized fertility transfers constitutes a qualitative leap which is part of the intensification process.

3.3.3. New demands and propositions

When the results of this study were presented to the farmers, new propositions were suggested for trials or study. Earlier proposals were modified with emphasis on

improved integration between crop production, livestock and soil conservation. The sloping perpendicular ridges are justified by draught farming and the incorporation of manure. The contours are associated with bands of *vetiver* or tree-covered alleys (gliricidia, leucaena, pigeon peas) which provide fodder or wood. It goes without saying that leguminous trees are planted in the alleys and small woods. The fact that labour is limited rules out any labour intensive propositions whose sole purpose is to conserve the soil without providing fodder, income or a rapid return in terms of fertility (gliricidia).

Lastly, the appraisal led to the identification of new research, including the impact of wooded alleys in terms of biomass production and fertilization of the soil, mixed crop trials, the role of trees and manure management. Proposals were put forward for a range of research and action projects that concern small regions and types of farmer because of the specificities of the agro-ecological zones and farmers' individual situations.

Conclusion

The exercise was extremely informative for the Paraíba project. The farmers were able to clearly identify the soils that were impoverished and the difficulties of restoring fertility. They attribute these problems to the fact that the same crops are grown on the same plots year after year and to the abandon of the systematic practice of fallow. They claim that there is little alternative in terms of cash crop or credit (for mixed cropping), the two options which mean that manure or artificial fertilizer can be bought. The lack of available labour and the priority given to the intensification of fodder production are constant problems.

The study provided the opportunity to review innovations that had already been tested. Several hypothesis were confirmed but new questions were raised. Using an integrated whole-farm approach to organic matter management meant that a qualitative leap could be

made in terms of the representation and management of soil fertility. This demonstrated the importance of examining the situation on different levels (regions, valley and catchment area).

Manure management has only recently become a problem. However, it is common to all the regions apart from Agreste which has experienced problems in the past. In fact, the lack of labour and water appear to be the two factors that limit the management and decomposition of organic matter. The attempt to diversify by reintroducing yam, fruit trees and mixed cropping with forage cactus, have encouraged the use of manure produced on-farm.

Farmers were quick to understand the flow model which meant that it was possible to discuss the issue with local groups. Research into alternatives reinforces the idea that a more integrated whole-farm approach to soil fertility is needed that highlights the problems of complementarity and competition that exist between the intensification of crop and livestock production.

Priority was given to proposals that include a fodder element because of the importance of intensifying livestock production. Previous recommendations suggested that biomass should be incorporated directly, whereas, this practice is only carried out when the vegetation cannot be used for fodder. Given that biomass with a forage value is fed to livestock systematically, proposals for restoring soil fertility should be based on:

- increasing the overall production of biomass on the farm;
- optimising the use of manure and crop residues on the cultivated areas.

This presupposes that the proposals to improve soil fertility on the whole farm and not just the cultivated plots should be developed, eg fertilising grass leys and fodder crops (spineless cactus), planting or maintaining hedges, wooded alleys and small woods. A

proposal to plant trees on different parts of the farm might be worth investigating because some tree species are valuable to farmers.

This appraisal suggested new subjects for research. Work is now underway to quantify biomass flows, assess the fertility of individual plots and assess fodder flows. The strategies and options for intensification, estimated family incomes and manure and crop residue management need to be specified so that new trials can be formulated and farmers can be given advice on the alternatives for intensification and investments.

Bibliography

Andrade, M. C. de, 1980. A Terra e o Homem do Nordeste, Hucitec, São Paulo, Brazil

AS-PTA, 1997. Agricultores Familiares do Agreste Paraibano. O caso dos municípios de Solânea e Remígio, AS-PTA, Solânea-PB, Brazil, 28p.

Dugue, P. 1998. Flux de biomasse et gestion de la fertilité à l'échelle des terroirs. Nord Cameroun. CIRAD, Montpellier, France, document Cirad-Tera n° 29/98, 68p

FIBGE. 1986 Censo Agropecuário, 1985, Fundação IBGE, Rio de Janeiro, Brazil.

Landais, E.; Lhoste, P. 1990. L'association agriculture-élevage en Afrique intertropicale: un mythe techniciste confronté aux réalités du terrain in: Societés Pastorales et Développement Bernus E. et Pouillon, F. (Ed.) *Cahiers des Sciences Humaines* , 26, (1-2), 217-235, ORSTOM Editions, Paris.

Leprun, J.C. ; Silva, F.B. 1995. Les dégradations des sols en régions semi-arides au Brésil et en Afrique de l'Ouest :comparaison et conséquences. Suggestions sur leurs réhabilitation respectives. In : Pontanier R et al., (Eds) L'homme peut-il refaire ce qu'il a défait ? John Libbey Eurotex, Paris, 267-291

Pieri, C. 1989. Fertilité des terres de savanes.Ministère de la Coopération, Paris, France, 445p.

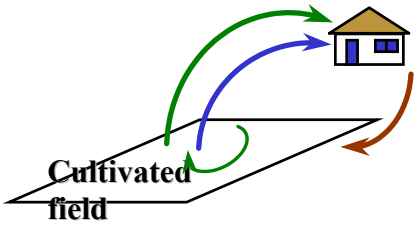
Sabourin, E; Silveira, L. M. da; Tonneau, J.P.; Sidersky, P. 1999. Gestão da fertilidade em unidades familiares do Agreste da Paraíba. AS-PTA, CIRAD, Recife, 40p.

Silveira, L.M.; Tiessen, H.; Tonneau, J.P. 1999. Organic matter management in family agriculture of semiarid Paraiba, Brazil. In: International Symposium "Organic Matter and Soil Nutrient Cycling", Bonn, 10p.

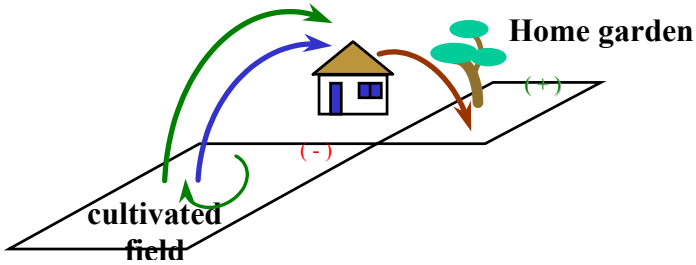
Tiessen, H.; Feller, C.; Sampaio, E.V.S.B.; Garin, P. 1998. Carbon sequestration and turnover in semiarid savannas and dry forest. *Climatic Change*, 40, 105-117

Figure 2: **Model for fertility management**

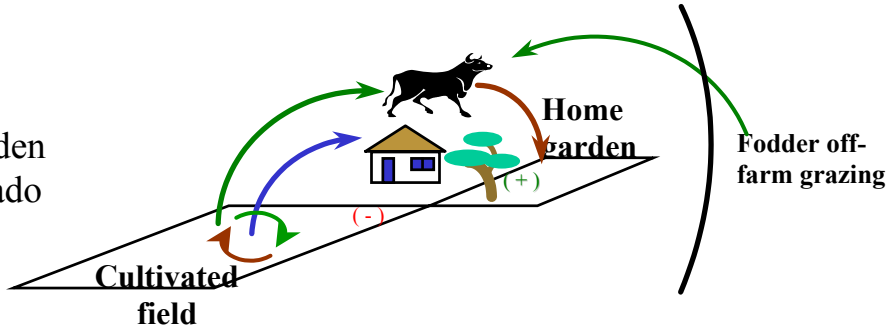
Basic model:
Cultivated field
(*roçado)*



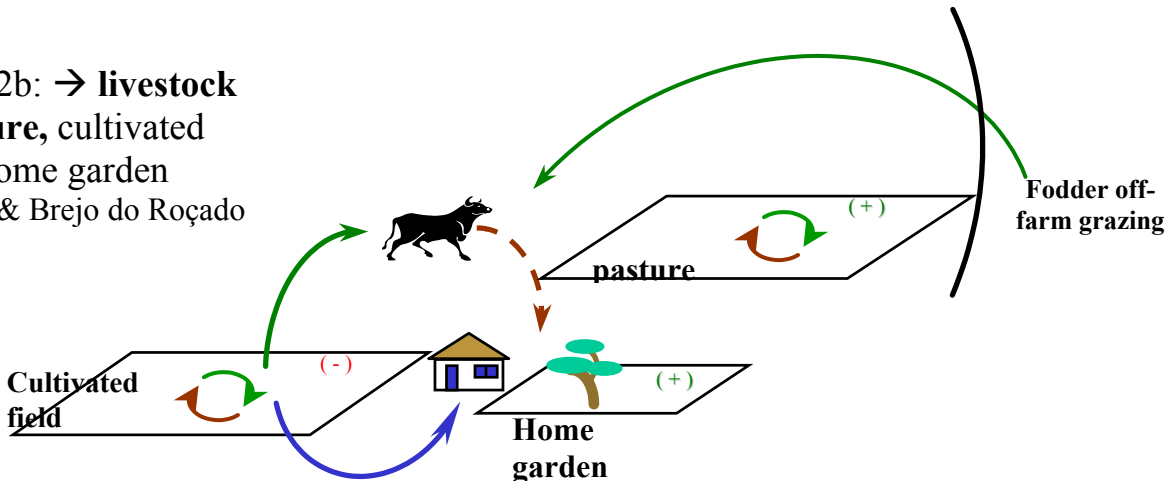
Model 1: **home garden**
(*quintal)* Cultivated
field without livestock
Brejo do Roçado



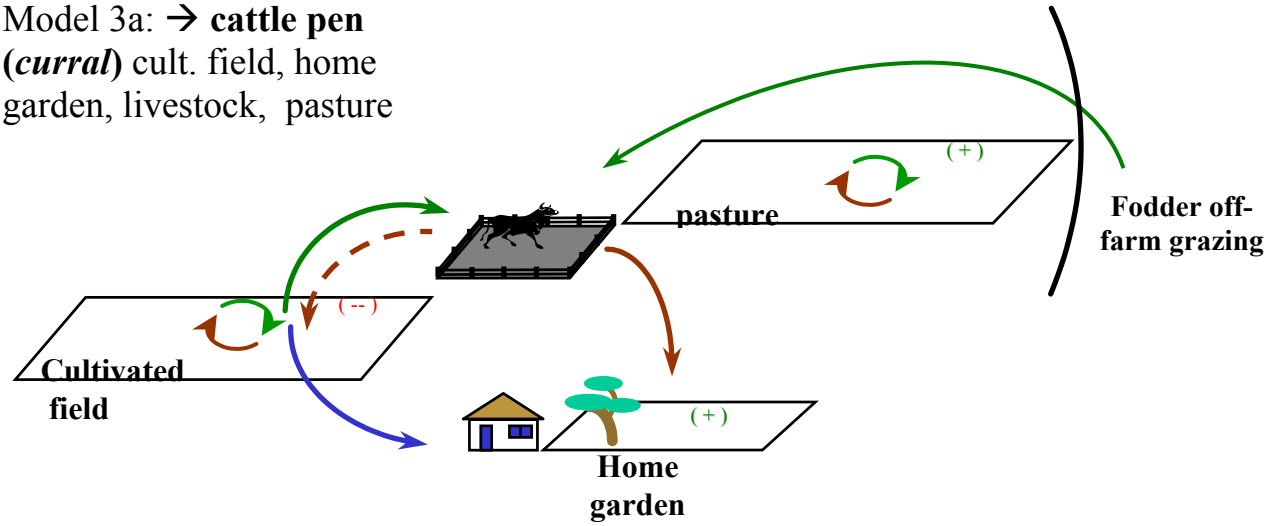
Model 2a: → **livestock**
Cultivated field, home garden
Brejo and Agreste do Roçado



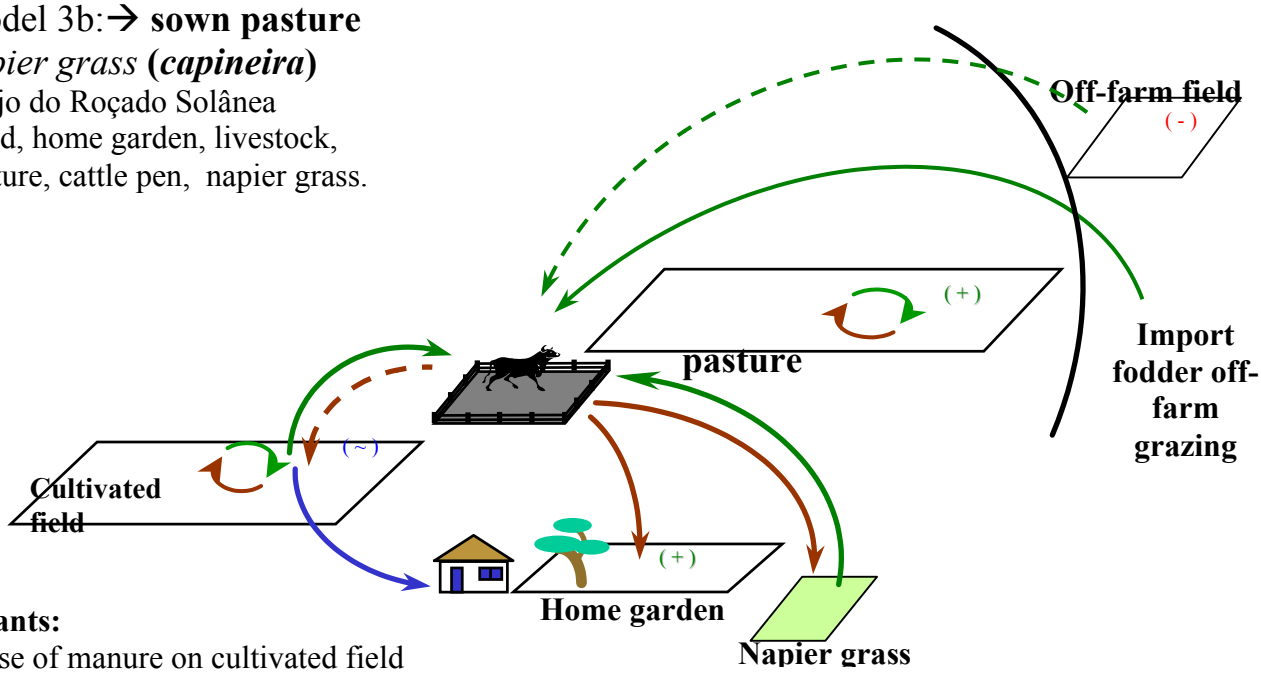
Model 2b: → **livestock**
+ **pasture,** cultivated
field, home garden
Agreste & Brejo do Roçado



Model 3a: → **cattle pen (*curral*)** cult. field, home garden, livestock, pasture

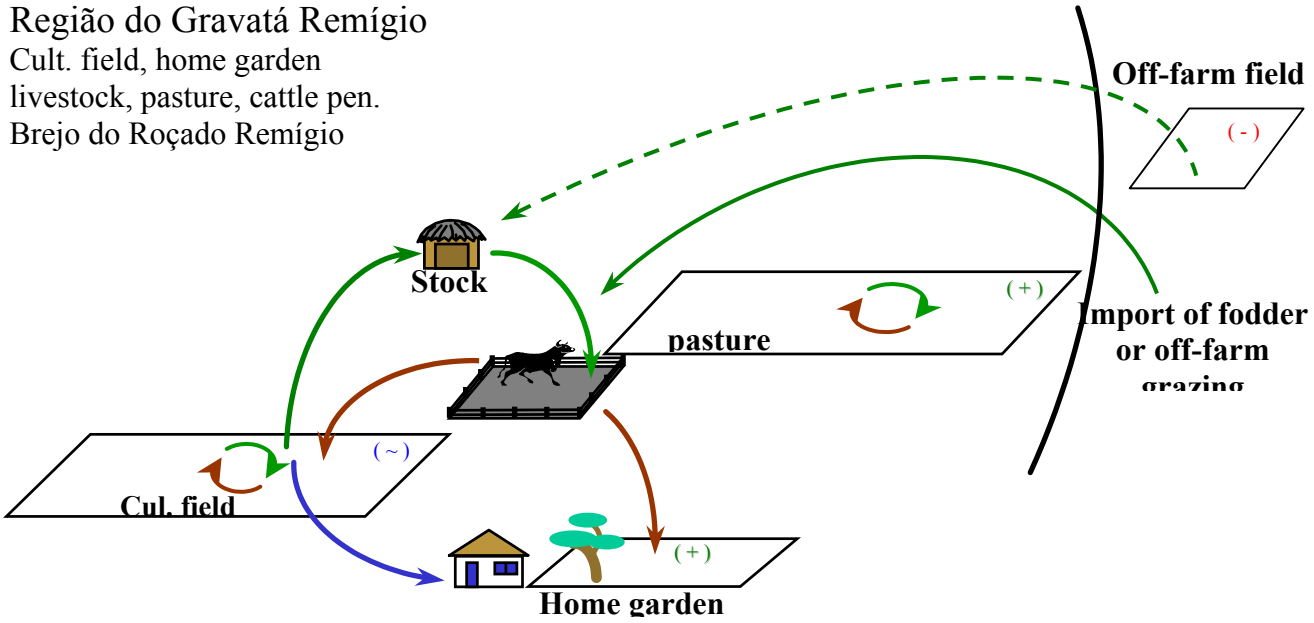


Model 3b:→ **sown pasture** *napier grass* **(*capineira*)**
Brejo do Roçado Solânea
Field, home garden, livestock, pasture, cattle pen, napier grass.



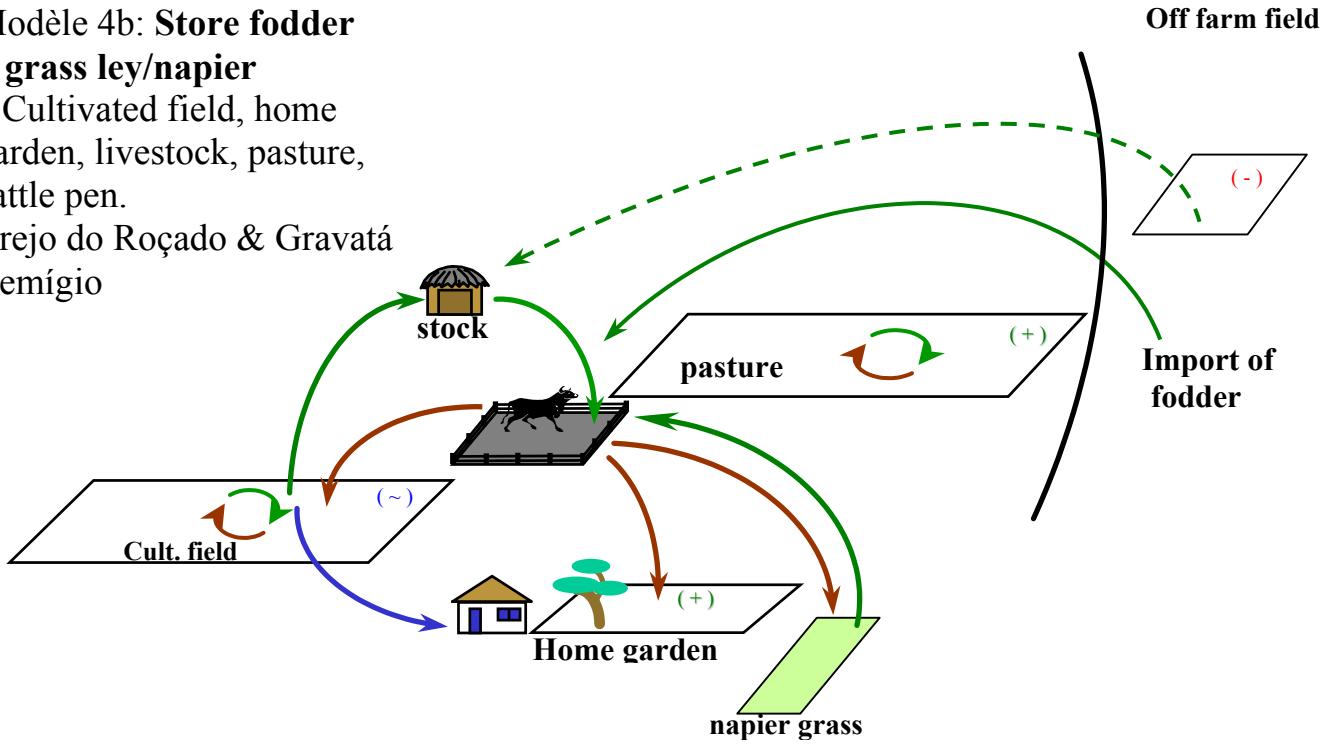
Variants:
---- use of manure on cultivated field
---- importation of fodder

Modèle 4: **store for fodder**
Região do Gravatá Remígio
Cult. field, home garden
livestock, pasture, cattle pen.
Brejo do Roçado Remígio

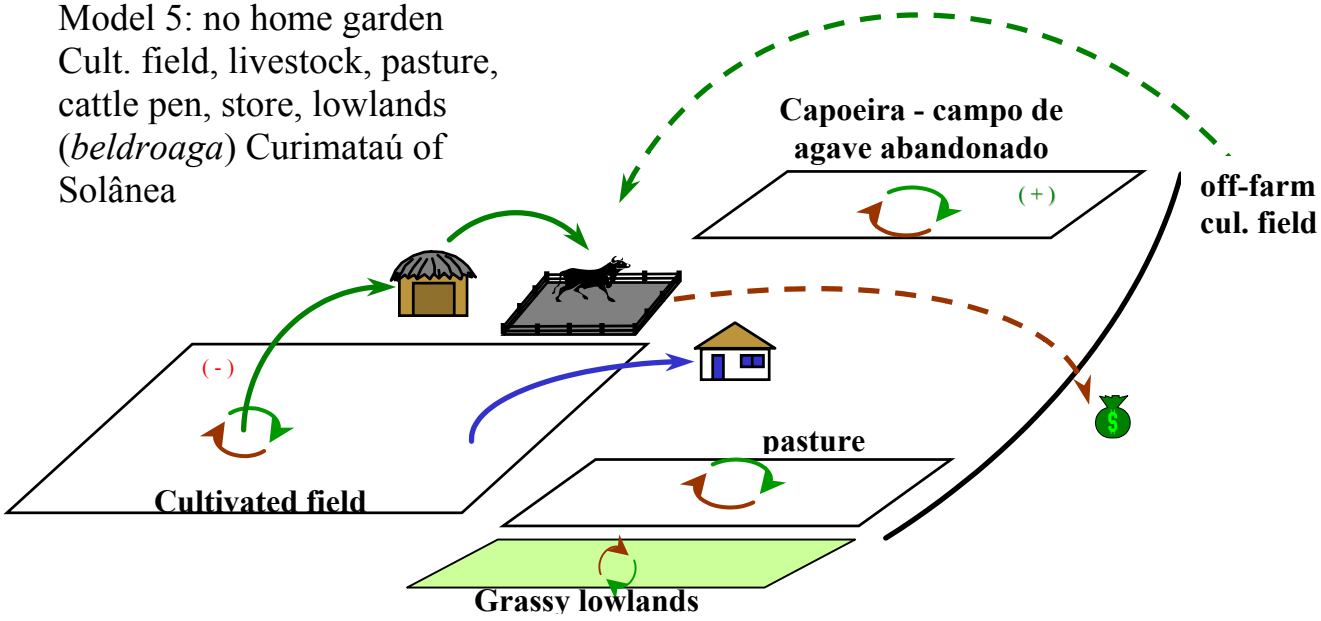


Variants:
---- cultivated field off-farm
---- fodder from outside the property
---- use of manure in field and home garden

Modèle 4b: **Store fodder**
+ grass ley/napier
– Cultivated field, home garden, livestock, pasture, cattle pen.
Brejo do Roçado & Gravatá Remígio



Model 5: no home garden
Cult. field, livestock, pasture, cattle pen, store, lowlands (*beldroaga*) Curimataú of Solânea



Variants :
----- sale of manure
----- use of local plants in case of drought (cactaceae, bromeliaceae)
- storage of maize canes

Model 6: **purchase of manure**
Agreste da Batatinha Remígio
Fields, livestock, pasture, cattle pen, storage, purchase of manure and chemical fertilizer
No home garden