Managing Africa's Soils No. 7

Integrated soil fertility management in Siaya District, Kenya

Nelson A.R. Mango

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About the Author

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About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa-Nutrient networks & stakeholder perceptions*. NUTNET is a partnership of 15 organisations coming from 6 African and 2 European countries. They are INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, Kenya; IER, Mali; Environment Alert & Makerere University, Uganda; IES, Zimbabwe; IIED & IDS, United Kingdom; AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, The Netherlands. NUTNET has been made possible through generous funding from the Netherlands Development Agency (NEDA), Ministry of Foreign Affairs, the Netherlands. It was drawn up with the primary aim of bringing together the following three research programmes:

- *The dynamics of soil fertility management in savannah Africa* co-ordinated by IIED and IDS/UK;
- *Spatial and temporal variation of soil nutrient stocks and management in sub-Saharan Africa systems* (VARINUTS) co-ordinated by SC/DLO the Netherlands;
- *Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda* (LEINUTS) co-ordinated by LEI/DLO, the Netherlands.

NUTNET has been made possible through generous funding from the Netherlands Development Agency (NEDA), Ministry of Foreign Affairs, the Netherlands

Acknowledgements

The research for this working paper was partly funded through the NUTNET programme.

Acronyms

AFRENA	Agroforestry Research Networks for Africa
DAP	Di-Ammonium Phosphate
ICRAF	International Centre for Research in Agroforestry
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute

Design and production by Eileen Higgins and Bridget Tisdall
Cover illustration © Christine Bass, based on Bogolan fabric patterns
Printed by Russell Press, Nottingham using Highland Velvet Pro 100% chlorine free

Summary

Most farmers in Siaya District, Western Kenya, regard soil fertility decline as one of their priority problems. It results in low crop yield, poverty and malnutrition. This paper analyses how farming systems in Siaya District have evolved and resulted in environmental degradation, what farmers' perceptions are of soil fertility decline and how they manage it. The paper concludes with an assessment of the potential of some new technologies.

The farming system in Siaya has evolved from shifting cultivation via fallow-based farming to permanent agriculture, mainly due to increasing population pressure and market integration. Long fallow periods were used to regenerate the level of organic matter and nutrients, until increasing pressure on land reduced its potential. Thereafter, application of animal manure became the most important source for soil fertility amendment. However, due to the decline in cattle population quantities of manure produced have become insufficient for restoring soil fertility on all fields. Most farmers find inorganic fertiliser too expensive.

The criteria that farmers use for judging that soil fertility is declining include reduced crop yields, change in soil colour, compacting of the soil, and the presence of certain weed species. They respond in various ways: parts of their land may be put into fallow for a period of at least six months; farmers also practise organic matter recycling, crop rotation, and crop associations. Soil and water conservation structures are established to avoid nutrient losses. More radical strategies include the development of low-lying, swampy land for growing high value vegetables or the search for off-farm employment.

Technologies developed by research institutes focus on improved fallow systems and green manure with leguminous shrubs and herbs. First results show a great potential for restoring soil fertility and improving crop yields. Improved fallow is produced primarily with *Sesbania sesban* for 6 or 12 months. Biomass for green manuring is cut from existing hedgerows in Siaya, especially *Tithonia*. However, this technology is very labour intensive. The amounts of biomass needed can be reduced when combined with inorganic fertilisers. Further improvements in crop yields may be achieved by adding rockphosphate and manure.

French summary

Résumé

La plupart des paysans du district de Siaya, au Kenya, considèrent le déclin de la fertilité de leur sol comme l'un de plus grands problèmes. Cela entraîne des rendements faibles, la pauvreté et la malnutrition. Cet exposé analyse la manière dont les sys-tèmes agricoles en sont arrivés à l'état actuel de dégradation de l'environnement, la perception des paysans à l'égard du déclin de la fertilité des sols et ce qu'ils font à ce propos. L'exposé s'achève par une évaluation des possibilités de certaines technologies.

Le système agricole à Siaya avait quitté l'agriculture itinérante pour adopter la culture avec jachère avant de devenir une agriculture permanente, principalement à cause de la pression démographique et de l'intégration au marché. De longues périodes de jachères permettaient de régénérer le niveau de matières organiques et d'éléments nutritifs jusqu'à ce que la pression sur les terres réduise cette possibilité. Après quoi, l'application de fumier d'origine animale est devenue la principale source de fertilisation des sols. Toutefois, le cheptel a énormément diminué et les quantités disponibles de fumier sont devenues insuffisantes pour restaurer la fertilité des sols de tous les champs. Par ailleurs, la plupart des paysans trouvent les engrais inorganiques trop chers.

Les critères retenus par les paysans de la région pour estimer que leurs sols deviennent sols. Certains mettent une partie de leurs terres en jachère pendant au moins six mois. D'autres pratiquent également le recyclage des matières organiques, la rotation des cultures et l'association de plantes. Des structures de conservation du sol et de l'eau sont mises en place pour éviter les pertes d'éléments nutritifs. Les stratégies les plus radicales concernent le développement de terres basses à caractère marécageux pour produire des légumes de haute valeur ou la recherche d'un emploi à l'extérieur.

Des technologies ont été mises au point par les instituts de recherche pour améliorer les systèmes de jachère et d'engrais verts faits à partir de plantes légumineuses et d'herbes. Les premiers résultats montrent de grandes possibilités de restaurer la fertilité des sols et d'améliorer le rendement des récoltes. La jachère améliorée utilise essentiellement *Sesbania* sesban pendant 6 ou 12 mois. La biomasse des engrais verts provient de la taille des haies présentes à Siaya, notamment *Tithonia*. Cependant, cette technologie nécessite beaucoup de main-d'oeuvre. Les quantités de biomasse nécessaires peuvent être réduites en l'associant à des engrais inorganiques. Ajouter du phosphate minéral à du fumier semble donner des rendements à la récolte encore meilleurs.

1 Introduction

Siaya District is located in the highlands of Western Kenya, an area which covers 85,000 km^2 and is characterised by high population densities. The highlands currently accommodate 12 million people, about half of the country's total population. The farming system is under considerable pressure from an increasing population, while crop yields and economic returns from farming are declining. The results are insufficient food production, increasing rural poverty, malnutrition and lack of income. Recent research in Western Kenya identified soil fertility decline as a major problem, affecting both crop and livestock production (Smaling 1993; RRP 1994; Mulamula 1992; Ogaro *et al*., 1997). The spread of the parasitic weed *striga* in maize is another factor affecting yields. Other constraints include rainfall unreliability and drought, shortage of land and labour, soil erosion, pests and diseases. The principal causes of nutrient losses include crop harvest, leaching, run off and soil erosion (Mango 1996). Farmers' efforts to restore soil fertility are inadequate since few can afford to use inorganic chemical fertilisers. At the same time, the use of manure is also restricted as farmers have only a limited number of animals.

Dommen (1988) characterised African rural communities as having the ability to work with the environment rather than attempting to override it. To maintain soil fertility, they use micro-environments deliberately, make a considered selection of crop varieties, develop appropriate cultivation practices and integrate livestock in the cropping system. Experience shows that farmers are adept at choosing crop combinations appropriate to different sites, capable of withstanding variable rainfall conditions and which are the most productive during periods with labour shortages (Richards, 1985; Norman *et al*., 1987).

The objectives of this study were to explore how farmers characterise soils and their perceptions of soil fertility decline, which soil improvement techniques are practised and why alternatives are not adopted. Following the introduction to the Siaya area and a description of the research methodology used, this paper analyses the processes of agrarian change which have resulted in the current farming problems and environmental degradation. It then discusses present farming systems and the major constraints faced in Siaya. Next, farmers' characterisation of soils and their perception of soil fertility decline are analysed. This is followed by a description of farmers' response to soil fertility decline within the context of the economic difficulties they are facing. It concludes with an analysis of several new technologies developed by research stations and their potential for adoption.

Research methodology

The study was undertaken in three villages, namely Luero, Muhanda and Nyamninia, all situated in east Gem location, Yala Division in the Siaya District. Luero village was selected because it is the site of a pilot project on soil fertility replenishment and recapitalisation, implemented by researchers from ICRAF, KARI, KEFRI and the Maseno National Agricultural Research Centre. The other two villages were selected because of their diverse farming practices and land use. The villages are located in the most densely populated areas of Siaya.

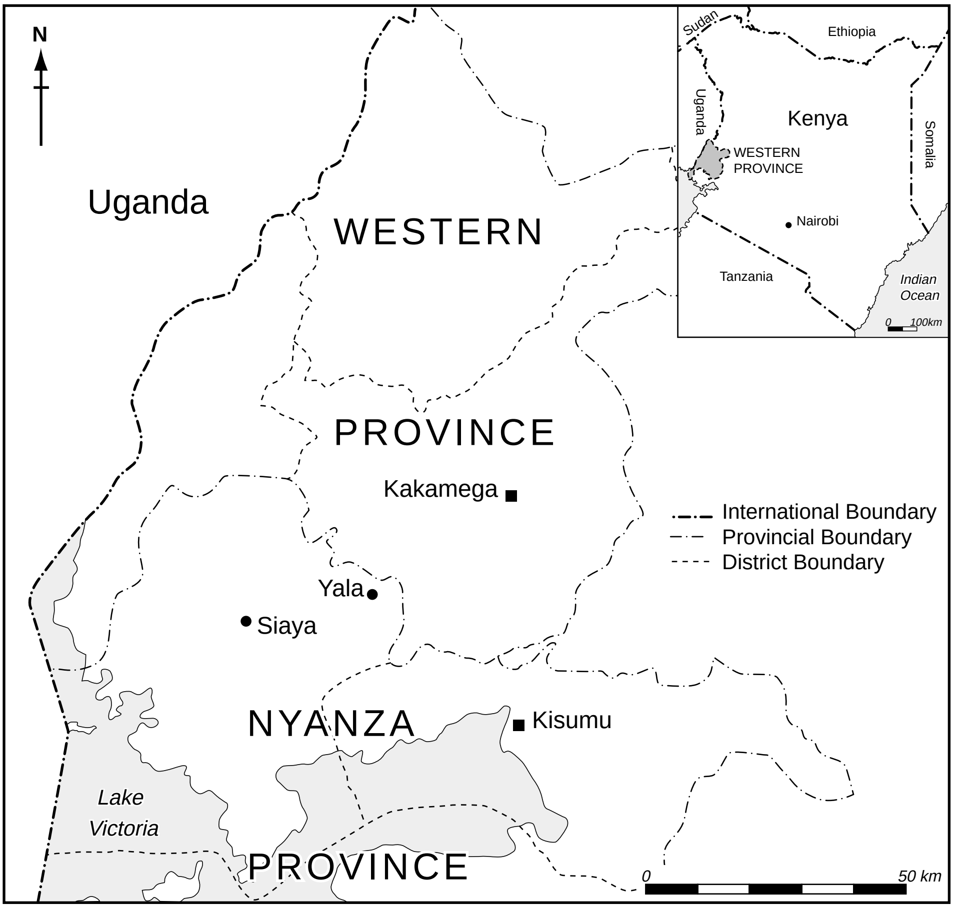
Data were collected through formal and informal surveys and participant observation. Methods used included the collection of quantitative data via questionnaires, transect walks, wealth ranking surveys and participatory rural appraisal tools, and anthropological techniques for recording oral histories. The sample for the quantitative surveys was 120 households, representing 10 percent of all households in each village. The case studies involved 2 key informants from each village.

Background to Siaya

Siaya District is part of Nyanza province, in the south-west of Kenya. Yala Division is situated in the Northern part (see Figure 1). The district is located 40 km to the south-west of Kisumu, the main town of the Luo speaking people, which itself is about 400 km from Nairobi. The population in Yala Division now stands at approximately 90,000 (Republic of Kenya 1997b), with densities ranging from 250-400 per square kilometre. Population growth rates are 2.8% for 1998 (Republic of Kenya, 1998). Figures also indicate a relatively high out-migration.

The altitude of Siaya District ranges from 1140m to 1500m above sea level. Yala Division is located at the higher end of this range. The landscape is characterised by undulating and rolling uplands, with slopes varying from 2 to 16%. Yala Division receives an average annual rainfall of between 1800 mm and 2000 mm. The rainfall has a bimodal pattern: the long rains occur from March to June and the short rains from September to December. The fertility of the soils in Siaya District range from moderate to low, and levels of nitrogen and phosphorus are particularly low. Vertisols and ferralsols are the most common soils in the three villages studied. Most soils are underlain by plinthite (Murram) at a shallow depth, resulting in low moisture retention.

Figure 1: Siaya District



2 Evolution of farming systems

This section analyses agrarian change in Siaya district. The farming system has evolved from shifting cultivation via fallow-based farming, to permanent agriculture, mainly due to increasing population pressure and market integration. This pattern of changes in Siaya is consistent with the model developed by Ruthenberg (1980) on the evolution of farming systems towards permanent upland cultivation in the semi-arid and sub-humid tropics.

Shifting cultivation

The Luo people immigrated from the Sudan during the 1500s (Atieno and Cohen, 1989). Prior the 1800s, the Luo operated an agro-pastoral system in Siaya, producing mainly milk, butter, blood and occasionally meat. Cattle were also used for wealth accumulation and exchanged for land or to pay the bride price. Shifting cultivation dominated and was subsistence oriented. The main crops grown were finger millet (*Elusine coracana*), sorghum (*Sorghum vulgare*), field pea (*Pisum sativum*) and melons (*Cucumis melo*). Farmers used iron bladed hoes for light seedbed preparation. Seeds were broadcast and manure was not applied systematically. Fishing for subsistence was also important. Men were mainly responsible for cattle and fishing and women for crop production.

Fallow-based agriculture

During the 1800s, cattle-rearing continued to be the dominant activity and an active trade in cattle operated between Uganda and Tanzania which passed through Siaya. During this period Luo people started to settle and which resulted in a transition from shifting cultivation to fallow-based agriculture. Staple foods were millet (*Panicum miliceum*), finger millet and sesame (*Sesamum indicum*). Migration to Siaya also increased during this period because of wars among Luo clans and the high population density in their region of origin in the Sudan. They were also attracted to the northern part of Siaya because of its good rainfall and availability of suitable land for arable farming. The Luo adopted the cropping practices of neighbouring Bantu people and started to grow new crops such as bananas (*Musa spp.*), maize (*Zea mays*) and sweet potatoes (*Ipomea batatas*).

Expansion of permanent cultivation

The transition towards permanent agriculture began during the colonial period. The pressure to intensify production was generated by an increasing demand for products to meet local needs and earn cash. However, at the turn of the century, a series of epizootic diseases devastated the Luo cattle herds which they only partly managed to reconstitute, using revenues generated through trade. Since the 1920s the area has become a net cattle importer. This collapse of livestock activities increased the importance of cropping and new land for arable farming was cleared at the expense of grazing areas. Although animals grazed on crop residues and in areas which were unsuitable for cultivation, crop-livestock integration was limited.

Agricultural commercialisation and intensification

The colonial government required households to pay poll taxes. Money was earned either by growing cash crops or by working on European farms. The cash crops introduced included cotton (*Gossypium spp.*) groundnuts (*Arachis hypogaea*) and sugar cane (*Saccharum officinarum*). Only sugarcane and cotton were adopted by farmers although their economic returns was limited.

When the colonial government stopped the expansion of tribal lands, people were forced to settle where they were and concentrate on arable farming. Reserves of clan land had ceased to exist and land scarcity was aggravated by increased population pressure. Sons could only acquire land by subdividing their parents' land. The settlement by Luos in the sugarcane zones during the 1960s presented a final moment to farm new land. Another policy which encouraged permanent settlement was the privatisation of agricultural lands with or without title deeds. This provided farmers with the incentive to develop their own lands and practise modern methods of farming. This was further stimulated by government extension campaigns. The expansion of perennial cash crops, such as coffee and sugarcane, also promoted permanent land use.

During the early 1900s, maize production increased. Maize performed better than sorghum in areas with good rainfall and well-drained soils. But it also replaced the ecologically better adapted sorghum and millet in the drier zones. Maize ugali was considered more palatable, while preparation time was shorter than for sorghum. Sorghum was also more vulnerable to bird damage, a problem that was aggravated by a growing scarcity of labour on small-scale farms. Since World War II, smallholder maize production in Kenya has further been encouraged by high, guaranteed prices for maize, and has benefitted from a well developed marketing system. Moreover, considerable resources have been allocated to maize research and dissemination through a well-established extension system. Hybrid maize was introduced by the colonial Ministry of Agriculture as part of a package which included cultural practices such as row-planting and a second weeding. Maize is also the cereal used in government organised relief programmes during periods of crop failure.

Decline of agriculture

As early as the 1940s, labour migration to Uganda, Nairobi as well as other Kenyan cities became an important livelihood strategy for the Luo. Throughout the 1950s and 1960s, the district was still a net food exporter, mainly supplying food to Luo labour migrants living in cities. Average population density rose to about 150 people/km^2 by 1970. Between 1970 and 1990, connections with major cities in Western and Central Kenya improved, and several small and medium-sized urban centres expanded in Siaya. The population in Siaya District doubled between 1969 and 1998 (Central Bureau of Statistics, 1969; 1996), with the average population density rising to 250 people/km^2, and reaching 400 people/km^2 in the high rainfall areas.

The intensive cultivation of food crops, including maize, using new husbandry practices such as frequent tillage, together with the absence of soil protection measures, exacerbated soil erosion. This accelerated during the 1970s and 1980s when soil degradation became widespread. Crop yields started to decline in many places and farmers responded by changing the crop composition. Aerial photos for Luo land show a sharp increase in the cultivation of bananas, sweet potatoes and particularly cassava.

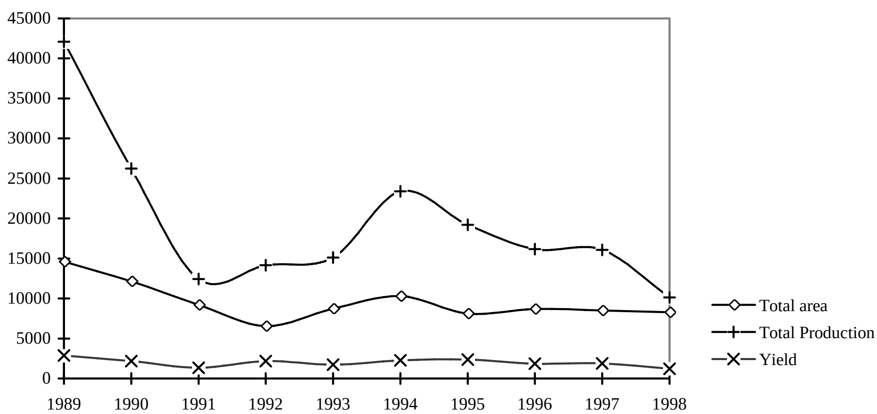
During the 1970s and 80s, investments in agricultural research and development to encourage innovation in Luo farming systems were low. A pilot project to introduce higher value robusta coffee and small-scale dairy production was carried out in the more humid areas of Siaya, while community-based groups have promoted small-scale production of high-value vegetables, fruits and other products to generate a cash income. During the 1980s, the government promoted the expansion of sugar cane production.

However, this has not prevented a decline in farm incomes. Accelerated migration has resulted in serious labour shortages on farms, with many becoming *de facto* female headed households. Many households have become dependent upon the cash remittances from migrant family members for the purchase of food. In the 1970s, the area was estimated to have one of the highest rates of malnutrition in Kenya (MPND, 1989).

Agriculture in the 1990s

The farming system in the 1990s is characterised by limited use of external inputs, low yields and low economic returns. It is also under considerable pressure from population growth. The trends in maize production for Yala Division are presented in Figure 2.

Figure 2. Maize production in Yala Division since 1989



The removal of fertiliser subsidies in 1990 also contributed to the decline in maize yields (see Figure 2). The overall downward trend in the area under maize seems to be the result of continuous land divisions and the establishment of new houses and compounds on previously farmed lands. The variation between the years is partly caused by prolonged droughts.

Maintaining adequate levels of soil fertility is no longer possible. The role of fallow periods to restore soil fertility has diminished because land has become scarce. This also makes crop rotation difficult because farmers need a large part of their land to grow maize. The limited rotation stimulates the expansion of striga, a parasitic weed which attaches itself to the roots of cereals and leguminous plants. It produces beautiful pink fields where maize is withering. Striga problems are aggravated by low soil fertility level. The only way to fight striga is to uproot it, which is a cumbersome and labour-intensive task.

Deficiencies particularly in nitrogen and phosphorus were observed during our survey. This may be due to a variety of reasons, including naturally low inherent levels in the soil, continuous cropping, lack of crop rotation, removal of crop residue from the fields, non-application of sufficient organic and inorganic fertilisers, reduction of fallow period and soil erosion.

Externally introduced innovations proposed for the Luo farming system are High Yielding Varieties (HYV) of maize, beans, sugar cane, coffee and cotton. Exotic breeds of livestock such as dairy cows are also increasingly adopted. The Ministry of Agriculture disseminates these ideas through its well-established extension system, using the rather 'top-down' transfer-of-technology model. NGOs are also involved in the dissemination of HYV and exotic breeds, but use a more 'bottom-up' approach while encouraging farmer participation.

Farmers, for their part are also experimenting. They modify new technologies before integrating them into their farming systems. Farmers also create networks amongst themselves to acquire information on alternative ways of growing crops such as local maize. They experiment with traditional crops like finger millet, sweet potatoes, arrow roots, local beans, cassava, groundnuts and bambara nuts.

Swamp development for vegetable production

Lowland vegetable farming, which is mainly an activity for women, has become a very prominent among farmers in Siaya. It is an alternative strategy for coping with declining soil fertility in the uplands. Farmers invested a lot of their resources in developing inland valley swamps in the lowlands so that it could be used for cultivating vegetables every year. The soils are fertile and can be used continuously, if well maintained. Valley bottom lands are not freely accessible as they are also privatised. Some farmers who cannot cultivate these fields themselves will lend their fields for free to women's groups. Farmers also acquired a plot on an individual basis either through renting or for free from a family member.

3 Present day farming systems

This section presents an overview of farming systems in Siaya District and is mostly based on the results of our research in the three villages.

Cropping systems

The main economic activity in Siaya district is intensive mixed farming. All households grow maize intercropped with beans in both the short and the long rainy season. Groundnuts, sorghum, finger millet, millet, sweet potato, cassava, cowpea, tomato, kale (*Brassica acephala*) and other varieties of vegetables, are grown on a smaller scale but form an important part of the local diet. Cotton is the major cash crop in the southern part of the district, and sugarcane, robusta coffee and dairy farming in the northern part of the district, where Siaya is located. Sisal is also grown. The percentage of farmers in Siaya district growing cotton is 5% while 11% are growing sugar cane (Republic of Kenya, 1997a). Banana cultivation has become more popular in the 1990s following the introduction of new cultivation methods by the NGO, CARE-Kenya. Bananas fetch good prices in the markets of Kisumu and Siaya town. The cultivation of vegetables is another new source of cash income, particularly for women.

The long rains from March to June are the most important. Sowing starts after the first showers and continues for several weeks to avoid peaks in the demand for labour and to reduce the risks from dry spells. Most crops can be harvested in July and August. The unreliability of the short rains increases from North to South. Cultivating during the short rainy period is therefore risky in the Southern parts of the District. Most farmers hand-till the soil, and only a few rent oxen for ploughing (see Table 1). Oxen are not used significantly because of the small field sizes and the scarcity of grazing land.

Most crops are intercropped and the combination of maize with beans is most common. Sometimes even cotton is intercropped. Certain farmers buy improved varieties of maize which should be grown in monoculture, although only a few farmers follow this recommendation. Some farmers even grow hybrid maize without fertilisers and will thus not profit from its potential. Farmers' soil fertility management practices will be discussed in the next section.

Table 1. Farmers using ox-ploughs per village in 1999 (in percentages)

Village	Using (%)	Not Using (%)
Nyamninia	40	60
Muhanda	28	72
Luero	13	87

Source: Own survey; N= 40 farmers per village

Livestock

Almost every farmer interviewed kept some livestock. At least a quarter of the households owned at least 1 or 2 heads of cattle (Table 2), while all households kept poultry and 40% held sheep and goats. The number of cattle, sheep and goats is higher in the southern part of the district since there is more land available for grazing. Moreover, farmers prefer to invest in cattle because of the risks of cropping associated with the unreliable short rains. The potential for crop-livestock interactions has been increasingly jeopardised by the expansion of agricultural lands at the expense of grazing land. Especially in the North, boys and men graze their cattle on fallow lands, along the roads, and on the crop stubble.

Some farmers have cows of improved breed. These are kept for dairy farming and held under a (semi) zero-grazing system which involves the cutting and carrying of fodder to the livestock pens (see Table 2). Improved crop-livestock integration can result from these zero-grazing systems when manure and slurry are applied to fields, sometimes after composting.

Table 2. Importance of various cattle management systems per village (in percentages)

Cattle management system	Nyamninia (%)	Muhanda (%)	Luero(%)
Zero grazing	15	3	0
Semi-zero grazing	8	5	3
Extensive grazing	32	25	20
Farmers without cattle	45	67	77

Source: Own Survey

Household organisation

Households in Siaya district are patrilineal and generally complex due to polygamy. The average number of resident members in Yala Division's households is 8 persons. The ratio of adults to children is 1:3. The head of the household is generally the husband if alive or otherwise his widow or eldest son. In over half of the households, men take day-to-day decisions about running the farm. In the case of *de jure* female-headed households, the woman takes all decisions but she may wish to consult her eldest son or brothers in-law. Although in *de facto* female-headed households, women manage the farm, they usually require men's approval for changes in crops or farming practices.

Most farms rely on family labour, but sometimes outside labour is hired. Farm work is carried out by both male and female members of the household although women perform most of the work in about half of the households. In only a few households work is shared by the couple, and in very few households men provide most of the labour. There exists a division of task by sex for certain activities. Ox-ploughing is carried out by men only, while the transport of manure to the fields is mainly a task for women and children. All members of the household spread manure and fertiliser. Herding and taking care of livestock is regarded as the responsibility of men. Construction of soil conservation structures, is done by both men and women.

Land tenure

The system of land tenure is dominated by individual freehold with or without title deeds. Access to land is mainly through membership of a kin group or of a broader community group. Most farmers have inherited land (see Table 3). The importance of land purchase for farmers varies from 8 to 31% between the three villages. Sharecropping is non-existent. People who do not have land can rent from others either at a fee or for free. From our survey, renting is the least frequently used for obtaining land.

Table 3. Farmers' ways of obtaining land per village (in percentage)

Village	Inheritance %	Purchase %	Renting %
Nyamninia	96	8	4
Muhanda	97	19	13
Luero	88	31	13

Source: Own survey. N = 40.
Figures do not add up to 100% because farmers may obtain land in several ways.

About 20% of the plots are family land which is cultivated in a block. Parents fear that a further subdivision might result in fields that are too small to manage, which is one reason why they prefer their sons to work it together. Sons who manage to obtain money from other sources will purchase their own land somewhere else. Sometimes even the family plot has become so small that some sons have to seek off-farm employment. Women do not usually inherit land, but gain access through marriage. Very few female farmers purchase land on their own. In the three villages, only 4 women had managed to buy land.

Farm size

The continuous subdivision of land has left many farmers with an inadequate area to meet subsistence needs. In 1989, average area in cropland on smallholdings surveyed by the Agro-Forestry Extension Programme (AEP) was 1 ha in the high rainfall zone, 1.25 ha in the medium-rainfall zone and 1.7 ha in the low-rainfall zone. Holding size was slightly larger in the southern part of the district. Average farm size in the sample is 0.8 ha and the average number of people supported by one hectare of land is 6.2. The land distribution in our sample is presented in Table 4.

Table 4. Average farmsize per household for the three villages (in percentages)

Farm size (ha)	Nyamninia (%)	Muhanda (%)	Luero(%)
< 0.4	17	19	6
0.4-0.8	34	32	57
0.8-1.2	13	15	25
1.6-2.4	18	17	6
>2.4	12	19	6

Source: Own survey 1999; N=40 per village

Cultivation is carried out in upland areas, on the ridge of slopes, and in the valley bottoms. The total area in Yala division under cultivation is 70%.

Credit

Although farmers were aware of the Agricultural Finance Corporation (AFC) there was little evidence of credit use to modernise agriculture in Yala. Of the 120 farmers interviewed, only 4 mentioned that they had applied for a loan from the AFC. Most farmers did not have title deeds for their lands and therefore possessed no collateral to secure a credit. Other farmers did not apply for credit for fear of defaulting on the loan and losing their land.

Food security

Most households in Siaya District do not produce enough food for their own consumption (MPND 1989). In our survey we found that about half of the households are not self-sufficient and produce on average enough food for about 7 months. Only 5-10% produce a surplus (see Table 5).

Table 5. Household food security status per village (in percentages)

Food Security Status	Nyamninia %	Muhanda %	Luero %
Insufficient	52	48	50
Break even	38	44	45
Surplus	10	8	5

Source: Own survey 1999, N = 40 per village

Siaya has become a maize deficit zone. Between February and April maize is imported from outside the district and supplied by the National Cereals and Produce Board (NCPB) and traders with lorries.

Off-farm employment and migration

Many men in Siaya responded to soil fertility decline and land fragmentation by abandoning farming altogether. They seek work in urban areas or in off-farm employment such as trading or by working for public services or private companies. In the three villages, trade was a very important source of off-farm income for both men and women. The most important activities were shop keeping, working in the hotel industry, fish mongering, dealing in second-hand clothes and cattle trading. Other trades include retailing food crops, selling vegetable crops, while some farmers own mills or are involved in charcoal making. In our sample, 38% of the men and 44% of the women interviewed received remittances from off-farm employment. About 40-50% of these remittances were spent on education, with the remainder being used to buy consumptive goods. Only a small part was spent on farm inputs and implements. According to most farmers, remittances are at the moment not very reliable given the current economic situation in Kenya.

Women and children remain on the farm and continue to cultivate part of the fields for their subsistence. Those engaged in off-farm employment contribute occasionally to farming activities by material and financial support and by returning to assist with major farming operations. Men will only return to agriculture when it becomes economically viable. This may be triggered by a combination of higher population densities and technical innovations.

4 Soil classification and soil fertility management

Farmers' criteria for assessing soils

Most farmers interviewed based their classification on the surface layer of the soil. They codified a soil by colour, texture and heaviness of working. Soils have local names. Some farmers with secondary education will also identify a soil by its English name.

Red soil (Luala or Rakua) is regarded as the best soil for producing food crops such as bananas, beans, maize and vegetables. It is also used for smearing and decorating walls of houses constructed from adobe. Red soils with sand are named '*Luala makuoyo*'. They are light and easy to work, but have a lower productivity. Some of these red soils have a plinthite layer and are then called '*Ge*', which is the poorest soil in the area and very hard to improve. The brown soil (*Rabuor*) is good for growing bananas, beans and maize. The white soil (*Pundo*) is used for growing cassava and sweet potatoes. It is also the best soil for plastering and decorating houses. The black soil (*Anyuang*) is a clayey black cotton soil, found in swampy valley bottoms. This soil is very rich in nutrients and used for cultivating vegetables and arrow roots. Farmers prefer the red soils for their high yields. Black soil, which is the second preference, is fertile but heavy and needs draining before it can be used. The third preference is brown soil which produces average yields. The least preferred for farming is the infertile white soil (see also Table 6).

Farmers' indicators of soil fertility

The term commonly used by farmers to indicate soil fertility decline is "soil weakness". When soils become "weak", yields will decline. Farmers use various indicators to assess the fertility of a field, such as yield, soil colour, compactness, soil odour and the composition of the vegetation. After a period of continuous cropping all these indicators change. The colour transforms from dark red to brown, the odour disappears, and the flora also change.

Table 6. Main Soil types

Local name of soil type**	Colour	Farmers' preference*	Land use	Management practices
Rakuar	Red	1	Maize, beans, bananas, vegetables	Addition of sufficient organic manure, fallowing
Rateng (anyuang)	Black	2	Vegetables, arrow roots	In valley bottoms; needs drainage and organic manure
Rabuor	Brown	3	Maize, beans, kale millet, sorghum, bananas	Addition of organic manure, fallowing
Pundo (Rachar)	White	4	Cassava, sweet potatoes, decorating houses	Fallowing, terracing

* The best soil receives the smallest number.
**Rakuar = Complexes of lithosols, chromic and orthic luvisols and (ferralo-) chromic acrisols partly petroferric or Pisoferric phases; Rateng = complex of acrisols, cambisols, arenosols, gleysols, and fluvisols. Rabuor = Orthic luvisols; Rachar = solonchaks and arenosals.

Yield – If a soil is alive and fertile, then crop yields are high. Farmers mainly assess yields in terms of crop performance and less on the amount of crop harvested per unit area of land. The thickness of the ear of maize, the number of tomato fruits and the thickness of cassava roots are indicators of soil fertility. The crops' performance indicates which parts of the plot are weakening. Other crops will then be grown in these spots.

Colour of the soil – Colour indicates the presence of organic material and varies between different parts of the field. After a fallow a soil is fertile, having a dark red colour. This shows that the soil has more humus. After a certain period of cropping, the soil colour turns brown, indicating a decrease in soil fertility.

Compactness of the soil – A fertile soil is rather soft and easy to work. When fertility declines the soil becomes hard and more compact. S*triga* has a similar effect on soils.

Odour of the soil – A fertile soil has a certain odour, particularly after it has rained. Three or four years after clearance and continuous cropping farmers notice that the soil loses its odour.

Flora of the soil – The composition and performance of weeds and trees indicate the level of soil fertility. Most of the older farmers know which species indicate a higher soil fertility in the Siaya area such as black night shade (*Solanum nigram*), pigweed (*Amaranthus hybridus*), thorn apple (*Datura stramonium*). Some plant species indicating poor soils are tick berry (*Lantana camara*), poverty grass (*Harpachne schimperi*), fleabane (*Conynza banariensis*) and black jack (*Bidens pilosa*).

Diversity of practices among households

The diversity of soil fertility management practices among the households in the three villages was assessed through a method based on participatory wealth ranking. First, farmers were asked to identify soil fertility management practices that differ between the households. Farmers listed the use of organic and inorganic fertilisers, the timing of farming operations, use of crop rotation and presence of striga.

Next, they were asked to identify criteria that caused differences in the use of soil fertility management practices. They concluded that good soil fertility management depends on access to labour, knowledge and experience, capital and off-farm remittances, livestock and information.

Farmers then used these results for classifying all households into three groups: good, average and poor managers of soil fertility. Each group used similar soil fertility

Table 7. Diversity in soil fertility management practices in relation to resource endowment

Category	**Group 1**	**Group 2**	**Group 3**
Quality of soil fertility management	Good	Average	Poor
Percentage of households	14%	22%	64%
Management practices			
Use of inorganic fertilisers	Yes	Sometimes	No
Use of organic fertilisers	Yes	Sometimes	Sometimes during long rains
Timing of land preparation and weeding	On time	On time	Often late
Crop rotation	Practised	Some farmers	Not practised
Soil conservation structures	Present	Some farmers	Absent
Presence of Striga	Low	High	High
Resource endowment			
Remittances from off-farm income	Available	Limited	None
Visited by extension staff	Yes	No	No
Knowledge of proper farming methods	Yes	Limited	No
Source of labour	Hire labour	Family labour only	Family labour, rent labour to group 1
Cattle ownership	Yes	Some	No
Formal education and training	Yes	Some	No

management practices and worked under comparable socio-economic conditions (see Table 7).

Long fallow periods were used in the past to regenerate the level of organic matter and nutrients in the top soil. However periods of fallow became shorter and gradually disappeared due primarily to increasing population pressure. Thereafter, the application of animal manure became the most important source for soil fertility improvement. However, the cattle population has declined and quantities of animal manure produced are insufficient for restoring soil fertility on all fields.

According to the farmers interviewed, the measures and practices needed for good soil fertility management include:

1 Soil and water conservation such as construction of terraces, grass strips and contour ploughing.
2 Application of organic manure and to a lesser extent inorganic fertilisers.
3 Fallowing - its potential depends on the size of the farm.

The measures most frequently used are the application of manure and construction of soil and water conservation structures (see Table 8).

Table 8. Farmers' opinion and use of various strategies to combat soil fertility decline

Strategies	**Relative Importance according to farmers***	**Farmers using these (%)****
Use of farmyard and composted manure	9	40
Constructing soil & water conservation structures	8	31
Proper land preparation	7	10
Use of inorganic fertiliser	6	18
Crop rotation/association	5	10
Use of improved or natural fallow	4	5
Application of green biomass as organic fertiliser	3	15
Swamp development	2	5
Using the micro-variability of soils	1	3

*Most important strategy receives highest number. Farmers may apply two or more strategies.
** percentage of interviewed farmers

Soil and water conservation

Rainfall is high in Western Kenya. Soil conservation structures are therefore important to reduce the loss of nutrients through erosion and leaching. Terraces, barriers of *Tithonia* and trash lines are the most important technologies used in Siaya District.

Before independence, the colonial government forced farmers to establish contour bands, terraces and hedges but this stopped after independence. Although terracing has been promoted for over forty years the impact on soil erosion has been surprisingly limited and initial successes are sometimes reversed almost immediately. In Siaya there has been almost no enduring effects, and by the early 1980's erosion was wide spread.

Participatory approaches are now used in all soil conservation promotion programmes. The Ministry of Agriculture, Livestock Development and Marketing assists and trains farmers in soil conservation measures. They follow a catchment approach and promote the creation of village soil conservation committees which then establish soil conservation structures on farms. Unfortunately, the performance of most soil and water conservation projects is poor and there is a need for a thorough assessment of existing practices and professional norms. Projects and programmes must find ways of building on skills, enthusiasm and knowledge of farmers. Forcing technologies on farmers that are developed without their involvement, although they seem technically appropriate, is likely to result in failure. These are often rejected by farmers when the external pressure is removed.

Terracing

Recently, land users have started to appreciate the need to use terraces on their farms. In total, there are 37 farms in the three villages that have terraces. There are also two long, communal terraces which were built in the early 1990s by the community as part of the catchment approach programme, following instructions from the Soil Conservation Officers. The terraces run from one corner of the village to the other.

However, the expansion of agriculture in the research area is reducing the adoption of terraces as these are competing for space with crops. Farmers complain that terraces can leave corners in some fields, which are at risk of being appropriated by a neighbour. Moreover, the use of ox-plough for land preparation requires that land is free of obstacles and terraces are regarded as a hindrance. The continuous subdivision of land among family members results in narrow strips of fields across the contour lines of a slope. Farmers are inclined to plough these lands down the slope thereby destroying soil conservation structures built along the contour lines.

Barriers of *Tithonia* and other plants

Many farmers have planted barriers of *Tithonia* on less slopy land, instead of constructing terraces, which is more labour intensive. By the end of short rains of 1998, some 40 farmers had planted *Tithonia* as a biological soil control measure. They used cuttings or seedlings that were raised in farm nurseries. On steep slopes, farmers first established terraces and planted *Tithonia* and napier grass to strengthen the structure. Some farmers also plant sweet potatoes as a cover crop to reduce erosion.

Trash Lines

Crop residues can be placed along the contour and act as trashlines which reduce runoff. Farmers prefer this technology because it is not as labour intensive as digging terraces.

Crop residue utilisation and mulching

Crop residues have multiple uses. They can be placed along the contour, fed to livestock or used as fuel. Crop residues are also an important source of organic fertiliser and most maize growers tend to return the stover to the soil. Crop residues were returned to the fields by 75% of the farmers interviewed. A few farmers burned them to save on labour for raking. Of the farmers with livestock, only 10% grazed their animals on crop residues. A part is also used for bedding in cattle pens. The resulting farmyard manure is returned to the fields. Very few farmers (about 3%) used crop residues for fuel.

Crop residues were only used as mulch for growing high value crops such as kales, tomatoes and bananas, because mulching is a rather labour intensive technology. It protects germinating seedlings, prevents soil hardening, improves cation exchange capacity and stimulates a favourable environment for microbial activities in the soil. However, the potential of mulch as a soil fertility improvement measure was not well understood by many farmers.

Organic manure application

Farmers in Yala used organic fertiliser in the form of compost and farmyard manures, a mixture of dung, urine and crop residues. Farmers stated that manure improved soil fertility, reduced the number of striga plants and was effective over longer periods. But farmers applied on average 2 tonnes per hectare, which is much lower than the recommended rate of 8 tonnes/ha. They were therefore advised to make the best of the limited amounts available through careful application. The recommendation is to apply a handful or organic fertiliser to each planting hole.

The availability of manure is constrained by the limited number of livestock and the tendency to graze the cattle away from the farm. Transporting manure to the fields is labour intensive which also limited its use. Sometimes the quality of the manure was low; it had not decomposed well or nutrients had been lost due to leaching or volatilisation. The manure is broadcast after the harvesting of the beans and then worked in the soil during ploughing. Again, about 1 or 2 hands of manure per hole are applied at planting.

Almost all farmers interviewed used some organic manure. About 40% of these farmers applied it regularly. The amount applied varied from farmer to farmer depending on the availability. When farmers have not enough manure, they will give priority to high value crops such as kales, tomatoes and bananas. About one quarter of this group composted the manure before application. Farmers who did not have cattle bought manure. Zero-grazing dairy farmers for example, kept their cattle all year round in a stable, and accumulated a lot of slurry and manure, part of which was sold[1].

Inorganic fertilisers

Fertiliser was only used by 18% of the interviewed farmers. Those who did use it generally applied less than the recommended rates of 60 kg N and 60 kg P_2O_5 per ha of maize. The most important reason for not using fertilisers was lack of cash to buy adequate quantities. Another problem was the unsatisfactory distribution of traders who stocked fertilisers. The non-timely availability of fertilisers may have also been a restraining factor.

Farmers also mentioned that inorganic fertiliser spoiled the soil and encouraged soil degradation. Many complained that after using fertiliser for some time, the texture of the soil changed. The upper part of the soil became very fine and prone to erosion, while a hard pan appeared in the subsoil. This may have been caused by the accumulation of phosphates in the soil. For three farming households this was a reason to stop using inorganic fertilisers and hybrid maize since maize would not perform well without fertiliser. Some farmers stated that a soil would become ‘addicted’ to fertiliser: the continued use of fertiliser is necessary to avoid a reduction in yields in the following season. It was mentioned particularly by one household who grew hybrid maize from 1983 until 1990, when they could no longer afford to buy fertiliser. They now grow maize without fertiliser but reported very low yields. Four other farmers were of the opinion that fertiliser application encouraged the expansion of striga. Two of them had therefore abandoned the use of fertiliser and hybrid maize.

The extension workers from the divisional agricultural office of Yala Division supported the view that fertiliser increased the growth of striga. According to them, the application of fertiliser, particularly DAP, produced more acid which is favoured by striga. Extension

[1] One wheelbarrow of manure will cost about 15-20 Ksh in Nyamminia village where there are a lot of zero-grazing units. Nobody sold manure in Luero village and only 1 farmer sold in Muhanda village at 40 Ksh a wheelbarrow.

officers also stated that farmers' inefficient use of fertilisers was another reason why they abandoned it. The benefits of fertilisers will be limited when farmers use the wrong type, apply too low rates, or use it at the wrong moment.

However, the majority of farmers in Yala wanted to use fertilisers. One farmer said *"Inorganic fertiliser is not bad at all, it only gives the plant ready made food"*. The most important constraint is the lack of finances. The price of DAP is steadily increasing and now stands at KShs 1600 (US$ 26) which is quite an investment for a resource poor farmer. Some farmers who have manure and can afford to buy fertiliser will use both when planting their crop. If they do not have sufficient funds, they will use manure at planting time and top dress with nitrogenous fertiliser after weeding.

Short duration traditional fallow

Farmers are of the opinion that "leaving a section of their land to rest" is the most important way to improve soil fertility. It is also used during labour shortages. Our survey indicated that fallowing was used by 52% of the farmers interviewed, which is much higher than reported initially (see Table 8). They left land fallow for at least one cropping season, generally during the short rainy season. Only small portions of their land, representing 10 to 25% of the total area, were left fallow. Most farmers had such small plots that they could not afford to leave more land under fallow.

Agronomic practices

Mono-cropping was not a common practice in the research area although it is recommended for growing hybrid maize. Only farmers with sufficient land at their disposal can grow maize in monoculture. Farmers considered crop associations and rotations as better for the soil. Maize is the main staple and thus has to be grown on a large part of the fields. Farmers were aware that leguminous crops (cowpea, groundnut, soya beans) supply "vitamin" to the soil. Growing an association of different species also stimulates a more efficient use of the soil, saves on land and labour, and reduces risks.

One response to soil fertility decline was to change the crop composition. Certain 'demanding' crops, such as bananas and maize were replaced by crops which perform on soils with low fertility or could improve the soil. These included millet, sweet potato and cassava. Farmers stated that sweet potatoes grow well on depleted soils and that its huge biomass production, in the form of leaves will improve soil fertility. Moreover, the soil will be turned during the harvest which, according to farmers, improves its fertility. Leguminous crops are also considered to improve the soil given their production of biomass and 'vitamins'.

Using intra-field soil fertility variations

Siaya farmers knew that some parts of a field were more fertile or easier to till than other spots. They exploited these gradations in fertility by adapting plant densities, crops species or intercropping combinations. This resulted in different micro-environments or niches within a field. Areas which were used for human settlements (old compounds or *gunda*) can be very rich in nutrients. They contained the cattle kraals with deposited manure, decomposed grass thatch from collapsed buildings, lots of household waste heaps and the former toilets. They were used for high nutrient demanding crops like maize and bananas.

5 Development of new technologies

Improved, short duration fallow

In order to restore soil fertility, land should remain under fallow for several years as the natural vegetation is slow in reaching its peak productivity. An alternative technology is to introduce new tree species for fallowing, which produce biomass more rapidly (Prinz 1986). These species produce wood and enhance soil fertility by bringing up nutrients from lower soil layers, through litter fall and by atmospheric nitrogen fixation. At the end of the fallow period, the trees are harvested and the biomass that cannot be used as fuel wood is returned to the soil, enhancing its fertility.

Farmers in Siaya are experimenting with two methods for improving fallowing, in collaboration with extension workers and researchers from ICRAF, KARI and KEFRI Maseno. A total of 158 farmers (over 10% of all households) are experimenting with improved fallowing on a total of 6.1 ha, combined for the three villages (Table 9).

Table 9. Number of farmers experimenting with improved fallowing and transfer of biomass in the three villages (1998)

Villages	No. of farmers improved fallow	Total plot sizes covered (M^2)	No. of farmers biomass transfer	Total plot sizes (M^2) covered
Luero	73	23 233	30	11 834
Muhanda	17	18 129	50	7 993
Nyamninia	68	10 204	40	3 268

Source: Own survey

The first method involves the establishment of a 6 month fallow. The preferred crop, usually maize, is planted during the long rainy season (April-July). After harvest, an improved fallow species such as *Sesbania* is planted on the same piece of land during the subsequent short rains (October-December). Researchers estimate the optimum density for *Sesbania sesban* to be about 20,000 plants per hectare. At the end of this season the fallow is cut down, and a crop of maize is planted on the same land in the next long rainy season. The second technology is based on a fallow period of one year.

Species such as *Sesbania sesban*, *Crotolaria grahamiana* or *Tephrosia vogelii* are planted between the maize rows during the long rains. When the maize crop is harvested, the fallow is left to grow right through the short rains and cut at the end. The land is then cleared for a new crop of maize during the following long rainy season.

In both cases, farmers lose only one growing season (the short rains), which is a period when crops do not grow very well. Farmers mentioned that this loss is compensated by a threefold yield increase in the following season. However, both the long and short rains are unreliable and farmers did not want to take the risk of leaving their entire field fallow. Instead they preferred to grow these shrubs on a small part of their farms or as a hedge around the field.

Green manuring and transfer of biomass

The majority of soils in Western Kenya are deficient in nitrogen, while maize is a major consumer of this nutrient (Smaling, 1993, Ogaro *et al*., 1997 AFRENA, 1996). Manuring with green biomass is therefore another improved technology proposed to farmers. Kahnt (1983) defines green manuring as the "working into the soil of green manure, non-woody plants, rich in water, sugar, starches, protein and nitrogen". The species used should have an extremely high capacity for assimilating nutrients from the soil. The biomass is then applied to the field. A regular flow of nutrients becomes available for the crop, when the organic matter is mineralised under normal decomposition conditions.

One of the most popular agro-forestry practices in the research area are hedges which demarcated boundaries of fields, farms and compounds. These hedges protect soils and crops as well as producing fodder, mulch and green manure. The most common species found in hedges are *Tithonia diversifolia* (wild sunflower) and *Lantana camara* (tick berry). *Tithonia* is also found along roadsides and on fallow land. Both species produce large quantities of biomass that can be incorporated directly into the soil as green manure or used as mulch. Farmers cut leaves and soft twigs of *Tithonia* from the hedges. They chop them into small pieces, and either place these in each planting hole or spread them evenly over the surface before incorporation into the soil. The leaves must be mixed well with the soil or left to decompose for at least one week before planting. Maize and other seeds may not germinate well if planted immediately after applying green manure. Farmers continuously apply this green manure during the growing period of the crop either by placing it along the rows of plants or by incorporating it into the soil.

Most farmers in the research villages applied less than the recommended rate of 5 tonnes *Tithonia* biomass per hectare (AFRENA 1996). Cutting and transport are very labour intensive. It takes about 4 minutes to cut 1 Kg of fresh *Tithonia* and one person can harvest 83-120 kg a day. Most farmers have therefore decided to plant *Tithonia* along borders, boundaries and contour lines. This will ensure a constant supply of biomass and reduces the labour needed to carry it to the fields. The technology is used by 120 farmers on a total of 2.3 ha (see Table 9). Half of the farmers in Luero village and almost all the farmers in Muhanda were of the opinion that biomass transfer required much more labour than the other technologies used for improving soil fertility. This is confirmed by the result of labour analysis which shows that the application of 5 tonnes *Tithonia* would require about 370 work days/ha (AFRENA 1996). The application of inorganic fertilisers or animal manure costs between 1 to 7 work days/ha (Jama *et al.*, 1996).

Experiments have shown that a combination of *Tithonia* and rock phosphate perform better than *Tithonia* only. The average maize yield on the 27 farms in Luero village involved in an on-farm research programme with ICRAF, was 1378 kg/ha for the combination of *Tithonia* and rock phosphate, and 807 kg/ha for Tithonia only. The bean yield was 809 kg/ha for the treatment combining *Tithonia* and rock phosphate, while the control produced 528 kg/ha. Rock phosphate is obtained from Minjingu in Tanzania and is not available on the market. Researchers now provide this free to those farmers who have offered their land for on-farm trials. The challenge is to create awareness on the benefits of rock phosphate for Western Kenya and to assure that it will be available from local traders.

6 Discussion and conclusions

Soil fertility decline is a major problem for farmers. It is caused by practices such as continuous cropping, lack of soil erosion practices, removal of crop residues from the field, reduction of fallow period, and insufficient application of manure and inorganic fertiliser. Underlying factors are increased population pressure, decrease in the size of land holdings, a decline in livestock numbers and a lack of cash. In response to soil fertility decline, farmers have developed soil fertility management strategies. Other coping strategies are swamp development to produce high value crops and urban migration to relieve pressure on the land.

Farmers use various indicators to assess soil fertility levels and will adjust management practices when they notice a decline in soil fertility. It is important to communicate with farmers by using their soil classification system. The science-based nomenclature of soils may prevent an effective interaction between extension agents, researchers and farmers.

Soil conservation methods should be encouraged. Unfortunately, the performance of most soil and water conservation projects is poor and there is a need for a thorough assessment of existing practices and professional norms. Projects and programmes must find ways of building on the skills, enthusiasm and knowledge of farmers.

This paper also reported on ongoing experiments with new technologies to restore soil fertility. One method is focussing on improved fallow with selected species of leguminous shrubs and herbs, especially *Sesbania sesban*. It performs best on soils that are deficient in both nitrogen and phosphorus. Preliminary results of trials indicate that crop yields can be improved considerably (AFRENA, 1997).

Biomass transfer is another potential technology for restoring soil fertility and improving crop yield. Biomass can be obtained from *Tithonia diversifolia* and *Lantana camara* which are found in hedges in the area. On-farm research has demonstrated a good response from maize when prunings are applied as green manure. However, the technology is very labour intensive. The quantity of biomass needed can be reduced when combining it with inorganic fertiliser. Crop yields will further increase when rock phosphate and manure are added. Another way of making biomass transfer more economically viable is by using it mainly for cultivating high value crops such as vegetables.

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ISSN 1560-3520