Managing Africa's Soils No. 13

# Managing fragile soils: A case study from North Wollo, Ethiopia

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SOS SAHEL

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## About the authors

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## About NUTNET

NUTNET is a network that aims to improve the management of soil fertility in Africa. It is a partnership of fifteen organisations from six African and two European countries: INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, Kenya; IER, Mali; Environment Alert & University of Makerere, Uganda; IES, Zimbabwe; IIED & IDS, United Kingdom; and AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, The Netherlands. NUTNET is funded by DGIS, Ministry of Foreign Affairs in The Netherlands.

## About *Enhancing soil fertility in Africa: from field to policy-maker*

The project *Enhancing soil fertility in Africa: from field to policy-maker* builds on the work done by NUTNET and receives funding from the European Union's International Cooperation for Development (INCO) programme. The NUTNET network has been extended to include the Swedish University of Agricultural Sciences (SLU), the Universidad Complutense de Madrid (UCM) and the National Agricultural Research Foundation (NAGREF) from Greece. The INCO programme links ongoing research projects related to the management of soil fertility in sub-Saharan Africa, paying special attention to the implications of diverse social, economic and environmental settings, and the differing perceptions stakeholders have of research and policy design.

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# Summary

This paper analyses the soil fertility management practices employed by farmers in the Meket district of North Wollo, Ethiopia. The environment in this area is severely degraded, and people have to cope with frequent droughts and chronic food insecurity. The average farmer in this low potential area cultivates less than one hectare of land, grows most crops for household consumption and often relies on livestock as the sole source of cash income. As many households do not own any livestock, the only option left to poorer farmers is to migrate in search of employment.

This study examines how farmers with varying resource endowments manage soils in three different agro-ecological settings: the highlands, the mid-altitude zone and the lowlands. Although the area was largely inherently fertile, degraded soils are now seen as the main constraint on production, as years of continuous cultivation and erosion have depleted stocks of nutrients and damaged the structure of many soils. Despite this state of affairs, farmers now use few of the techniques that were common in the past, and soil fertility management is largely limited to the application of mineral fertilisers and some measures to control erosion. Hardly anyone still uses mulch, manure or trash lines on their fields, as all the crop residues are needed to feed livestock, while the eradication of most forests from the zone means that manure is used as fuel rather than as a fertility input.

Over the past twenty years agricultural extension has tended to focus so exclusively on packages of specific technologies that it has failed fully to address the problems faced by farmers in the area. In the 1980s extension revolved entirely around soil conservation, ignoring other forms of soil management and land use, and since 1995 the emphasis has shifted to promoting mineral fertilisers and improved varieties of crops.

Mineral fertilisers may provide a valuable source of nutrients and they are now used by 50% of farmers in the study sites, given the scarcity of manure and biomass in the region. However, our survey suggests that the potential for fertiliser-based extension is limited to the better-off farmers working on deep soils in the highlands. Extension packages focusing solely on mineral fertilisers are inappropriate for farmers in marginal areas, who can only consider low cost, low risk strategies.

In view of the fact that farming systems in Wollo are in desperate need of effective support, agricultural extension should focus on developing systems of integrated nutrient management, which combine the use of mineral fertilisers with organic inputs and soil conservation measures, and can be adjusted to suit the specific circumstances of different farmers.Given the lack of available land in Wollo, there is also an urgent need to explore the possibilities of diversification and off-farm activities as a means of reducing pressure on land and achieving some measure of security of livelihood.

# French summary

Ce document analyse la gestion de la fertilité des sols pratiquées par les paysans du district de Meket dans le Wollo-Nord en Ethiopie. La région a un environnement sévèrement dégradé, connaît fréquemment des sécheresses et souffre d'une insécurité alimentaire chronique. Le paysan moyen dans cette région à faible potentiel cultive moins d'un hectare de terre, produit essentiellement pour la consommation familiale et, souvent, dépend de son bétail pour sa seule source de revenus. Comme beaucoup de ménages n'ont pas de bétail, la seule option pour les paysans pauvres est de migrer à la recherche d'un emploi.

Cette étude examine comment les paysans de différents milieux agroécologiques (haute, moyenne et basse altitude) et avec les différentes ressources à leur disposition, gèrent leurs sols. Bien que la plupart des sols de la région étaient intrinsèquement fertiles, la dégradation du sol est maintenant perçue comme le principal obstacle à la production, après des années de culture ininterrompues et d'érosion qui ont épuisé les réserves d'éléments nutritifs et endommagé la structure de nombreux sols. En dépit de cette situation, les paysans appliquent désormais peu des techniques de gestion de la fertilité des sols qui étaient couramment utilisées par leurs aïeux. La gestion de la fertilité des sols se limite souvent à appliquer des engrais minéraux et à contrôler un peu l'érosion. Pratiquement plus personne ne répand de paillis, de fumier ou de déchets végétaux dans les champs car tous les résidus de récolte servent à nourrir le bétail. La disparition de la plupart des forêts de cette région signifie que les déjections servent de combustible au lieu de vecteur de fertilisation.

Depuis une vingtaine d'années, le développement agricole a eu tendance à porter de manière tellement exclusive sur quelques technologies spécifiques qu'il est passé à côté des problèmes auxquels les paysans de la région sont confrontés. Dans les années 1980, il portait essentiellement sur la conservation des sols, laissant de côté les autres formes de gestion des sols et d'utilisation des terres. Après 1995, l'accent est mis sur la promotion des engrais minéraux et l'amélioration des variétés cultivées.

Du fait de la rareté du fumier et de la biomasse dans la région, les engrais minéraux peuvent constituer une source précieuse d'éléments nutritifs et 50% des paysans maintenant les utilisent. Cependant, notre enquête semble indiquer que les possibilités de développement par les engrais sont limitées aux paysans les plus aisés travaillant les sols profonds des hautes terres. Les engrais minéraux ne conviennent pas aux agriculteurs des zones marginales qui ne peuvent considérer que des stratégies peu chères et peu risquées.

Cela est particulièrement dommage, car les systèmes de culture à Wollo semblent avoir atteint un point crucial et ont terriblement besoin d'un soutien effectif. Le développement agricole devrait se pencher avant tout sur les systèmes de gestion intégrée des éléments nutritifs qui associent l'emploi d'engrais minéraux, les apports de matières organiques et les mesures de conservation des sols. Ces systèmes devraient s'adapter aux situations particulières des différents exploitants. Vu la pénurie de terres disponibles à Wollo, il convient aussi d'explorer les possibilités de diversification et les activités non agricoles afin de réduire la pression sur les terres et de prendre des mesures pour améliorer la sécurité des conditions d'existence.

# 1 Introduction

While North Wollo has a long history of settled agriculture dominated by cereal-based farming systems, this drought prone, low-potential area of Ethiopia is now subject to severe environmental degradation, which has provoked chronic food insecurity and occasional famines (FAO, 1986; Getachew, 1995). In 1999 and 2000 rains have failed again and the people in North Wollo are now facing severe food shortages.

The most important technical constraints on crop production in the Meket district of North Wollo (see map) are soil erosion and declining soil fertility. This study analyses the diversity and dynamics of soil fertility management practices employed by farmers, examining how they perceive environmental change and deal with the constraints on production. It also considers the nature, dynamics and diversity of soil fertility management practices in each agro-ecological zone and socio-economic group, focusing on the key question of whether these practices can reverse the process of soil degradation.

Meket was of particular interest as a study site because the NGO SOS Sahel is coordinating an integrated rural development programme in the area, which is concentrating on the management of natural resources and the promotion of initiatives to improve the ways in which farmers manage soils and nutrients.

## Methodology

Preliminary surveys done by SOS Sahel prior to the launch of the project provided useful background information for this study, while a review of other secondary sources revealed much about the dynamics of the farming system and changes in land husbandry practices in Wollo.

Having reviewed the published material relevant to our study, we embarked on six months of fieldwork, which included formal and informal farm surveys, and detailed case studies of innovative soil fertility management practices. The surveys were carried out in three different agro-ecological zones: the humid highlands, sub-humid areas at mid-altitude, and the semi-arid lowlands. Development agents from the Woreda Office of Agriculture and SOS Sahel field staff, who were all very knowledgeable about the area, assisted with the selection of one representative village from each zone. Twenty resource people were selected from each village and asked to participate in a group discussion. We also used focused questionnaire to interview fifty households from each agro-ecological zone (one hundred and fifty in all). The set up for this study, the method of selecting samples, and the format of the surveys are similar to a previous study of farming systems based on enset and root crops in southern Ethiopia (Eyasu, 1997; Eyasu, 1998: Eyasu, 2000).

The sample for the questionnaire was stratified into socio-economic groups that were defined in a wealth-ranking exercise carried out by key local informants from Meket, who were assisted by extension workers. The main indicators of wealth were identified as ownership of livestock and household food security. A household is considered to be prosperous if it has at least one pair of draught oxen and sufficient grain reserves to sustain the family over a prolonged drought or through successive crop failures. Although the size of land holding influences the prosperity of a household, farmers did not use it as a criterion of wealth, reasoning that all land belongs to the State and is subject to redistribution. They used the selected indicators to categorise all households into four socio-economic groups: rich, moderately wealthy, poor and very poor. Table 1 below summarises the relative proportions of the different groups, showing that the highest concentration of very poor people was found in the lowland zone. A proportional sampling technique was then used to select farmers from each socio-economic group for the questionnaire.

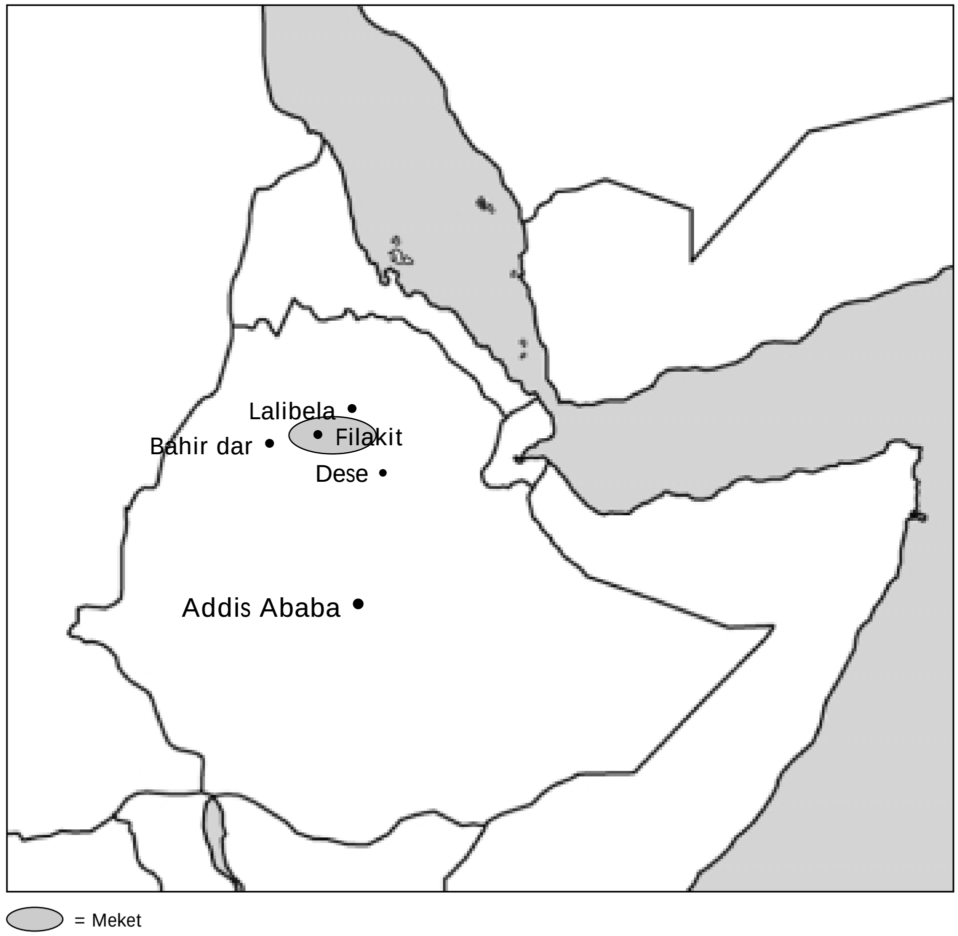
Table 1. Relative proportion of socio-economic groups per agro-ecological zone (%)

| *Resource group* | *Highland* | *Mid-altitude* | *Lowland* |
|---|---|---|---|
| Rich | 10 | 12 | 10 |
| Moderately wealthy | 26 | 22 | 16 |
| Poor | 28 | 34 | 24 |
| Very poor | 36 | 32 | 50 |

Data for 1999, N=50 per zone.
*Source*: own survey.

Group discussions covered local perceptions of agricultural history and environmental change, developments in the management of soils and nutrients, crop and livestock husbandry practices, and changes in yields. The indigenous system of classifying soils was also assessed, and further explored during transect walks. The questionnaire was used to collect more precise information about the range of strategies currently used to manage soils and nutrients, and about the socio-economic factors affecting the management of soil fertility.

Location of the Meket district



# 2 Agriculture in Meket District

Meket district is located 600 km north of Addis Ababa, in the North Wollo zone of Amhara regional. The landscape of North Wollo is spectacular and very rugged. The terrain is composed of mountains whose peaks rise to over 3,500 meters above sea level (masl), surrounded by steep gorges and broad valley escarpments, and high plateaux dissected by deep valleys created by rivers and streams.

There are four main agro-climatic zones in the study area (SOS Sahel, 1997). These are the semi-arid lowlands less than 2,300 masl, the sub-humid midlands at 2,300 to 2,800 masl, the humid highlands 2,800 to 3,200 masl, and the very-humid high altitude plateau, which, at over 3,200 masl, is often battered by frost and hail. These definitions are particular to North Wollo, and differ from standards generally applied in Ethiopia, as an area classified as lowland in Meket would be regarded as part of the highlands elsewhere.

The highest densities of humans and livestock are found in the humid and sub-humid highlands. The very-humid *wirch* zone is characterised by cool, wet weather conditions, and as frost makes the area unsuitable for cultivating crops, farmers specialise in rearing livestock, particularly sheep. The combination of erratic rainfall and poor soils, and the prevalence of human and livestock diseases in the semi-arid lowlands make this area unattractive to farmers.

Although there are no meteorological stations in Meket, some of the farmers in the area record rainfall data for the Woreda Office of Agriculture. The estimated average annual rainfall ranges from 600mm in the lowlands to 1000mm in the highlands (SOS Sahel, 1997). Farmers reported that there used to be two distinct seasons; the *belg* or short rains between February and May, and the main *meher* rains from June to August. The *meher* rains are generally reliable and evenly distributed, but the *belg* rains have become increasingly unpredictable, often failing completely. This has resulted in a growing tendency to cultivate crops only in the *meher* season, which has significant implications for annual production levels, as the *belg* crop used to account for up to 40% of the total harvest (Dessalegn, 1991).

Most of the Meket district is now used for agriculture, and there is little left of the original vegetation, although some *Juniperus procera* (tid), *Podocarpus gracilior* (zigba) and *Olea africana* (woira) can still be found in church compounds and deep, inaccessible gorges. There is widespread deforestation and erosion, areas of bare rocks are now common in the district and several farms are covered with stone mantles. Farm borders and riversides are severely overgrazed, and in the eroded wastelands only a few shrubs and scattered small trees rise above stands of annual grasses. The area used to provide enough wood and grazing lands to meet the needs of local people, but these natural resources have been virtually exhausted as fields and settlements have expanded, and more and more wood is removed for domestic consumption. Firewood is now so scarce that dung cakes are used as fuel. Some farmers plant eucalyptus around their homesteads, carefully protecting it with stone walls.

## Soils

The wide diversity in climate, topography and vegetation in the area has given rise to marked variations in soils, even within relatively small areas. No detailed soil surveys have been carried out in Meket, but the red to red-brown clay soils common on the high, rolling plateaux seem to be relatively fertile, with a higher organic matter content and lower susceptibility to erosion than other soils. However, many years of continuous cultivation, limited application of nutrients and the removal of all crop residues have depleted the stocks of soil nutrients. Soils in depressions and at the foot of the mountains tend to be black and liable to water logging during the rainy season, while those in elevated areas are likely to be highly leached, acidic and deficient in phosphorus and nitrogen. Erosion is the major problem on steep slopes (Murphy, 1968; World Bank, 1983; FAO, 1986).

Farmers in the area have their own way of describing and characterising soils in their fields, based on levels of fertility, and physical properties such as colour, depth, workability, susceptibility to erosion, and drainage and water holding capacity (see Table 2). The management of soil fertility and other agronomic practices vary according to each soil type. Two types dominate all the agro-ecological zones: *walka* and *keyate. Walka* is a relatively fertile black cotton soil, but it has physical limitations similar to Vertisols, cracking when dry and becoming waterlogged and difficult to work when wet. It covers an extensive area in the mid-altitude zones and the lower parts of the mountains. The red-brown *keyate,* which has similar properties to Nitisols, dominates the high plateaux and escarpments, and farmers estimate that it covers about 60% of this area. The major problem with this soil is that it is highly susceptible to erosion and therefore likely to become shallow, infertile and unproductive. *Nechate* is a highly degraded, whitish soil associated with *walka* and *keyate* soils, where patches of bare rock render the area unsuitable for the cultivation of crops. Other, less important soil types include *taskima*, a well drained, humus rich soil found along the escarpment, and generally planted with wheat and lentil; and *tazmima*, a brown, stony and very shallow soil that is usually planted with sorghum and chickpea.

Table 2. Local system of soil classification in Meket

| *Soil type* | *Properties as described by farmers* | | | | | *Management practices* |
|---|---|---|---|---|---|---|
| | *Fertility* | *Colour* | *Depth* | *Soil moisture* | *Workability* | |
| *Walka* (black cotton soil) | ++ | Black | ++ | +/– | – | Only ploughed after good rains; becomes waterlogged when wet, cracks when dry |
| *Keyate* (Nitisols) | – | Red-brown | – | + | ++ | Requires soil conservation, stone mantled at times |
| *Taskima* | + | Brown | + | ++ | ++ | Requires soil conservation |
| *Tazmima* | +/– | Brown | – | – | + | Stones in field |

Source: SOS Sahel baseline survey (1997) and PRA exercise with farmers carried out during the study.

## Settlement patterns and local organisations

The average family in the district consists of four to six people. The estimated population density is 76 pp/km$^2$, with an annual growth rate of about 2.4% (SOS Sahel, 1997), although this average masks variations between the different agro-ecological zones. Population density is highest in the most elevated areas, gradually decreasing towards the lowlands, which were previously avoided because of the prevalence of disease and less favourable conditions for agriculture. However, settlement in the area is now increasing as population pressure mounts in the highlands.

The stone walled houses in this area are generally located on the plateau or on hilltops. Almost totally bare of trees or vegetables, dwellings are clustered into small hamlets of 30-40 families, all members of the same lineage. This pattern evolved from the practice of establishing settlements near church compounds, for reasons of security and to meet social needs. Ten to twenty such compounds form a parish, and a group of parishes makes up a *got.* NGOs have found that these traditional community organisations are effective and efficient channels for planning and managing development programmes.

The smallest administrative units in the area are the Peasant Associations, or PAs, which were established after the revolution of 1974. Meket district has forty PAs, each covering around 800 ha. They have a wide range of functions, including the administration of land within their area, the resolution of local conflicts, issuing regulations, and responsibility for the security and development of infrastructures such as schools, clinics and roads. Each PA also has a formal village development committee, the *mengistawai budin*, which is mandated to mobilise people for various development activities, such as the construction of conservation bunds and infrastructures.

Some PAs have formed Service Co-operatives (SCs), which are now the main channel through which farmers obtain fertilisers and other agricultural inputs. Using loans from the Commercial Bank of Ethiopia or the Amhara Credit and Saving Institute, Service Co-operatives purchase fertiliser from trading companies and distribute it to farmers on credit.

## Land tenure

Radical changes in government over the last thirty years have had a significant impact on land tenure in Ethiopia.[1] Until the revolution of 1974, the country had an imperial regime, and was a feudal state under Amhara rule. There were three tenure arrangements in northern Ethiopia: *rist,* which was communal or village land; *gult*, land that belonged to the ruling class but was worked by farmers who paid tributes to the landowners; and *semon* or church land, which was also cultivated by farmers in return for a tribute (Dessalegn, 1984). The *rist* system covered most cultivated land, giving individuals with kinship ties to the original founder access to land. However, holdings became smaller and fragmented as *rist* land was periodically redistributed to accommodate newcomers and, as their tenure became insecure, farmers were less willing to invest in measures to conserve soil and water.

After the Revolution of 1974 the government implemented radical land reforms, nationalising all rural land, which has since been administered by the PAs. Tenants were freed from paying feudal contributions and the obligation to work for their landlords, and acquired use rights to the land they cultivated. However, these rights were by no means secure, as land was subject to reallocation by the PA authorities. No land has been distributed in Wollo since 1997, and the government has prohibited any further reallocations until it has clarified its land policy.

## Patterns of land use

The Meket district covers a total area of 21,600 ha, 39% of which is agricultural land, 18% is settled, 7% is taken up by grazing land, and 8% consists of bush and scrub. The remaining 28% is eroded wasteland that is no longer suitable for cultivation (Azene, 1995). Farms contain several types of fields: the home fields, or *wojed,* which are plots close to the homestead, and the outfields, or *teklit,* located 3 to 5 kilometres from the house. Some farmers in the highlands also have private grazing plots.

[1] For a detailed description of the dynamics of tenure arrangements in Wollo see McCann, 1987; Dessalegn, 1984 and Pausewang, 1990.

Women are mainly responsible for managing the homestead plots, which are grown with crops that require good soils and plants that will provide seeds for the next season. These include maize and high value cash crops, such as vegetables and flax, and *noug* (G*uizotia abyssinica)* and safflower, which are grown for oil. Some organic fertiliser is applied to these plots, in the form of household refuse, or droppings and dung deposited when livestock are penned in the area. The more distant *teklit* plots are largely planted with wheat and barley, and are not fertilised.

The average area cultivated by each household is 0.7 ha in the highlands, 0.6 ha in the mid-altitude zone and 0.9 ha in the lowlands. In the highlands, farmers have private grass plots whose average size is 0.14 ha (see Appendix 1 for more details).[2] Arable land is more plentiful in the lowlands, although the soils are more fragile and less productive than those in the highlands. The main constraints on production in the lowlands are the lack of draught oxen and labour, which result in some areas of land being left fallow. Sharecropping is rare in North Wollo.

Landholdings are unevenly distributed and in all zones the biggest holdings are held by richer farmers (see Appendix 1). It seems that those who are currently better off benefited from the fact that they had large families when land was distributed after 1974, and were therefore allocated more land than households with fewer members. Having acquired plots of varying levels of fertility in several locations, such as the valley bottom and plateau, these farmers could also exploit different niches, reducing the risk of overall crop failure and improving their food security.

## Farming systems

There are four main farming systems in Ethiopia, one of which is the cereal farming system of the north-central highlands.[3] With widespread soil erosion and low, erratic rainfall, Meket district is classified as a low potential cereal zone (FAO, 1986), and farming in the area is based on a combination of crop cultivation and livestock rearing.

Crops are mainly produced for home consumption, while most of the income for household expenses is raised by selling animals. Resource-poor people often migrate on a seasonal or permanent basis, going to towns or state farms in search of employment. In one lowland village, it was found that 20% of those with limited access to productive assets such as land, draught oxen or seed had migrated out of the area.

In the highlands the main cereals are wheat, barley and teff, while sorghum and maize predominate in the lowlands. Root crops are not widely cultivated in the study area. In the high and midland areas about 60% of the total cultivated area is planted with a

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2 These data are comparable to the size of average recorded for western Wollo (Desalegn, 1991; Alemneh, 1990).

3 The other farming systems are the enset planting complex of the southwestern highlands; shifting cultivation in the southwest of the country; and the pastoral systems in the driest zones of Ethiopia.

mixture of wheat and barley, known as *wassera*, which is planted, harvested, threshed and eaten as a single crop. Farmers said that this enables them to use land and the moisture and nutrients available in the soil more efficiently, while reducing attacks by pests, which do less damage to *wassera* than to pure stands.

Legumes are no longer commonly rotated in the area, although poorer farmers with limited access to draught oxen tend to grow more field peas and horse beans, as it is not necessary to repeatedly plough the seedbed for these crops. Despite their awareness that a rotation with legumes will improve soil fertility and interrupt cycles of disease and pests, farmers prefer to increase their total grain harvest by concentrating on cereals. By no longer cultivating legumes, they also avoid the problems caused by their sensitivity to certain pests and diseases such as weevils, mildew, and the damage caused by hail.

Farmers start to prepare land in December, using local ploughs drawn by draught oxen or donkeys. They believe that ploughing improves fertility by incorporating organic matter and crop residues into the soil.

## Livestock management

Livestock not only provide draught power and manure, but also a measure of security, since they can be sold to raise cash when times are hard. Cattle are generally the preferred species because they are the main source of draught power, and also provide fuel in the form of dung cakes (Appendix 2). Sheep are more important in the high altitude zones, while goats are better adjusted to the climatic conditions in the lowlands.

In the intermediate and lowland zones communal areas are freely grazed, although the predominantly scrubby bush provides only limited forage. Livestock are given teff straw and other crop residues as supplementary feed, with draught oxen receiving preferential treatment. As population pressure in the highlands has increased, the area under cultivation has expanded, and most of the land previously used as communal grazing is now taken up by agriculture. The remaining grazing areas have been allocated to individual households, with land apportioned according to the number of animals owned at the time the land was distributed. Forage has become such a scarce resource that some farmers have even started watering their grass plot during the dry season.

On average, livestock ownership is highest in the highlands, where there is the greatest concentration of sheep. The average farmer in the highlands owns 3 TLUs,[4] compared to 1.3 TLUs in the mid-altitude zone and 1.2 TLUs in the lowlands (see Appendix 1), where livestock are most at risk from periodic droughts and outbreaks of disease. Many farmers in this area have to sell animals to meet their daily needs, but then lack

4 Tropical Livestock Unit. TLU is calculated on the basis of the following standard values for Africa given by Jahnke (1982): 1 adult cattle or equine = 0.7 TLU, 1 goat or sheep = 0.1 TLU, 1 calf = 0.4 TLU.

the means to restock their herds. Shared rearing of livestock is not very common in North Wollo.

In view of the fact that wealth ranking was mainly based on the ownership of livestock, it was not surprising to find that the richer groups own the most animals in every zone. It was found that 33% of the households interviewed had no livestock, and as all of these households belong to the least endowed group, one can assume that they have limited or no access to draught power, manure or cash from the sale of animals. Data from the survey also revealed that 24% of households had only one ox, and about 60% had none at all. Those who own a single ox make arrangements with friends in the same situation, taking turns to use the pair. Farmers without oxen can rent or borrow them, although they have to wait until the owners have finished ploughing. As the going rate is two to three days of human labour to use a pair of oxen for one day, poorer farmers have less time to invest in their own farms, and little chance of improving their economic situation.

# 3 Dynamics of soil fertility management

## Changes in crop yields

The rural population in North Wollo has suffered from successive droughts and famines, with an average of one famine every five years over the last few decades (Getachew, 1995). These have been provoked by drought, invasions of locusts, the degradation of land, a decline in landholding caused by population growth, and the fact that certain policies have proved to be disincentives to farm (Getachew, 1995; Dessalegn, 1991; McCann, 1987). The civil war that erupted in the 1980s reduced most parts of Wollo to a battlefield, with grave implications for land husbandry practices and agricultural production.

All the farmers that we interviewed reported that yields of the main cereals have declined dramatically over the past thirty years. Table 3 presents the mean crop yields of the major cereals grown in Meket, which were calculated on the basis of estimates made by farmers, and are compared with data on national yields. As they looked back at trends in production, farmers identified three periods: the time before the revolution of 1974, the post-Revolution period (1974-1994), and the start of the PADTES extension programme in 1995.

The year 1974 was used as a bench mark against which people measured subsequent environmental changes, having been etched in the collective memory as a year of drought, famine and revolution. Farmers estimated that before 1974 the major crops yielded more than they do now (Table 3), and that in climatically good years the average household could meet the nutritional requirements of the family. Although there were periodic food shortages caused by drought or invading locusts, they were less frequent than they are now, occurring every twenty years or so, and the production system was able to recover from such calamities without outside help.

The redistribution of land that occurred between 1974 and 1994 does not seem to have influenced agricultural production, and crop yields remained stable in the high and mid-altitude zones. Although they fell significantly in the lowlands, farmers attributed this to the fact that rainfall was lower and more erratic over this period. In 1995 the government extension programme started promoting the use of mineral fertilisers, which were new to this area, although the farmers we interviewed seem to think that these fertilisers had less effect on crop yields in Meket than they did in the high potential cereal zones (Quinones et al., 1997).

Yields for wheat and teff remained stable, but increased for barley grown in the highlands. However, all cereal yields declined sharply in the mid-altitude and lowland zones which farmers mostly attributed to declining and increasingly erratic rainfall. Farmers in the lowlands do not use mineral fertilisers, as unreliable rainfall increases the risk of crop failure and reduces expected returns, while their colleagues in the mid-altitude zones noted that fertilisers were washed off the sloping land by runoff water. These inputs are of limited benefit in the mid-altitude zones anyway, as erosion has reduced the depth of the soil, diminishing its capacity to hold water and depleting the supply of available nutrients. In view of estimates that soils in 72% of the highlands in Wollo over 1500 masl are only 10 cm deep (Barber 1984), the response to mineral fertiliser and improved seeds will be limited in many soils in the Meket area.

Table 3. Estimated changes in crop yield given by farmers (kg/ha)

| *Zone* | *Crops* | *Before 1974* | *1975 to 1994* | *1995 to present* |
|---|---|---|---|---|
| Highlands | Wheat | 850 | 800 | 800 |
| | Barley | 800 | 750 | 860 |
| | Teff | 600 | 500 | 500 |
| Mid-altitude zone | Maize | 1200 | 1000 | 400 |
| | Wheat | 800 | 700 | 350 |
| | Barley | 780 | 700 | 200 |
| | Teff | 500 | 600 | 350 |
| | Sorghum | 600 | 500 | 200 |
| Lowlands | Maize | 1550 | 800 | 400 |
| | Teff | 600 | 400 | – |
| | Sorghum | 900 | 700 | 300 |
| National average | Maize | 1400 | 1200 | 1600 |
| | Barley | 1000 | 1200 | 1100 |
| | Teff | 800 | 900 | 800 |

Source: Own survey and Ministry of Agriculture.

## How farmers assess constraints on production

Table 4 below presents the way in which farmers rank constraints on production. All those interviewed identified declining soil fertility as the main problem, commenting that "*the soil used to be full of energy and productivity in the past, but now it has become dumb, blind and deaf, without response to management. It is shallow, stony and easily erodible, and produces some unwanted vegetation.*" They believe that this decline in fertility is caused by soil erosion, the fact that land is no longer left fallow, and insufficient use of fertiliser.

Other key problems across the area were the shortage of oxen and low, erratic rainfall. Scarcity of land is also a major constraint in the high and mid-altitude areas, while lack of labour causes the most concern in lowland zones. Other challenges included pests, animal disease and, in the case of resource-poor farmers, lack of seed.

Table 4. How farmers prioritise constraints on production

| *Zone* | *Most serious constraint* | *2nd most serious constraint* | *3rd most serious constraint* | *4th most serious constraint* | *Other problems* |
|---|---|---|---|---|---|
| Highland | Low soil fertility | Lack of draught oxen | Erratic rainfall | Shortage of land | Crop pest (army worm) |
| Mid-altitude | Low soil fertility | Shortage of land | Erratic rainfall | Shortage of oxen | Animal disease |
| Lowland | Low soil fertility | Erratic rainfall | Shortage of oxen | Shortage of labour | Lack of seed |

Source: Own survey.

Erosion is often seen as the main cause of declining fertility in the north central highlands (Hurni, 1988; Campbell, 1991; FAO, 1986), where it has been exacerbated by the clearing of forests and cultivation of marginal lands. Scarcity of land has forced farmers in the high and mid-altitude zones to cultivate slopes on mountains and escarpments, where the gradients often exceed 50%. Part of the problem is that farmers not only lack the resources to install measures to prevent erosion, but that some of their farming techniques may actually trigger it. These include the repeated ploughing of soil for some cereals; the removal of crop residues, which leaves fields without any protective vegetative cover during part of the rainy period; and the fact that animal dung is primarily used as fuel rather than for maintaining soil fertility. As runoff removes fine particles and organic materials from the productive topsoil, the physical structure of the soil deteriorates, making it shallower and reducing its capacity to hold water (FAO, 1986; Eyasu, 1997).

## Soil fertility management strategies

### A historical perspective

In the past, farmers used to let land lie fallow for at least ten years to maintain and restore soil fertility, as well as growing legumes in rotation with other crops, and using soil conservation measures such as stone bunds. As the human and livestock population increased, land became scarcer, and farmers abandoned the practice of letting land lie fallow for long periods. Although it is generally believed to be beneficial by farmers, only 18% of those interviewed indicated that they use seasonal fallow. Researchers considered seasonal fallow to be of limited use because it is of such short duration. Most of these farmers that still use fallow come from the less densely populated lowlands, and it seems that many only continue with the practice because they lack the labour or draught power to cultivate their land.

Long periods of continuous cropping and sustained erosion have depleted soil nutrient stocks and undermined the physical condition of the soil, while population pressure has pushed agriculture into marginal areas where slopes are steep and soils shallow. Unless conservation measures are installed and regularly maintained, these sites are particularly prone to erosion.

Having come to the conclusion that the great famine of the 1970s and 1980s was precipitated by the overuse and degradation of natural resources caused by overpopulation, the government initiated a series of resettlement programmes, which were also implemented for political reasons. Thousands of families from areas of Wollo affected by the drought were forced to resettle in relatively fertile and unoccupied regions in the south and south west of Ethiopia, many of whom have since returned to the villages from whence they came.

In the 1980s, recognising the extent to which soils had become degraded, the government also initiated a massive programme of soil conservation and rehabilitation in the worst affected areas, which included Meket. The technical package for cultivated fields recommended the construction of stone and soil bunds at 1 metre intervals along the contour, to reduce the speed of runoff, allow deposits to accumulate behind the bunds and gradually form bench terraces, and to protect the soil below (Hurni, 1988). Other activities included the construction of hillside terraces, the enclosure of certain areas to allow vegetation and soil to regenerate, some tree planting and the construction of checkdams in gullies (Hurni, 1988; Campbell, 1991; Kruger et al, 1996).

Soil and stone bunds were built on hundreds of thousands of hectares of cultivated land in the central and northern highlands. The conservation work was centrally planned, and community labour mobilised in food for work schemes. However, as they had not been consulted about the installation of these conservation structures, neither farmers nor the community felt any sense of responsibility for them (see Wood, 1990; Campbell, 1991; Kruger et al, 1996), and only 35% of the farmers interviewed in our survey said that they maintained some bunds constructed by the food for work programme. These programmes did not take sufficient account of the diversity of biophysical and socio-economic conditions in the country, and imposed technical solutions without properly understanding the priorities or soil management strategies of the farmers they were supposed to be helping. The enforced measures were generally incompatible with existing practices, and consequently neither lasted nor achieved much in terms of improving degraded land.

It is now accepted that farmers have to be involved in the decision making process, and that they should be given a central role in the development of agricultural technology. Furthermore, in order to achieve solutions that are both sustainable and socially acceptable, interventions should be based on a solid understanding of local land husbandry practices. The design of such solutions requires an approach that allows for adaptive testing and monitoring of alternative options, with farmers at the centre of the process.

Although there is still an element of coercion in the way in which some conservation structures are installed on communal lands at village or PA level, it seems that some positive changes are afoot. The zonal department of agriculture of North Wollo is discussing a new initiative to manage natural resources and promote sustainable agriculture, with a view to developing community-led, participatory approaches at catchment level (DoA, 1999). This will involve stakeholder analysis, joint planning and implementation and the establishment of coordinating committees at catchment level. The first step is to develop methodologies and technologies, and to build capacity within the ministry and other agencies such as NGOs, to facilitate the implementation of such an approach.

### Current soil and nutrient management practices

Table 5 summarises the soil fertility management strategies employed by farmers from different socio-economic groups and agro-ecological zones. They include the application of mineral fertiliser, very limited use of organic manure, the practice of spreading soil from termite mounds on fields, and various soil conservation measures. Despite the fact that farmers in Meket consider declining soil fertility to be the main constraint on agricultural production, the use of soil and nutrient management practices seems to have declined over time.

The soil and nutrient management practices employed in Meket are relatively simple compared with those used in Wollaita, in southern Ethiopia. Another densely populated mountainous area, Wollaita has higher rainfall and is at lower altitude than Meket, with a farming system based on enset and rootcrops in the homefields, and cereals in the outfields. Farmers invest a considerable amount of labour in enriching the soils of the homefields, using intensive conservation practices and a wide range of inputs such as manure, compost, household refuse and leaf litter. Manure is used primarily as a fertiliser rather than for fuel, and ashes and household residues are used extensively to maintain soil fertility (Eyasu, 1998; Eyasu and Scoones, 1999).

## The use of mineral fertiliser

The first extension programme promoting mineral fertilisers in Meket was launched in 1995 under the Participatory Agricultural Development Training Extension System (PADTES). Under this programme ‘demonstration plots’ of 0.5 ha were set up, where

Table 5. Soil fertility management strategies employed by farmers in different agro-ecological zones (%)

| *Strategy* | *Highlands (n=50)* | | | | *Mid-altitude (n=50)* | | | | *Lowlands (n=50)* | | | | *All (%)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rich n=5 | Average N=13 | Poor N=14 | Very poor n=18 | Rich n=6 | Average n=11 | Poor n=17 | Very poor n=16 | Rich n=5 | Average N=8 | Poor n=12 | Very poor n=25 | |
| Mineral fertilisers | 80 | 100 | 79 | 44 | 100 | 100 | 82 | 38 | 20 | 31 | 0 | 0 | 50 |
| Manure | 40 | 0 | 0 | 6 | 17 | 9 | 0 | 0 | 0 | 0 | 25 | 0 | 5 |
| Termite mounds | 0 | 0 | 0 | 0 | 67 | 82 | 10 | 63 | 60 | 63 | 0 | 12 | 32 |
| Short fallow | 0 | 8 | 0 | 6 | 33 | 36 | 59 | 19 | 80 | 38 | 42 | 8 | 18 |

Source: Own survey.

farmers could use mineral fertilisers in combination with improved seeds and other agrochemicals. A blanket recommendation of 100 kg Di-Ammonium Phosphate (DAP) and 75 kg/ha of urea is promoted by PADTES all over Ethiopia, with the DAP to be applied at the time of planting, and urea as a top dressing after the first weeding or 40-45 days after the plants emerge. Potassic fertilisers are generally not applied, on the assumption that there are adequate supplies of potassium, although the Soil Science Society of Ethiopia is currently considering the growing concern that certain highland soils may be deficient in this mineral.

While the number of farmers participating in PADTES has increased considerably over the last five years, there is a marked tendency for poorer farmers to use the least mineral fertilisers (see Table 5). Our survey showed that about 50% of all those interviewed now use some mineral fertilisers to restore soil fertility. Almost all came from the high and mid-altitude zones, although two richer farmers from the lowlands who have fields with good soils reported that they use fertiliser.

The extension package focuses only on mineral fertilisers as a means of improving soil fertility, but since subsidies on fertilisers were removed in early 1996, many farmers can no longer afford them. Producers in marginal areas can only consider low cost, low risk technology options. Most of the farmers who do not use mineral fertilisers cited poor response and high cost as the main constraints, coupled with the fear of running into debt in the event of poor harvest or crop failure. In the highlands, the main risk is crop damage by frost, while the most common cause of poor harvests in the lowlands is inadequate rainfall and pest attacks. As crop response to fertilisers is generally poor on severely eroded and degraded soils, farmers tend to focus on sorghum, which yields satisfactorily on poor soils, whether or not inputs are applied.

### Rate of application

Table 6 shows the amount of fertiliser applied by farmers from different zones and socio-economic groups. On average, those in the highlands use 50 kg DAP and 28 kg urea per ha, while in the mid-altitude zones farmers apply 28 kg DAP plus 25 kg urea. Only a few resource-rich farmers use the recommended rate. With more cash, and livestock that can be used as collateral for credit to buy fertiliser, the richer farmers can purchase much more fertiliser than their poorer colleagues. We found that two or three resource-poor farmers share a 50 kg bag of fertiliser, which is carefully applied to small, infertile patches of land.

There is also some variation in the amount of fertiliser applied in each zone. Farmers in the mid-altitude zone use less than their counterparts in the highlands, as it is liable to be washed away by runoff on the steep slopes of the escarpment, and there is also the risk of crop failure due to moisture stress.

Farmers adjust their applications to each soil type and its perceived fertility status, the gradient of the slope, and the type and variety of crop; while taking account of how vigorously plants are growing and the extent to which lodging is likely to be a problem. Mineral fertilisers are generally concentrated on fields that are expected to give the best response, and therefore the best economic return on inputs, so they are on *keyate* soils, but not on the waterlogged *walka* soils (see Table 1). Most fertiliser is applied to wheat, followed by barley, while applications to teff are kept low to avoid lodging, and none is used on sorghum, which responds poorly to inputs.

## The use of organic fertilisers

A wide range of organic materials can be used to maintain and improve soil fertility. Manure, compost, crop residues, green manure, household refuse and leaf litter all improve the structure of the soil and its capacity to hold water, while maintaining soil organic matter and contributing to the nutrient content of the soil. However, Table 5

Table 6. Amount of fertiliser applied by each socio-economic group in the highland and mid-altitude zones of Meket (kg/ha)

| *Group* | *Highlands* | | *Mid-altitude* | |
|---|---|---|---|---|
| | *DAP* | *Urea* | *DAP* | *Urea* |
| Rich | 80 | 63 | 46 | 46 |
| Moderately wealthy | 80 | 47 | 48 | 37 |
| Poor | 52 | 20 | 25 | 22 |
| Very poor | 19 | 10 | 11 | 11 |
| *Mean* | *50* | *28* | *28* | *25* |

Average for fields receiving mineral fertiliser
Source: Own survey.

shows that only 5% of farmers in Meket apply manure from the livestock pen to their homestead fields, where it is used very sparingly. Hardly anyone uses compost, household refuse or crop residues to maintain soil fertility, although 32% of farmers believe that soil from termite mounds can make land more fertile by altering the structure of topsoil and improving drainage in water logged soils. It is employed most frequently in the lowlands, where termite mounds are plentiful.

Most farmers know that manure and crop residues can improve soil fertility. They were extensively used when the forests could provide enough firewood to satisfy local needs. However, firewood is now scarce, and most manure is made into dung cakes for household fuel. In fact, one study estimated that dung accounts for about 50% of all the fuel consumed in households in the central and northern highlands (Bojo and Cassels, 1995).

In many parts of Ethiopia, kitchen ash is added to compost pits, but as some farmers in Meket believe that it attracts evil spirits, they dispose of it outside their hamlets. They also maintain that putting household refuse and sweepings on the fields will spread weeds, rot seedlings and cause lodging in crops, and therefore burn these residues outside the farm. After the harvest, many crop residues are removed from the fields and stored near the house, and cattle are then turned out to graze the remaining stubble. Although farmers are aware that removing vegetation deprives the soil of organic matter and exposes it to erosion and runoff, they need to use crop residues for feed, and can only incorporate them back into the soil if they have access to alternative sources of nutrition for their livestock.

Because there are so few trees and bushes left in Meket, there is very little biomass available to use as compost. SOS Sahel has experimented with a system of making compost in two pits, but it has only been adopted by a few farmers, as most are put off by the high labour requirements and shortage of biomass and manure. Those that have tried the system are mostly poorer farmers, who have found that it not only reduces their need for mineral fertiliser, but also improves the capacity of their soils to hold moisture, and therefore increases crop yields (see Box 1).

## Soil and water conservation practices

While farmers recognise that erosion is a significant problem, they no longer combine certain crops or use many of the management practices previously adopted to combat it, such as stone bunds and cut-off drains, or ploughing along contours to slow down runoff and prevent soil from being washed away. Most of the land is covered with stones, and as generations of farmers have cleared it for cultivation they have used the stones to construct bunds at regular intervals along the contours. The spaces between stones are filled with earth, preventing the bunds from collapsing and providing a foothold for various fodder plants. As permanent structures that are built up and

Box 1 An experiment with composting

Fifty-year old Ato Ayenew Akele is a moderately wealthy farmer. He owns two oxen and a cow, and cultivates 1.2 ha of land on the escarpment in the mid-altitude zone, which is subject to erosion. Finding that stone bunds only had a limited effect on erosion, he decided to use compost to improve soil fertility, and began composting in 1997. With help from SOS Sahel, he dug a deep, wide pit, into which he piled grass and leaves collected from the wastelands, as well as leftover animal feed, manure and fine topsoil. He dug another, shallower pit next to the first one, where he could occasionally turn material, adding water to speed up the process of decomposition.

He used the compost on small plots in his homestead fields, combining it with small amounts of DAP in the first season to ensure that the crops were getting their full nutrient requirements while the compost decomposed fully and started releasing nutrients. After the first season it was not necessary to use additional inputs on plots where he had applied compost.

According to Ato Akele, the best thing about composting is that he now needs to buy less mineral fertiliser than before. He used to purchase 150 kg of DAP every year, but now only has to buy 100 kg, saving himself about 150 birr (20 US$). He is also pleased to see that the structure and water holding capacity of his soil has improved, and increased crop yields have augmented the household food supply. He wanted to stop using any mineral fertilisers, but lacked the necessary organic materials and labour to make enough compost. Although his neighbours initially opposed him, saying *"this is not our fathers' way of doing things, digging pits in the hamlet is not our culture",* they now acknowledge the benefits of the system, although the high labour requirement prevents many from adopting it.

extended over time, bunds are generally built by family labour, although some richer farmers organise working groups to construct and maintain them.

In the past crop residues were commonly used as a mulch on fields and trash lines laid to block runoff, but all crop residues are now used as fodder. However, some farmers have indicated that the tiny pebbles and stones covering fields in stone mantled areas create a protective layer or 'stone mulch', conserving moisture and protecting the soil from the impact of rainfall.

While cultivating grasses or fast growing species of shrubs on bunds would both provide more effective protection against erosion and produce fodder, attempts to use agro-forestry systems to raise grass, herbaceous legumes or multipurpose trees have been hampered by the fact that cattle graze the fields in the dry season after harvest. However, a few farmers have started to combine soil conservation with food production, planting *noug* (*guizotia abyssinica*) along stone bunds to stabilise and consolidate them. As animals do not find this oilseed very palatable, the considerable amount of biomass it produces can be left in the field to improve soil fertility. This practice should be encouraged and promoted, as it strengthens the stone bunds, provides vegetative cover for the soil and generates cash for the household.

Box 2 below describes the measures taken by an innovative farmer who has combined several strategies for soil and nutrient management, providing an example of the real benefits that may be derived from an integrated approach.

Box 2 Combining soil and water management strategies

Ato Dessalegn is a resource rich farmer from the highlands. He is 65 years old, and owns about 1.2 ha of land on the escarpment, as well as three oxen, two cows, three calves and a sizeable number of sheep. The four adult members of the family all work on the farm, where severe erosion has caused soil fertility to decline and crop yields to fall. Ato Dessalgen has links with development work done by NGOs, and being open to new ideas, he has adopted a variety of strategies to protect the soil from erosion and enhance its fertility, using agro-forestry techniques, planting grass strips, constructing soil bunds and making compost. He has also tried using mineral fertiliser, but having found it expensive and ineffective, as much of it was washed away by runoff, he concluded that *"applying fertiliser to my farm without first curing the land is like feeding a bleeding person".*

He has planted rows of multipurpose forage trees, such as *lucerne,* along the contours of the escarpment, where they control erosion, improve soil fertility and provide fodder for livestock kept in the animal pen. Some of the manure from the pen is applied to the vegetable gardens in the homestead, where he uses a micro-irrigation scheme to grow cabbages, carrots, etc. for sale.

In order to prevent runoff and trap sediments, the contours are interrupted at regular intervals by strips of *phalaris* and *digitaria spp.* grass, in addition to the soil and stone bunds that the family work on during the dry season. Ato Dessalgen started making compost in 1996, applying it to the vegetable garden and severely degraded spots in his fields in order to improve the structure and organic matter content of the soil, and reduce runoff by increasing its capacity to hold water. When asked about the overall impact of these strategies, Ato Dessalgen reported that they had reduced erosion and improved soil fertility, increased his crop yields and income, and provided fodder and household fuel.

# 4 Conclusion

Chronic food insecurity is a growing problem in North Wollo. The average farmer in this low potential area cultivates less than one hectare of land, growing most crops for household consumption and often relying on livestock as the sole source of cash income. As many households do not own any livestock, the only option left to poorer farmers seems to be to migrate in search of employment.

Although most soils in the area were inherently fertile, soil degradation is now seen as the main constraint on production, as years of continuous cultivation and erosion have depleted stocks of nutrients and damaged the structure of many soils. Despite this state of affairs, farmers now employ few of the soil fertility management practices that were common among their forebears. Fallow, which used to be the most widespread strategy for maintaining fertility, has mostly disappeared, and is often only used because there is insufficient labour or draught power to cultivate the land. Hardly anyone still uses mulch, manure or trash lines on their fields, as all the crop residues are needed to feed livestock. The eradication of most forests from the zone means that manure is used as fuel rather than as a fertility input. Some farmers have constructed bunds to combat the erosion that seriously affects a large part of the area, but more still needs to be done to prevent runoff and the damage it causes.

Over the past twenty years, agricultural extension has tended to focus so exclusively on packages of specific technologies that it has failed to fully address the problems faced by farmers in the area. In the 1980s it revolved entirely around soil conservation, and bunds in particular, ignoring other forms of soil management and land use. After 1995, the emphasis shifted to promoting mineral fertilisers and improved varieties of crops, and 50% of farmers now use mineral fertilisers.

Although policy makers have recognised the severity of soil erosion, previous technical interventions have taken a top-down approach, focusing exclusively on physical conservation measures implemented through annual campaigns to mobilise local labour forces. This approach is neither effective nor sustainable, as people do not feel that they own the conservation structures imposed upon them and consequently fail to maintain them. Soil conservation should not be taken in isolation, but considered as part of an integrated range of measures to maintain soil fertility; it is one of several elements needed for agricultural improvement. Discussions currently under way within the Ministry of Agriculture about developing a community-led catchment approach to the management of natural resources therefore constitute an important change for the better.

Given the scarcity of manure and biomass in the region, mineral fertilisers may provide a valuable source of nutrients. However, our survey suggests that the potential for fertiliser-based extension is limited to the better-off farmers working on deep soils in the highlands. Even in these areas, an exclusive focus on mineral fertilisers without adequate return of crop residues or application of other organic inputs may actually result in soil degradation in the long run. At present, serious erosion has reduced the depth of the soil in many areas of Meket, making the use of mineral fertilisers of limited value. Furthermore, extension packages that focus solely on mineral fertilisers are inappropriate for farmers in marginal areas, who can only consider low cost, low risk strategies.

This is particularly unfortunate, as the farming systems in Wollo seem to have reached a turning point, and are in desperate need of effective support. Biomass is in such short supply that farmers are no longer able to use traditional soil fertility management strategies to sustain fertility and halt erosion. While they are aware of the value of organic fertilisers, they have to use crop residues, other biomass and manure for fuel and fodder, while local beliefs preclude the use of other potential resources such as kitchen ash and household waste.

Agricultural extension should now focus on developing integrated nutrient management systems that combine the use of mineral fertilisers with organic inputs and soil conservation measures. It is essential that such systems be adjusted to suit the specific circumstances of different farmers, as our survey clearly showed that soil fertility management practices and opportunities for change are influenced by the resources available to each household and the agro-ecological conditions within which it operates.

Some solutions to the many problems confronted by farmers in Wollo may lie in agroforestry, which could be particularly relevant to the major challenge of producing more biomass, not only providing vegetative cover without taking land out of production, but also producing fodder and household fuel. As increasing numbers of poor farmers have to rely on off-farm activities and migration to secure a living, any plans to improve soil fertility management strategies must also consider the broader context within which farmers earn a livelihood. Given the lack of available land in Wollo, there is an urgent need to explore the possibilities of diversification and off-farm activities as a means of reducing pressure on land and achieving some measure of security of livelihood.

# Appendix

**Appendix 1.** Average size of farm and amount of land held by households from each socio-economic group and agro-ecological zone in Meket, North Wollo

| **Zone/group** | Cultivated land (ha) | Grass plot* (ha) | Total land holding (ha) |
|---|---|---|---|
| **Highlands** | | | |
| Rich | 1.13 | 0.27 | 1.40 |
| Moderately wealthy | 0.52 | 0.10 | 0.62 |
| Poor | 0.56 | 0.05 | 0.61 |
| Very poor | 0.45 | 0.09 | 0.54 |
| *Mean* | *0.67* | *0.14* | *0.79* |
| **Mid-altitude** | | | |
| Rich | 0.90 | – | 0.90 |
| Moderately wealthy | 0.70 | – | 0.70 |
| Poor | 0.45 | – | 0.45 |
| Very poor | 0.29 | – | 0.29 |
| *Mean* | *0.58* | - | *0.58* |
| **Lowlands** | | | |
| Rich | 1.25 | – | 1.25 |
| Moderately wealthy | 0.78 | – | 0.78 |
| Poor | 0.76 | – | 0.76 |
| Very poor | 0.67 | – | 0.75 |
| *Mean* | 0.87 | – | 0.87 |
| *Overall mean* | *0.60* | - | *0.77* |

* Private grass plots are not found in the intermediate zone and in the lowlands

**Appendix 2.** Livestock owned by households from each socio-economic group and agro-ecological zone in Meket, North Wollo.

| **Zone/group** | Draught oxen | Cows | Calves | Sheep | Goats | Donkeys | Horses | TLU |
|---|---|---|---|---|---|---|---|---|
| **Highlands** | | | | | | | | |
| Rich | 2.4 | 2.8 | 2.2 | 16.2 | 2.8 | 1.2 | 1.6 | 9.6 |
| Moderately wealthy | 1.3 | 1.8 | 1.5 | 7.1 | 1.5 | 0.3 | 0.6 | 4.8 |
| Poor | 0.1 | 1.0 | 1.3 | 4.1 | 0.6 | 0.0 | 0.6 | 2.3 |
| Very poor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Mean* | *0.6* | *1.1* | *1.0* | *5.0* | *0.8* | *0.2* | *0.5* | *3.0* |
| **Mid-altitude** | | | | | | | | |
| Rich | 2.3 | 0.5 | 1.0 | 4.0 | 2.5 | 0.8 | 0.0 | 3.7 |
| Moderately wealthy | 1.3 | 0.9 | 1.2 | 2.4 | 1.1 | 0.2 | 0.0 | 2.5 |
| Poor | 0.5 | 0.5 | 0.4 | 1.1 | 0.8 | 0.1 | 0.01 | 1.2 |
| Very poor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Mean* | *0.7* | *0.4* | *0.5* | *1.3* | *0.8* | *0.1* | *0.01* | *1.3* |
| **Lowlands** | | | | | | | | |
| Rich | 2.0 | 1.4 | 2.0 | 2.0 | 3.2 | 0.8 | 0.0 | 4.5 |
| Moderately wealthy | 1.4 | 1.3 | 1.0 | 1.6 | 1.0 | 0.3 | 0.0 | 2.8 |
| Poor | 0.3 | 0.5 | 1.1 | 1.6 | 2.1 | 0.0 | 0.0 | 1.4 |
| Very poor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Mean* | *0.5* | *0.5* | *0.6* | *0.8* | *1.0* | *0.1* | *0.0* | *1.2* |
| *Overall mean* | *0.6* | *0.7* | *0.7* | *2.4* | *0.9* | *0.2* | *0.2* | *1.8* |

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