Managing Africa's Soils No. 10

Farmers' knowledge of soil fertility and local management strategies in Tigray, Ethiopia

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About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa – Nutrient networks & stakeholder perceptions.* It is a partnership of fifteen organisations that come from six African and two European countries: INERA from Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, from Kenya; IER from Mali; Environment Alert & Makerere University, from Uganda; IES from Zimbabwe; IIED & IDS from the United Kingdom; and AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, from The Netherlands. NUTNET was conceived with the primary aim of bringing together the three following 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 in 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 in The Netherlands.

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Summary

Declining soil fertility is a major constraint on crop production in the semi-arid highlands of Tigray, Northern Ethiopia. In order to design more appropriate research and development programmes geared to improving integrated nutrient management practices, researchers need to understand farmers' knowledge and perceptions of soil fertility. This working paper presents the results of a participatory survey designed to characterise and analyse local knowledge about soil fertility and soil fertility management practices. The survey was carried out in two villages in Tigray.

The first step was to analyse how farmers assess soil fertility. They categorise their soils into three classes: *reguid* (fertile soils), *mehakelay* (moderately fertile soils) and *rekik* (poor soils). As farmers in the study sites base this classification on the soils' potential to produce crops, it is not limited to their perceived nutrient status. The classification is closely related to topography, and takes account of the soils' depth and water holding capacity. Soil fertility is seen as dynamic, since a particular unit of land can become more or less fertile. The principal indicators used for identifying declining soil fertility are reduced yield, weed infestation, rocky outcrops, and crops wilting early in the growing cycle. Farmers also use another local system of classifying soil types according to their colour, texture, and certain physical characteristics. This classification correlates with the categories of soil fertility.

Particularily, land shortage and land fragmentation have increasingly forced farmers to abandon soil fertility management practices such as fallowing, manuring, terracing, and using crop residues. Unless farmers use other sources of nutrients, the disappearance of these traditional practices will have a considerable impact on soil fertility. One option would be to integrate the livestock and cropping systems more closely, maximising the use of crop residues, and producing more manure. Mineral fertilisers are another possible source of nutrients although expensive. However, farmers need to recognise that organic and mineral fertilisers should be used to complement, and not replace each other. Achieving timely, low-cost delivery of fertilisers to farmers should be made a matter of public concern.

Farmers' experimentation with new practices is an important element of site-specific learning, that enables them to adapt the new practices to the conditions in which they live and work. Experimentation is also an important element in learning about Integrated Soil Fertility Management, and both researchers and extension workers could do more to assist farmers in this process.

Résumé

L'appauvrissement des sols représente une difficulté majeure pour la production agricole sur les hauts plateaux du Tigré, dans le nord de l'Ethiopie. Si les chercheurs veulent concevoir des programmes plus appropriés de recherche, destinés à améliorer les pratiques de gestion intégrée des éléments nutritifs, ils doivent comprendre les connaissances et perceptions des agriculteurs sur la fertilité de leurs sols. Le présent document présente les résultats d'une étude participative dans deux villages du Tigré cherchant à caractériser et à analyser les connaissances locales sur la fertilité des sols et les pratiques de gestion à cet égard.

La première étape a consisté à analyser la manière dont les agriculteurs évaluent la fertilité des sols. Ils les classent en trois catégories : *reguid* (sols fertiles), *mehakelay* (sols modéré-ment fertiles) et *rekik* (sols infertiles). Dans la mesure où les agriculteurs de la zone étudiée basent cette classification sur la capacité des sols à produire des récoltes, elle n'est pas limitée à leur perception en matière d'éléments nutritifs. La classification est intimement liée à la topographie et prend en compte l'épaisseur de terre et sa capacité à retenir l'eau. La fertilité est un concept dynamique puisqu'une parcelle donnée peut devenir plus ou moins fertile.

Les agriculteurs utilisent aussi un autre système local de classification des sols qui distingue quatre types de sol en fonction de la couleur, de la texture et de certaines caractéristiques physiques. Cette classification recoupe les catégories précédentes de fertilité des sols.

Le manque de terre et sa fragmentation sont les facteurs les plus importants qui forcent de plus en plus les agriculteurs à abandonner les pratiques habituelles de gestion de la fertilité des sols telles que jachère, fumure, culture en terrasses et emploi de déchets agricoles. Si les agriculteurs n'utilisent pas d'autres sources d'éléments nutritifs, la disparition de ces méthodes traditionnelles va avoir un impact considérable sur la fertilité des sols. Une option serait d'intégrer plus étroitement l'élevage à l'agriculture, en maximisant l'emploi des déchets agricoles et en produisant plus de fumier. Les engrais minéraux sont une autre source possible d'éléments nutritifs mais ils sont coûteux. La mise à la disposition des agriculteurs d'engrais pas trop chers et en temps voulu devrait être un objectif des pouvoirs publics.

L'expérimentation des nouvelles méthodes par les agriculteurs est un élément important du savoir spécifique à un site car elle leur permet d'adapter ces nouvelles méthodes aux conditions dans lesquelles ils vivent et travaillent. Cette expérimentation est aussi une manière importante d'arriver à une gestion intégrée de la fertilité des sols et aussi bien les chercheurs que les vulgarisateurs devraient s'efforcer davantage d'aider les agriculteurs à ce niveau.

1 Introduction

The importance of local knowledge

Soil fertility is declining in many parts of sub-Saharan Africa (SSA) (Stoorvogel et al., 1993). One of the major constraints to crop production faced by smallholder subsistence farmers is the inadequate supply of nutrients (Quinones et al., 1998; Shapiro and Sanders, 1998). Farmers are either entirely abandoning the traditional practice of using natural fallow to restore soil fertility, or are unable to leave land fallow for long enough for it to be effective. The use of mineral fertilisers is declining as they are increasingly beyond the means of most small-scale farmers (Larson and Frisvold, 1996). Erosion and severe run-off are further depleting existing soil nutrient reserves, while levels of soil organic matter are declining as land is subject to over-use.

Sustaining soil fertility has become a major issue for agricultural research and development in SSA (Smaling and Oenema, 1997). In the past, most research consisted of trials to determine the appropriate amount and type of fertiliser needed to obtain the best yields for particular soil types and specific agro-ecological locations. This approach emphasised the use of external inputs and expensive technologies, and often disregarded farmers' knowledge and the resources at their disposal. Since then, research has gradually shifted towards an approach based on Integrated Soil Fertility Management (ISFM), which combines various existing soil fertility management techniques. This approach is based on a thorough scientific understanding of the underlying biological processes of ISFM and aims to promote options that make the best use of locally available inputs, and that are tailored to suit local agro-ecological conditions, and farmers' resources and interests.

Improving farmers' knowledge, and their capacity to observe and experiment, is an essential element in the development of ISFM technologies (Deugd et al., 1998). It is also important to build on local systems of knowledge, as they relate to specific locations and are based on experience and understanding of local conditions of production. Such systems are a source of site-specific ecological information, and provide the key to understanding peoples' socio-cultural conditions (Pawluk et al., 1992). Many development projects and policies have collapsed because of a failure to understand local knowledge, and how this influences the way farmers manage natural resources (Schoonmaker-Freudenberger, 1994).

Several studies have been undertaken to assess local knowledge about soils. Research in this area has predominantly focused on documenting how farmers classify their soils (Talawar and Rhoades, 1997). Less attention has been paid to studying and understanding how soil fertility is perceived and managed at farm level, and how various physical, economic and socio-cultural factors interact. The objective of this paper is to characterise and understand farmers' perceptions and technological knowledge of soil fertility in Tigray. It then goes on to analyse how the prevalent local systems of knowledge influence soil fertility management practices in this semi-arid northern region of Ethiopia.

The majority of the soils of this region are reported to be shallow, have low soil fertility, high run-off, and low infiltration capacity (Mitiku, 1996). Declining soil fertility is particularly severe in Tigray because of high nutrient losses through soil erosion, and extremely low use of external nutrient inputs (Virgo and Munro, 1978). The insights from this study should make it possible to develop more sustainable ISFM research and development programmes, and to design more appropriate policies for maintaining and enhancing soil fertility in this region.

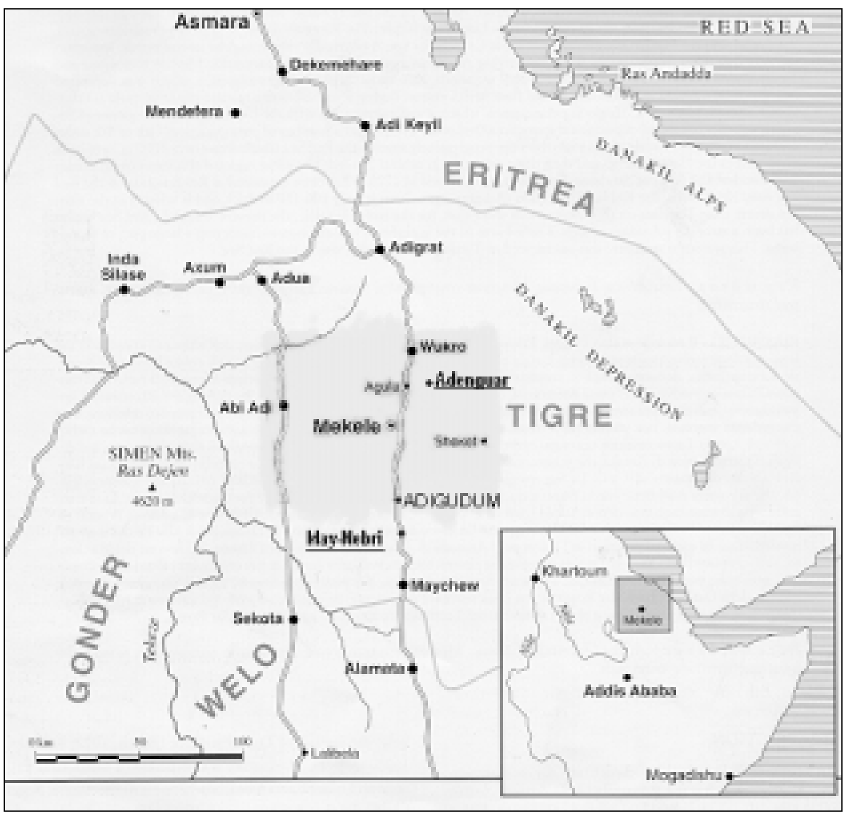
Methodology

The research was undertaken in two villages in Tigray, Northern Ethiopia, which were considered to be representative of the highland areas. In each village, the research team selected a representative group of 25 farmers of both sexes and various ages and social classes. The team used several participatory research techniques during the study (Pretty et al., 1995). Resource flow maps were prepared and used to analyse the current use of natural resources, and management practices at village level. The team used interview guides during individual and group discussions so that they could analyse farmers' perceptions of soil fertility, and their management strategies. They also held semi-structured interviews to explore how the farmers classified soil fertility. During transect walks the team and the farmers studied the variations between different types of soil, and analysed diversity in soil fertility management practices. They then ranked the soil types identified according to their fertility and potential productivity.

2 The study area

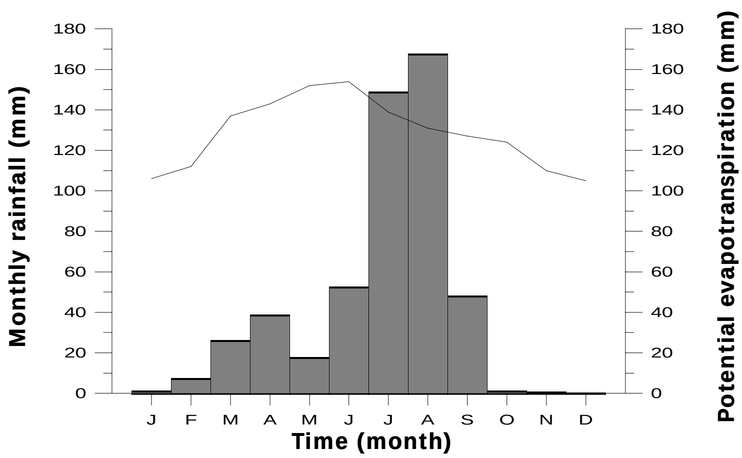
The two villages selected for this study were Adenguar in the sub-district of Mesanu (2000 to 2300 masl) and May-Nebri in the sub-district of May-Nebri (2000 to 2500 masl, see Fig. 1). The average population density in Mesanu district is 139 persons/km2 and in May-Nebri district 151 persons/km^2, while the average farm size is 1.1 ha in Mesanu district and 0.9 ha in May-Nebri.

Figure 1. Location of the two sample villages



Both study areas have a cool, tropical, semi-arid climate. The mean annual temperature is around 18°C, and the average daily temperature is fairly constant throughout the year. The mean annual rainfall in both sites is about 700 mm, but varies considerably between years, and is characterised by unpredictable droughts. Although the rainfall distribution is bimodal, from an agricultural point of view it is actually unimodal, because farmers can only grow one rain-fed crop per year (see Fig. 2). The growing period lasts between 45 to 120 days.

Figure 2. Average monthly rainfall and potential evapotranspiration



Bar: monthly rainfall; line: evapotranspiration. Average data for a period of 18 years.
Source: Adigudum meteorological station.

The agricultural season is closely associated with the rainfall pattern. Table 1 gives an overview of the different seasons in the study area. The local names for the seasons are:

- *Belg* (March to June): a little rain falls during this season. If the rains look promising, some Belg crops like maize and sorghum may be planted. However, as these rains are very rare in the study area, farmers mostly use this season to prepare their land,
- *Kiremti* (July to September) is the main rainy season. Crops are planted at the beginning of this period,
- *Kewie* (October to February) is the dry season, when crops are harvested, threshed and stored.

Table 1. Seasonal periods in the study areas

Local classification	Period	Average amount of rainfall
Kewie	October-February	Less than 50 mm
Belg	March-June	50-100 mm
Kiremti	July-September	200-600 mm

The dominant soils in Adenguar are derived from calcareous sedimentary rocks, classified as Eutric Cambisols and Eutric Fluvisols (HTS, 1974). They are located on various topographic units ranging from undulating and hilly plateaux to broad valleys between steep slopes. The relatively flat area, with a slope of 0.5 to 2%, is cultivated and used for pasture. The gently undulating area, with a slope of 2 to 5%, is used for habitation, and the hilly area, where slopes may be 15 to 30%, has no specific use.

The topography at May-Nebri varies from flat to gently undulating. The flat areas (0.5-5%) are cultivated, and the undulating (3-5%) areas are used for habitation. The principal soils around the May-Nebri area are Cambisols (HTS, 1974). The fluvisols on the flatter land along the river were formed on recent alluvial materials, and have a moderately deep to deep profile (HTS, 1974).

The predominant agricultural practice is small-scale mixed subsistence farming. Average land-holdings in the two villages are less than one hectare. Land is prepared with an ox-drawn plough, the *maresha*, and the main crops are wheat (*Triticum sp*.), barley (*Hordeum sp*.) and teff (*Eragrostis sp*.). Farmers plant local varieties of crops, and apply very few external inputs. The results of a household level socio-economic survey covering the whole of Tigray show that only 12% of farming households use mineral fertilisers, 53% apply manure, and 25% use crop residues as nutrient inputs on their land (SAERP, 1997).

Wheat and barley yields range from 600 to 1000 kg ha^{-1} in good years, and from 100 to 400 kg ha^{-1} in years with low rainfall (Table 2). Yields are frequently below the production potential, mainly because farmers use poor quality seeds, which are often diseased. Crop stands are consequently riddled with disease, and the sparse plant growth has to compete against a high volume of weeds. Livestock feed on common

Table 2. Average yields (kg ha^{-1}) of the main rainfed crops in Tigray

Crop	**Scientific name**	**Yield**	
		1993/94	**1994/95**
Teff	*Eragrostis sp.*	510	690
Barley	*Hordeum sp.*	410	930
Wheat	*Triticum sp.*	400	1000
Maize	*Zea mays*	400	1510
Sorghum	*Sorghum bicolor*	610	1800
Millet	*Pennisetum typhoides*	1100	690
Horse bean	*Vicia fabia*	700	1440
Lentils	*Lentilla lens*	310	480
Field pea	*Pisum sativa*	260	760
Vetch	*Lathyrus sativa*	350	280
Linseed	*Linum usitatissimum*	270	300

Source: based on NEDECO, 1997.

grazing lands and on stubble. Farmers often make the stubble last longer as fodder by letting grass and weeds grow among the cereal. Labour is mainly provided by household members.

Table 3 below presents the different types of land-use and the area they cover in both villages. The common grazing land in May-Nebri lies far beyond the village, and is not included in the study. The arable land in both villages includes irrigated and non-irrigated land.

Table 3. Land-use types and their area in the two villages.

	Adenguar **Area** **(Tsimidi*)**	**%**	**May-Nebri** **Area** **(Tsimidi*)**	**%**
Arable land	20	17	224	43
Pasture	10	8	–	–
Residence	25	21	240	46
Forest	–	–	60	11
Bare land	65	54	–	–

*1 Tsimidi ≅ 0.25 ha
Source: Own survey.

3 Farmers' perceptions of soil fertility

Local concepts of soil fertility

It became clear from group discussions in both villages that farmers and scientists understand soil fertility in different ways. Scientists often only take account of the soil's nutrient status, without considering its physical properties. They define fertile land as land that is capable of producing consistently high yields in a wide range of crops.

Farmers describe productive and fertile land as '*reguid*', which literally means fat. Well-prepared land with a good seedbed is known as '*limui*', which says nothing about its fertility or productivity. Farmers' perceptions of soil fertility are not limited to the soil's nutrient status. Fertility is assessed through outcomes such as crop performance and yield and includes all soil factors affecting plant growth. In fact, the farmers' interpretation of soil fertility reflects the definition of soil productivity used by the International Soil Science Society (ISSS). The ISSS describes it as the capacity of a soil in its normal environment to produce a specified plant or sequence of plants under a particular system of soil management (ISSS, 1996). In their critical analysis of how farmers in different settings classify and manage soils, Talawar and Rhoades (1997) also found that farmers see soil fertility as a multi-faceted concept. It includes factors such as the soil's capacity for sustainable productivity, its permeability, water holding capacity, drainage, tillage and manure requirements, and how easy it is to work.

The farmers in our case study use various easily observable indicators to assess whether soil fertility is declining. The principal indicator they mentioned is reduced crop yield. In this semi-arid region where rainfall is low and erratic, soil moisture conservation is often regarded as the most critical factor for successful crop production. Farmer perception of soil fertility is therefore closely related to the soil's water holding capacity. However, even in climatically good years, low crop yields are not perfect indicators of declining soil fertility, since yields may be significantly affected by a range of other factors, such as weeds or pests.

Farmers use the appearance of specific weed species, like *Echinips hispidus* and *Xanthium spinosum,* as indicators of declining soil fertility. As individual weed species or communities are adapted to particular habitats, their presence may indicate problems with the soil's nutrient status or structure. However, the ability of weeds to act as unambiguous indicators is limited, because their presence may reflect cropping practices rather than soil conditions.

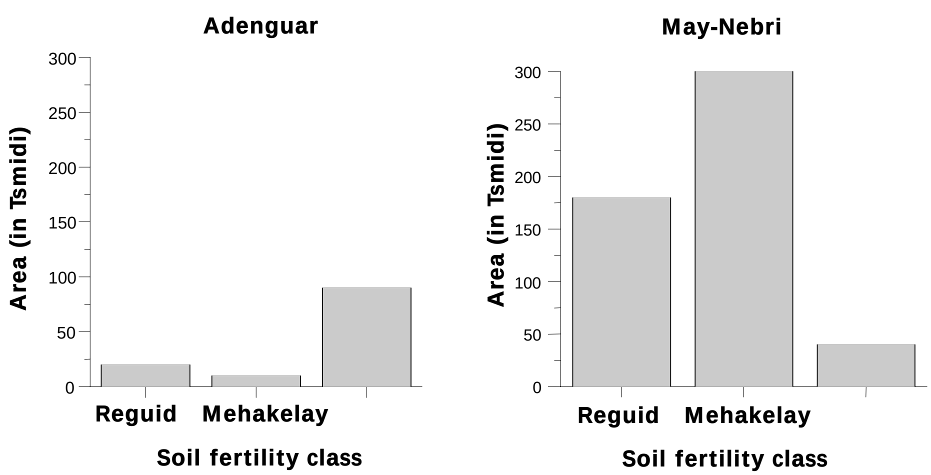
Farmers also listed rocky outcrops and crops wilting at the end of the rainy season as indicators of declining or low soil fertility. Rocky outcrops may appear as result of high levels of erosion, and they are often associated with shallow, infertile soils. Crops that wilt just after the rainy season ends are an indication that the soil has low water holding capacity, which is related to certain physical characteristics such as depth and texture.

Farmer knowledge of soil fertility

When they were asked to categorise different levels of soil fertility, the farmers in the two villages classified their land into three classes: *reguid meriet* (fertile), *mehakelay meriet* (moderately fertile), and *rekik meriet* (infertile) (see Table 4). Figure 3 below shows the estimated areas covered by each class of soil in both villages.

The entomological origin of the words indicates that *reguid* means thick, *rekik* means thin, and *mehakelay* describes something in between the two. *Meriet* means land. Certainly, this nomenclature refers directly to the soil's depth. It is also clear from the transect map (Fig. 4) that in this region the three units of classification are strongly correlated to topographical position. According to the farmers, this influences the depth of the soil, its suitability for particular crops, and crop productivity. On a given

Figure 3. Area covered by each class of soil fertility in the sample villages



*1 Tsimidi ≅ 0.25 ha
Source: Own survey.

Table 4. Local classification of soil fertility

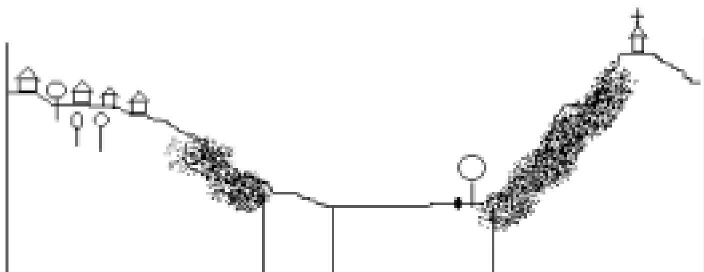
Characteristics	***Reguid***	***Mehakelay***	***Rekik***
Fertility status	Most fertile	Moderately fertile	Least fertile
Local soil type	*Keyih* and *Andeleway*	*Andeleway*	*Bahakel* and *walka*
Colour	Red and brown	Brown	White and black
Texture	Heavy	Medium	Light
Depth	Deep	Medium	Shallow
Workability	Difficult	Average	Easy
Stoniness	Slight	Moderate	High
Degree of erosion	Slight	Moderate	High
Topography	Level (valley bottoms)	Gentle slope (between valley bottom & hills)	Very steep (hilly)
Yield	Maximum and most reliable	Medium, with slight risk of crop failure	Low, with high risk of crop failure
Description range of crops.	During rainy season grasses emerge, slowly and generally survive. Supports a wide crops	During rainy season grasses emerge and dry slowly. Production is limited to certain limited.	During rainy season grasses emerge fast and die quickly. Crop choice is very
Agricultural use	Intensively cultivated arable land	Some cultivation, also used for pasture	Not cultivated.

Source: Own survey.

toposequence *reguid* soils usually represent deep soils (>100 cm). They mostly appear in valley bottoms and natural terraces, and are generally found further down the slope than *mehakelay* soils. *Rekik* soils are found on the upper portions of a toposequence, and are usually shallow. Topographical position is often a criterion in local land and soil classification systems, such as those of southern Mali (Kanté and Defoer, 1994) and the highlands of Rwanda (Habarurema and Steiner, 1997).

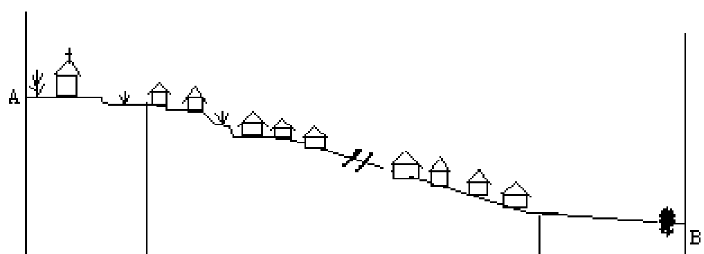
There is also a strong correlation between these units of classification and the soil's water holding capacity. In semi-arid conditions this is a determining factor for the potential to produce crops. The soils at the bottom of the toposequence generally have a high water holding capacity because of their considerable depth and clayey texture, while the shallow soils on the upper slope are sandier, and have low water holding capacity.

Figure 4a. Transect map of Adenguar area



Soil fertility class	Rekik	Reguid	Reguid	Rekik
Vegetation	Cactus, Sisal and Acacia	Grass	Crops	Cactus, Sisal and Acacia
Land use	Residential to Unused	Pasture	Arable	Unused
Slope	2-5% gently undulating	1.5%	Unused	15 - 30%

Figure 4b. Transect map of May-Nebri area



Soil fertility class	Rekik	Mehakelay	Reguid
Vegetation	Eucalyptus Sisal	Sisal, Acacia and Kinchib	Arable
Land use	Arable	Residential area crossed y main road	Crops
Slope	2 - 5%	Variable (3 - 8%)	0.5 - 2%

The diagrams of the transect walk shown in Figure 4a and 4b illustrate how the farmers' system for classifying soil fertility determines land use in the study area. *Rekik* soils are used for habitation and forestry, whereas the *reguid* soils are cultivated. The most fertile soils are cultivated more intensively than other soils. The farmers indicated that they vary the amount of seed they use according to the soil's fertility status, and that they generally use more seed on *reguid* soils than on *rekik* soils.

Local systems for classifying soils

Farmers have developed a local system of soil classification based on their experience of the potential and constraints of their soils. They use the system to determine how they will manage soil fertility. Farmers in the region distinguish between four different soil types, mainly on the basis of soil colour and texture (Table 5). The four types are *walka* or *tselim meriet* (black, clayey soil), *keyih meriet* (reddish, medium-texture soil), *andelewayi* (brownish, medium-texture soil) and *bahakal* (light coloured, lightly textured soil).

The soils are classified according to recognisable and easily identifiable soil and field characteristics. In our study area the farmers' criteria for classification are yield, the topographic position of the field, the soil's depth, colour and texture, its capacity to hold water, and the presence of stones. Farmers ranked these criteria in the following order: yield > topography > soil depth/colour/texture/waterholding capacity/stoniness. Yield is the most important criterion, and farmers are also aware that soil productivity is closely related to its position within the landscape. They regarded the other five criteria as equally important.

Soil colour is an important criterion for farmers, as it often reflects the soil's hidden parent material, which determines specific soil characteristics. The texture of the surface layer has some influence on many other soil properties, and gives farmers a clear indication as to whether a soil can be cultivated after the first rains of the season. Other criteria mentioned by farmers are soil compaction, structure, cracking patterns, stoniness, drainage, and the ability to retain moisture. All of these physical characteristics are related to soil texture.

Farmers were asked to rank the different local soil types according to their fertility and potential productivity. They ranked them as follows: keyih meriet *(most fertile)* > *andelwayi* > *bahakel* > *walka* (least fertile), suggesting that in their perception the local soil classification is well correlated with soil fertility and productivity. Soil colour and texture are important, but they are not the only indicators of fertility.

Mitiku (1996) also showed that the local soil classification used in Tigray only partly reflects soil nutrient status, as farmers believe that the level of nutrients is only one of several factors determining a soil's fertility. The black *walka* soils are relatively fertile, clayey soils, with a high organic matter content (between 1.5 and 1.9 %) and a high cation exchange capacity (CEC) of between 44 and 52 cmol(+) kg^{-1} soil. In contrast, chemical soil analysis revealed that *bahakel* soils represent a heterogeneous group of soils of varying levels of fertility. The *bahakel* CEC ranged from 7 to 35 cmol(+) kg^{-1} soil, and their organic matter content ranged from 0.3 to 1.4%.

Most systems of classification are developed for a particular purpose, and reflect the priorities of their inventors. In our study sites the local systems of classification reflect the

Table 5. The main characteristics of local soil types*

Characteristics	Soil type			
	Keyih meriet	***Andelwayi* (also *Chincha* or *Hutsa*)**	***Bahakel***	***Walka* (or *tselim meriet*)**
Soil name (FAO classification)	Luvisols	Leptisols	Cambisols	Vertisols
Organic matter content	Relatively high	Low	Extremely low	High
Texture	Medium	Medium	Light	Heavy
Depth	Deep	Shallow	Shallow	Variable
Compaction	Moderate	Low	Low	High
Colour	Red	Brown	White	Black
Cracking	Slight	Slight	Slight	Severe
Drainage	Well-drained	Well-drained	Well-drained	Poorly drained
Moisture retention	Low	Low	Low	High
Response to fertiliser	Moderate	Good	Good	Moderate

Source: Adapted from Mitiku (1996).

limited availability of water. These systems focus on the soil's depth, which affects the availability of soil moisture, and its texture, which determines its workability and water holding capacity. The use of productivity as the principal criterion to distinguish soil types is also widespread. Other studies in various settings have also shown that farmers commonly classify their soils using a range of well-identified criteria that are relevant to their local situation. The most common criteria noted in studies on local systems of soil classification reflect the physical properties of soils, or related factors such as texture, colour and workability (Talawar and Rhoades, 1997; Tamang, 1993). Farmers are well acquainted with these characteristics through their daily observations of soils, and particularly of their surface (Habarurema and Steiner, 1997; Kanté and Defoer, 1994).

4 Soil fertility management practices

Soil fertility management practices

Farmers were asked to describe how they try to improve soil productivity. The most common practices and the constraints on their implementation are outlined in Table 6 below.

Table 6. Soil fertility practices and the main constraints

Soil fertility practice	Constraints
Fallowing	Shortage of land
Crop rotation	(no constraint mentioned)
Application of crop residues	Use of residues for fodder and fuel
Manuring	Land fragmentation, and use of manure as fuel
Incorporation of weeds	Scarce vegetation (shortage of land)
Terraces	Land ownership, shortage of land
Tillage practices	(no constraint mentioned)

Source: Own survey.

Fallowing

The traditional method of restoring soil productivity is fallowing, or *mistigao*. Farmers said that yields on irrigated land decline if they continuously grow three crops a year without any fallow period. The decision to leave a field fallow is not a matter for an individual farmer to decide on. It is agreed by a group of farmers, who select a site where they want to create a uniform piece of grazing land for the village herds. Fallowing thus also has an important function in the livestock production system.

Farmers in Adenguar explained that fallowing used to be the main way of improving soil fertility. The length of the fallow period varied according to the type of soil. *Reguid* soils were commonly left fallow for one year, while *rekik* soils were left for two to three years.

However, the fallow periods dropped from an average of three years before 1970 to only one year in the 1980s. Farmers in both villages had to abandon long-term fallowing altogether in the 1990s because their land holdings became too small. The average household currently only has one hectare of land.

Farmers in the study area report two methods of seasonal fallowing. *Mekan tsegie* refers to a field which is left completely fallow for one year. It is then ploughed in July/August to incorporate weeds and grasses into the soil as green manure, and to increase water infiltration. The most common seasonal fallow now practised in the study area is growing chickpea or vetch as a green manure crop, which also produces some food. However, although these legumes may restore soil fertility more effectively than other crops, farmers consider this practice as less beneficial than traditional fallowing.

Crop rotation

Farmers are well aware they can improve soil productivity by rotating crops. They said that as fallowing is no longer possible they now rotate crops on the fields away from their homesteads, which receive very little manure. Farmers choose which crops to grow in rotation according to how they adapt to the soil and the rainfall pattern. Personal preference and economic considerations such as the price of the crop also influence the farmers' choices. The major crop rotations practised by the farmers we interviewed are:

- Barley – wheat – barley
- Teff – barely/wheat – teff
- Teff – vetch – teff
- Barley – chickpea – barley

Most farmers think that starting the rotation with teff or other cereals and then planting chickpea or vetch improves crop productivity more than rotations based solely on cereals. However, crop rotations in the region are dominated by cereals. Farmers in Adenguar did not include any legumes in their rotations, unlike their counterparts in May-Nebri. Their choice of crop rotation is mainly influenced by the desire to reduce the need for labour intensive land preparation or weeding. Farmers made the following observations about certain crop rotations:

- The frequent ploughing required to create a fine seed bed for teff reduces the need to prepare the land for subsequent barley or wheat crops;
- As teff is intensively weeded, the subsequent barley or wheat crop is less likely to be infested with weeds;
- Weeds such as *Argimeno mexicano* will grow among teff, but will not appear in a barley crop. Similarly, some grasses that grow as weeds in barley will not appear in a subsequent teff crop;
- Growing vetch before teff reduces the number of weeds in the teff crop;
- The crop residues from teff left on the field are considered as *tsigie* for the following crop;

- Sowing chickpea immediately after harvesting a cereal crop is known as *tsigie* but its application is mostly limited to the soil type *walka*.

One of the key features of local farming practice, which has also been reported in other studies (Talawar and Rhoades, 1997), is the careful matching of crops and crop varieties to soil potential. Farmers in the study area are knowledgeable about the relationship between crops and soil types, and said that some crops influence the productivity of certain types of soil. They distinguish between crops that have a similar effect to fallowing and improve the soil, and crops that deplete the soil. Chickpea and vetch improve *walka* soils, lentil improves *andelwayi* soils, linseed improves *bahakel* soils, and teff improves *walka* and *keyih meriet* soils.

Crop residues

Few farmers in the region use crop residues to maintain soil fertility. They are mainly used as animal feed, construction material, or fuel. All crop residues apart from wheat are cut at ground level, and the straw is stored as fodder for livestock. Wheat straw is left on the field because it is not considered to be good fodder after it has been stored. Most of the wheat stubble is grazed in the field, as food for livestock is in short supply at harvest time.

Farmers in May-Nebri often burn crop residues to prevent animals from grazing them. They consider that the ash acts as fertiliser and increases crop yields. In the region around Adenguar it used to be common practice to burn crop residues, but since 1985 all crop residues have been used as fodder for cattle or sold at the local market.

Manuring

Livestock have various functions in the production system. Oxen are essential and indispensable for preparing land and threshing grain, and farmers keep cows, sheep and goats as a source of stable income. Poultry provide food and cash, and donkeys are used for transport. The existing livestock management system does not include practices for improving the quality of manure or for increasing manure production.

Manure is an important input for maintaining and enhancing soil fertility. Farmers distinguish between two types of manure: *zikereme dukie* or *husse* and *zeykereme dukie* or *aleba*. The first type of manure is gathered and allowed to decompose during the rainy season. When it is applied this manure is highly decomposed, and rich in available plant nutrients. *Aleba* manure is collected during the dry season. It does not decompose as much as the other type of manure, and has a less direct effect on crop yields. It also increases the number of weeds in the fields.

According to farmers' estimates, they applied between 0-800 kg/ha of manure in Adenguar, and 0-1000 kg/ha in May-Nebri. Manure tends to be used only by a few rich farmers, who apply it to small areas around the homesteads. There are various reasons why most farmers only apply limited amounts of manure to their fields:

- The relatively small number of livestock per household limits the amount of dung available;
- Dung is often used as fuel;
- Manure is used for constructing grain silos, which are made of *keffo*, a mixture of mud and cow dung. Dung is also used to smoke the silos to keep pests down;
- Farmers use a mixture of animal dung and water to protect seeds against diseases;
- It is expensive and labour intensive to transport manure, particularly to fields far away from the homestead;
- Farmers do not have time to transport manure to the field, as they are involved in many off-farm activities such as selling fire wood, or working as building labourers in town;
- Manuring stimulates the appearance of shoot fly, especially in teff;
- Manure increases the number of weeds in the fields.

Mineral fertilisers

The use of mineral fertilisers is very limited in the two villages. Although this is mainly attributed to a lack of purchasing power, some farmers in the study area argued that low and unpredictable soil moisture content makes it unprofitable to use mineral fertilisers. They claimed that urea burns the crops when rainfall is low.

Weeding

Farmers in Tigray enrich their soils by uprooting and burning weeds (Mengesha, 1996). Farmers in both study villages are aware of this practice, but they no longer use it, as surface vegetation has become too sparse. Only a few farmers incorporate grasses and weeds into the soil as green manure, since most farmers use them as fodder for livestock.

Terraces

Farmers traditionally constructed terraces to improve soil fertility and productivity, and *dagets* or lynchets are common in the study area. They run between the fields and are not ploughed. *Dagets* are between 0.5 to 3m high, and have a grass strip on their shoulder. They are only found on certain types of soil, and are not constructed on fields with sandy soils. *Dagets* gradually develop on small strips of uncultivated land at the bottom of slopes, where farmers deposit stones, weeds and bushes, and are also built up by sedimentation. However, farmers have recently ploughed in many *dagets* to make more land available for crop production.

Terraces slow down water runoff and capture sediments. Farmers regard these sediments as fertile soil material, and believe that terracing can make an infertile soil more fertile. This shows that they see soil fertility as a dynamic characteristic of soils, and not as an inherent quality in itself (see also Data, 1998). Bocco (1991) observed that farmers in central Mexico mainly used local conservation techniques to manage sedimentation rather than erosion.

Tillage practices

Tilling is the most demanding farming activity in terms of labour and energy. Farmers mainly use oxen to pull the traditional plough or *maresha*, although horses or mules are also used, often in combination with an ox. Ploughing is also seen as a way of improving soil productivity.

The two main problems with preparing land are that the ox-plough is not very efficient at turning the soil to a suitable depth, and that ploughing requires a lot of time and labour. It is particularly difficult to plough vertisols, especially during the first tillage after harvest. The frequency of ploughing differs according to the type and variety of crop. The field is ploughed a minimum of five times for teff but only once for vetch. Improved varieties of wheat need three rounds of ploughing but local land races only two. Each phase of tilling has a particular local name: the first ploughing is called *tsigie*, the second is known as *aimi*, the third is *salsio*, and the fourth ploughing is called *rewhi*. When fields are ploughed immediately after harvest, the crop residues are incorporated into the soil to improve soil fertility. Farmers also do some ploughing after planting to destroy weeds.

Factors determining nutrient management

During group discussions, farmers identified a set of factors that determine local soil fertility management practices (Table 6). Increasing land fragmentation was cited as the main constraint on traditional practices. As a result of land fragmentation many fields are far from the homestead, which makes transporting dung a time-consuming and labour intensive operation. Moreover, the impact of population pressure on land-holdings has led to a decline in practices such as fallowing. However, as land becomes increasingly scarce, farmers are more aware of the need to make the best use of it (Scoones and Toulmin, 1998).

Land ownership also seems to have an impact on soil fertility management practices. Farmers are more motivated to invest in improving soil fertility if they have some assurance that they will profit from their efforts. This is the case when land is owned or not distributed too frequently. Land reform in Ethiopia started in 1975 following the Ethiopian revolution and involved land alienation, redistribution and resettlement programmes (‘villagisation’). During the civil war the then rebel movement the Ethiopian People’s Revolutionary Democratic Front (EPRDF), carried out three rounds of redistribution between 1978 and 1987 in areas under their control, such as Tigray. All persons over 18 years of age were entitled to land, which includes women who had been denied access to land during the first land reform. Overall, landless youth were the main beneficiaries but the size of average land holdings became smaller and smaller. Guidelines for future land redistribution have been developed by the Ethiopian Government, but there are no plans for implementation.

Wealth status also seems to have a significant impact on the way farmers manage their land. Wealth ranking exercises and interviews with farmers revealed that those with the most livestock and children had access to more manure, transport and labour, and implemented more soil fertility management practices than other farmers. Moreover, farming in Tigray is risky. Pests and unreliable rainfall mean that farmers are liable to lose investments made in the crop. Having more resources, a rich farmer is better able to cope with harvest failure than a poor farmer. Socio-economic issues are therefore key driving forces in nutrient management, and have a considerable influence on decision making at farm level (Scoones and Toulmin, 1998).

5 Experimentation with nutrient management

Farmers' interest and capabilities in experimentation are important elements in generating local knowledge. A group of ten farmers in May-Nebri have set up a trial to compare the effects of different types of manure on crop yield. The manure was used on onions, tomatoes, wheat and barley and the soil type was *bahakel*. This trial was also monitored by researchers from Mekelle University College. Farmers ranked each type of manure according to its effect on crop productivity, rating chicken manure most highly, and going down through goat manure > sheep manure > cow dung > donkey manure, which was considered the least effective. They concluded that donkey manure contributes nothing to the land, no matter how much is applied. They also observed that cow dung is more effective if it is burned before application. This is probably an indirect effect of reducing the number of weed seeds in the dung, which lessens the competition between weeds and crops in the field. The farmers' ranking of the different types of manure correlates with laboratory analysis of their value for soil fertility (Table 7).

Farmers in Adenguar also described how they had learned about soil fertility management through testing and observation, although they had not actively planned any experiments. Some farmers had noticed differences in the development of plants in the field around the homestead where manure was deposited. When one farmer started to apply manure purposely, colleagues working adjacent fields watched how the crop developed, and how its yield was affected. The following year they all decided to apply some manure.

Table 7. Average composition of different types of manure

Type	Organic matter (%)	N (%)	P_2O_5 (%)	K_2O (%)
Chicken manure	29	1.5	0.4	0.8
Sheep/goat manure	31	0.7	0.4	0.3
Cattle manure	16	0.3	0.2	0.2
Horse/donkey manure	22	0.5	0.3	0.3

Source: Mueller-Saemann and Kotschi (1994).

6 Conclusions

Farmers in the study area see soil fertility as a broader concept than the soil's nutrient status, and closely related to crop productivity. They use various indicators to assess changes in soil fertility, such as yield levels, the degree of weed infestation, the appearance of rocky outcrops, and crops wilting early. In this semi-arid area, crop productivity largely depends on soil moisture content. The way that farmers categorise soil fertility reflects therefore the soil's water holding capacity. The local system for classifying soils, which determines soil fertility management practices, is based mainly on soil colour and texture.

Socio-economic factors such as a shortage of land and land fragmentation have led to a decline in traditional soil fertility management practices. This will have substantial effects on soil fertility, unless farmers use other measures to add nutrients to their soils. Farmers in the study area are aware of the problems caused by declining soil fertility.

There is considerable scope for improvement through integrating livestock and cropping systems, and using crop residues and animal manure more effectively as sources of nutrients. Current livestock management practices are not geared to producing as much farmyard manure as possible, and maintaining soil fertility is only one of a variety of uses to which manure is put.

Mineral fertilisers may also have an important role to play, but farmers should recognise that organic and mineral fertilisers have to be used to complement, and not replace, each other. Extension packages focusing on the use of fertiliser should take account of how farmers assess soil fertility dynamics, and relate this to recommendations for fertiliser application. Achieving timely, low-cost delivery of fertilisers to farmers should be made a matter of public concern.

Agricultural research and extension should adopt an approach based on Integrated Soil Fertility Management as a matter of urgency. Addressing soil fertility management in isolation from overall land management issues will lead to a simplification of the problem. Moreover, ISFM promotes a positive interaction between crop and livestock production systems, and the use of locally available inputs.

ISFM also builds on local systems of knowledge. Farmers have developed local practices which they continuously adapt. These practices have proven over time that they can sustain the use and conservation of land resources.

Farmer experimentation is an important element of site-specific learning. It helps them adapt practices to the specific local conditions in which they live and work. The ISFM approach can build on farmers' particular interests, and on their capacity to observe, experiment, and interpret the results of new techniques (Deugd et al., 1998). Researchers can help farmers to improve their experimentation, but they should not select the experimental treatments for them. The researcher's role is to strengthen the farmers' capacity to systematise the learning process. They can do this by working to improve the planning and design of the experiments chosen by farmers. Researchers and extension staff can also assist farmers with their experimentation by providing technical back-up and understanding of the biological processes underlying farmer practices.

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