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Managing Africa's Soils No. 26

Participatory diagnosis of soil nutrient depletion in semi-arid areas of Kenya

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Summary

This paper describes the participatory diagnostic process undertaken as part of a 5-year research programme aimed at developing improved land and water management techniques in semi-arid areas of Kenya. Such diagnosis is an essential initial step in a Participatory Learning and Action Research (PLAR) programme whose goal is to develop appropriate techniques at farm level and formulate suitable policy recommendations.

The diagnostic process started at a village meeting, where farmers classified themselves into three soil fertility management groups and participants were selected to take part in the research programme. The next steps involved looking at soils from the various participatory farms, which were characterised by farmers and analysed by researchers, and then monitoring nutrient and economic flows into, out of and within the farm over a one-year period. This process generated various types of information, such as nutrient flow maps drawn by farmers, quantitative estimates of nutrient balances and indicators of financial performance, which were discussed at a joint meeting between farmers, extension agents and researchers. The differences between various farms were analysed, and a research agenda developed for the following season.

Experience has shown that farmers, extension agents and researchers all gain considerable insights into the causes of soil nutrient depletion from their involvement in soil sampling and nutrient monitoring activities with farmers. Farmers are more willing to participate in research when they receive direct feedback on the results of these activities, and are involved in the process of comparing differences between farms. The results of the diagnostic phase described in this paper have been incorporated into a comprehensive programme, in which the same group of farming households test appropriate technical innovations and use similar participatory procedures to evaluate their performance. In this way it is hoped that farmers and researchers will be better able to understand the possibilities for maintaining soil fertility and increasing sustainable output in the harsh ecological and economic conditions prevalent in the study area.

1 Introduction

Rural areas in Kenya are going through a period of profound change. This is partly due to rapid population growth, which has caused increasing migration into urban centres by people seeking better job opportunities, and out-migration, as others leave the densely populated areas of high and medium rainfall to look for new farmland in arid and semi-arid lands (ASALs).[1] When they move, farmers continue to use the production technologies common in their place of origin, which are not always appropriate to conditions in the new area and sometimes have disastrous consequences for the natural resource base in ASALs. This migratory trend has increased the population density in dryland areas of Kenya, intensifying pressure on land and heightening the risk of further degrading soils in these zones.

If insufficient nutrients are returned to the soil to replace those exported in crop products or lost from the system during cultivation, levels of soil organic matter and chemical soil fertility, especially nitrogen and phosphorus, will decline. Physical soil qualities like infiltration and water holding capacities also deteriorate, thereby increasing the risk of further losses through processes such as erosion and leaching (Ridder and Keulen, 1990). Yields will then decline and may only be maintained by increased applications of external inputs, but if these are unavailable or inaccessible, and no soil and water conservation measures are put in place, soil nutrient balances will tip into the negative. This is the situation in ASALs in Kenya, where land degradation is becoming a significant problem (Smaling, 1998; Stoorvogel et al., 1993).

Yields may be affected lack of water in dry years and insufficient plant nutrients in wet years, and although measures can be taken to maintain or improve productivity, farmers working in medium and low potential areas like ASALs have little incentive to invest in external inputs or other means of improving their land when national and international policies have significantly reduced the price of agricultural produce. With little financial return on their crops and the added risks caused by low and erratic rainfall, they may never recover their investment in inputs such as mineral fertiliser. Improvements such as terracing can make the use of fertilisers worthwhile, but these represent a long-term investment (Tjernstrom, 1986). For farming in ASALs to be profitable, more complex soil and crop nutrient management is required than in areas like the Kenyan highlands, which benefit from more favourable agro-ecological conditions.

[1] 44.6 million hectares of Kenya is made up of arable land, about 33.6 million ha of which is classified as arid or semi-arid lands (ASALs). Substantial areas of ASALs are located in Machakos, Mwingi, Makueni, Kitui and Kajiado districts.

The NUTSAL project

This five-year project started in 1998, with the aim of developing improved land and water management practices that will enhance productivity and control the rampant land degradation currently affecting semi-arid areas of Kenya. The following activities are planned during the project cycle:

- Implementation of NUTMON methodology (Jager et al., 2001) to diagnose problems in 5 semi-arid districts of Kenya;
- Scaling up farm-level nutrient flow data to district-level;
- Implementation of Participatory Learning and Action Research (PLAR) to develop appropriate integrated nutrient management technologies;
- Formulation of technology and policy recommendations to address soil nutrient depletion in semi-arid areas of Kenya.

Six representative clusters were selected to cover the most important semi-arid areas in Kenya. Working on the assumption that problems with maintaining soil fertility will be more pronounced in densely populated areas, these clusters were chosen on the basis of population density, as well as for their agro-ecological characteristics and farming systems. The next step was to identify within each cluster representative and accessible villages with predominantly intensive and diverse agricultural activities (see Table 1 below).

Table 1. Characteristics of the six selected clusters

Cluster site (and District)	*Annual rainfall (mm)*	*Farming systems*
Kionyweni (Machakos)	500	Cross-bred cattle, maize, beans and fruit trees
Matuu (Machakos)	600	Local cattle, irrigated farming, maize, beans and sorghum
Kasikeu (Makueni)	700	Maize, pigeon peas, beans and cowpeas
Kibwezi (Makueni)	550	Irrigated farming, pigeon peas, cowpeas, sorghum
Kiomo (Mwingi)	600	Maize, beans, sorghum, millet, pigeon peas
Enkorika (Kajiado)	500	Maize, beans, pastoralism

Machakos District

This paper discusses the approach and results of the diagnostic phase of the NUTSAL project in Machakos district, which is characterised by low but highly variable rainfall. Average annual rainfall varies between 500 and 800 mm, with bimodal distribution that allows for two growing seasons. Soils vary in depth depending on the parent material and slope. They are generally low in organic matter and deficient in nitrogen and phosphorus, but with adequate levels of potassium. Low infiltration rates and susceptibility to sealing make the prevailing soils prone to erosion, as heavy rains fall mainly at the beginning of the growing seasons when the land is bare (Jaetzold and Schmidt, 1983; Kilewe and Mbuvi, 1987; Gachimbi, 1996).

Most farming systems are based on rain-fed crop production integrated with varying levels of livestock rearing and, where water supplies permit, limited furrow irrigation (KARI-NDFRC, 1995). The main rain-fed crops are maize and beans, which are grown in monoculture or as mixed crops complemented by smaller areas of pigeon pea, cowpea, sorghum and millet. Irrigated agriculture is dominated by vegetables such as tomato, eggplant, okra, pepper, hot chilli and onion. Most farmers use semi-extensive grazing systems to rear indigenous cattle, which are resistant to local diseases and adapted to poor quality local feeds, although there are a few zero grazing livestock units in the area where improved crossbred animals are kept. The major problems affecting farming systems in Machakos are similar to those in other semi-arid regions, such as low and erratic rainfall and fragile soils with declining chemical and physical soil fertility. With low and unreliable agricultural production and dwindling natural resources, the livelihoods of local people are under considerable pressure.

Average farm size in Machakos District is about 2.5 ha. The area has a high population density of over 150 persons per km^2, which some claim has contributed to ‘induced innovations’ such as increased investment in soil and water conservation, improvements in recycling animal manure and diversifying crops to minimise the risk of crop failure (Boserup, 1965; CBS, 1989; Tiffen et al., 1994; Mortimore and Tiffen, 1995;). Households derive roughly a quarter of their income from farming activities (Jager et al., 2001; Nandwa et al., 2000), earning the rest from off-farm occupations like trading and casual labour in urban centres or on other farms.

Selecting farms and identifying farm management groups

Interested farmers were invited to village meetings (*baraza*) where participatory procedures were used to select farms from each village or cluster. Members of farm households, researchers, extension agents, the assistant chief and village elders then attended a one-day village meeting in Kionyweni village in Machakos District, held to present the global objectives of the project, its activities and expected outputs. The next step was to ask separate groups of men and women to identify the causes of declining soil fertility, signs of poor soil fertility and strategies for coping with the problem, before bringing all the farmers together to reach a consensus on strategies for coping with declining soil fertility.

Their first task was to identify local criteria for distinguishing between high, medium and low levels of soil fertility management used to sustain crop production. Next, they were asked to use their own criteria to assess each other according to these three categories, and their individual assessments were used as 'votes' so that each farmer could be classified into one of the three categories (see Defoer and Budelman, 2000). The final stage of the selection process was to identify colleagues for the NUTSAL study on the basis of their situation and willingness to participate in the study. In the end, 54 farmers were selected from a total of 218 households. Care was taken to ensure that participants were evenly distributed between the three categories, and that they were hard working (self-motivated), able and willing to teach other farmers, accessible, hospitable and ready to share costs during experimentation.

2 Soil characterisation

The available land resources on each farm selected for the study were classified in terms of Farm Section Units (FSU), which are defined as a continuous field within the farm that is assumed to have relatively homogeneous soil properties, slope, flooding regime and land tenure. It is assumed that FSUs represent the variability of more or less permanent soil properties and that they are not immediately influenced by variations in soil and crop management, although in the long run, modified management will alter 'permanent' soil properties. For example, applying manure over long periods will cause changes in the organic matter content and total levels of nitrogen and phosphorus (Okalembo et al., 1990).

Participating farmers drew up soil maps showing the local names for different soil types, and after each FSU had been identified, soil samples were taken to determine their physical and chemical characteristics. These became a central input in the participatory soil fertility assessment. Since 'homogeneous' farm units are heterogeneous at micro-level, it is necessary to create a composite sample containing material from the entire FSU. This may be obtained by walking along a transect through the unit, and taking a sample (to a depth of 30 cm) at every tenth step. The characteristics determined include soil texture and total content of nitrogen, phosphorus, potassium and soil organic matter.

NUTMON approach

The NUTMON approach was also used during this study. This starts by contacting people at village and farm level in order to obtain a representative sample of farming households from the study area who are interested in the objectives of the study. The next step is to assess the quality of the natural resource base, soil and crop management and farm financial performance. This is done through a process of farm inventory and monitoring, with a particular focus on nutrient flows into and out of the farm, and between different components within the farm. It is carried out at plot- and farm household level, as this is where most of the decisions about nutrient management are taken. The inventory is taken at the beginning of the growing season, while monitoring occurs at least twice per season: immediately after planting and at harvest time. A variety of participatory tools are used, ranging from general tools such as natural resource flow mapping, transect walks and soil maps drawn by farmers (Martin and

Sherington, 1997) to the specially developed NUTMON tool for quantitative monitoring and analysis, which is used to assess nutrient flows and indicators of financial performance (Bosch et al., 2001; 1998; Jager et al., 1998b).

The purpose of the diagnostic phase is to identify the main constraints to sustainable development at farm level, which provide the basis for the next, iterative *technology and policy development* phase (Jager et al., 1998a; Bosch et al., 1998). In the NUTSAL project PLAR approaches are used to identify appropriate technologies for testing by a selected group of farmers (Defoer and Budelman, 2000), and NUTMON procedures employed to monitor the performance of these technologies. Once the effects of these trials on the performance of various indicators have been assessed, participants can select the new technologies best suited to their needs.

3 Results and discussion

Causes of declining soil fertility

The main results of the process used to identify the causes of declining soil fertility, signs of poor soil fertility and strategies to cope with the problem are presented in Boxes 1, 2 and 3 below. Most of the men from farming households in Machakos earn the bulk of their income through off-farm activities, and as it is the women who are in charge of farm management, they tend to know more soil fertility management strategies than men. However, as they are generally quite reserved in mixed discussions, we found it useful to separate men and women into different groups for brainstorming sessions on the causes and signs of declining soil fertility, and strategies for addressing the problem. They were then reunited in a group session to discuss and arrive at a consensus on strategies for coping with declining soil fertility (see Box 4 below).

Box 1. Causes of soil declining fertility

Causes identified by women	*Causes identified by men*
• Soil erosion • Overgrazing (too many animals on a small piece of land) • Continous cultivation of the same land without adding manure/ fertiliser	• Overgrazing due to too many animals • Poor soil cultivation • Failure to apply farmyard manure and/or fertiliser • Soil erosion • Continous cultivation of the same land (no fallow)

Box 2. Signs of declining soil fertility

Signs identified by women	*Signs identified by men*
• Weak or stunted crops • Low yields • Failure of crops to flower • Appearance of weeds characterising poor soil fertility • Soil becomes hard and compacted	• Soil erosion • Nature of the soil (sandy) • Lack of soil conservation practices • Lack of income

Box 3. Strategies to cope with declining fertility

Signs identified by women	*Signs identified by men*
• Apply fertiliser and/or farmyard manure • Install *fanya juu* terraces • Rotate crops • Grow crops that could provide leaves for composting • Use compost as a fertiliser • Use soil from charcoal burning pits	• Install *fanya juu* terraces • Adopt good practices, such as deep cultivation/ox-ploughing • Apply farmyard manure • Use correct doses of fertiliser

Box 4. Strategies for coping with declining fertility

- Applications of assorted stover
- Applications of farmyard manure
- Crop rotation
- *Fanya juu* terraces
- Changing seed type
- Using mineral fertiliser

Soil fertility management groups

We have already described how farmers classified themselves as good, moderate or poor farm managers. The criteria they chose to identify these groups are presented in Table 2 below.

Table 2. Characteristics and practices used by each category of manager

Good managers	*Moderate managers*	*Poor managers*
• Plant early • Terrace their farms • Apply farmyard manure • Prepare land early for planting • Weed early	• Lack the means fully to implement the practices used by good managers	• Plant late because they lack implements or work for others • Have no livestock and therefore no farmyard manure to use as fertiliser • Lack seed – rely on borrowing from other farmers • Own small pieces of land so use mixed cropping • Are lazy

These criteria indicate that in this dryland farming system, good soil and crop management is perceived mainly in terms of strategies related to soil and water conservation, rather than the use of mineral or organic fertilisers. This is partly because it is considered risky to use fertiliser in this dry environment, and partly because in the past, lack of knowledge and information about these inputs resulted in crops being damaged by fertilisers that were supplied as part of a famine relief package.

Soil analysis and feedback

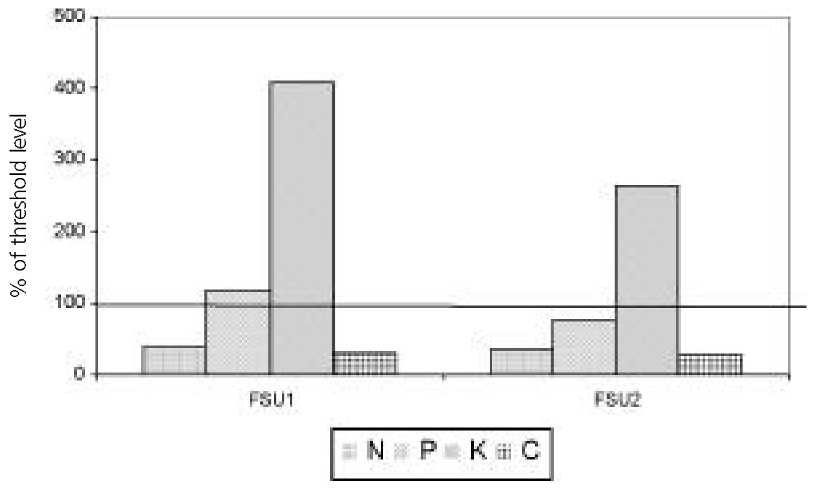
The soil chemical and physical characteristics of the samples collected from the FSUs were identified and analysed in the laboratory, and the results fed back to farmers. Table 3 below shows an example of a complete set of soil characteristics for a farmer from the Kionyweni cluster.

Table 3. Example of a complete set of soil characteristic, showing laboratory and farmer classifications

Farmer's name for soil	*English equivalent*	*pH*	*OM (%)*	*P (ppm)*	*N (%)*	*K (me/ 100g)*	*Sand (%)*	*Silt (%)*	*Clay (%)*
Nthangathi	Sandy clay loam	6.0	0.62	22	0.06	0.14	64	10	26
Nthangathi na Kitune	Sandy loam	6.6	0.27	5	0.05	0.26	78	12	10

As farmers found it difficult to relate these data to the identified indicators, or to understand the implications for possible changes in soil fertility management practices, the information was presented in the simplified graphic form shown in Figure 1 below.

Figure 1. Example of a soil sample farm report



At a joint meeting attended by participating farmers, extension agents and researchers, simple examples of the symptoms of deficiency were used to illustrate the concept of nutrient deficiency in plants. Farmers seemed easily able to identify a range of symptoms associated with poor soil fertility, such as reddish-purplish leaves, poor maize cobs, stunted crops, low crop cover, hardened soil, yellowish-green leaves and weak roots, but they were less clear about the relationship between symptoms and deficiencies in individual nutrient elements. The next step was to use the graphic presentations to discuss the results of individual soil samples and compare farms. To put them in perspective, the values measured are expressed as a percentage of the critical crop nutrient value identified as 'agronomically adequate' (Mehlich et al., 1964).

From Table 4 it appears that the values for soil nitrogen and organic matter are less than half of what is considered to be agronomically adequate, while there is plenty of potassium available, with values ranging from 2 to 4 times the adequate level. Figure 2, which shows the total soil N, P, K and C content for the high fertility management group, indicates that while there is little variation between households in N and C levels, average P levels vary more between farm households.

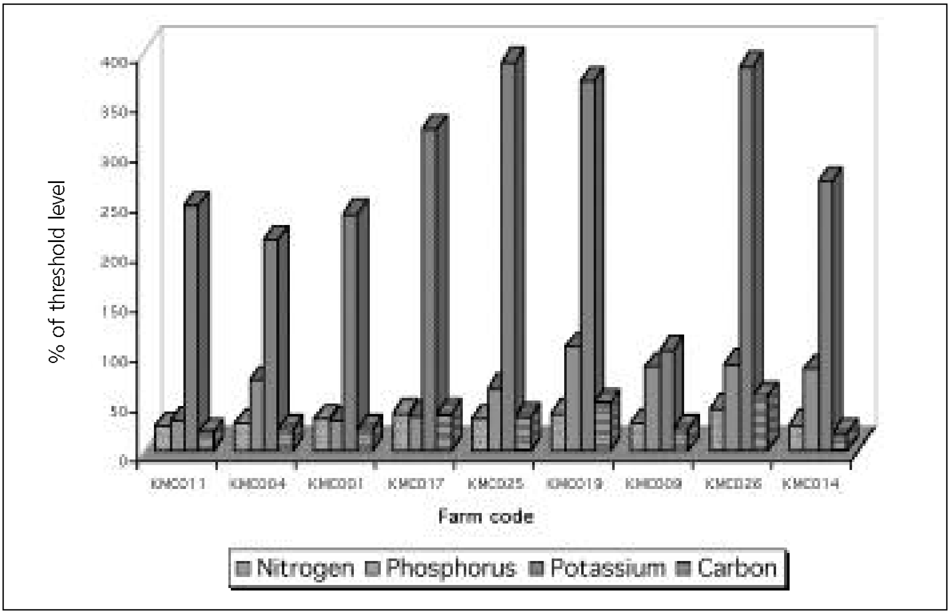
Table 4. Results of soil sample from the Kionyeweni cluster (in % of threshold level)

	Average	*High fertility management group*	*Low fertility management group*
Total nitrogen	30	32	29
Total phosphorous	56	65	62
Total potassium	255	281	217
Total organic matter	28	30	28

This combination of N and P values is typical in situations where soil fertility management largely revolves around mixed farming and the use of animal manure as a major source of nutrients. Manure contributes little to the soil nitrogen store because nitrogen is highly mobile in the soil-plant system, and is therefore liable to be lost through leaching and volatilisation during storage and after application. However, as phosphorus is far less susceptible to losses, a substantial proportion of the element contained in animal manure goes into the soil store.

Surprisingly, only marginal differences were observed in nutrient and organic matter content between the high and low soil fertility management groups. Given the accumulation of P, which presumably originates from animal manure, these results suggest that substantial amounts of manure have been applied, even though they do not show up in the C-content. It is highly probable that most of the organic components of the manure had decomposed before it was applied, due to the fairly high temperatures and moisture

Figure 2. Total N, P, K and C content in soils of farmers in high soil fertility management group in Kionyweni



levels in the upper soil layer, which favour microbial action (Ridder and Keulen, 1990). A further, more detailed analysis is necessary to clarify these results.

Nutrient flows and financial performance

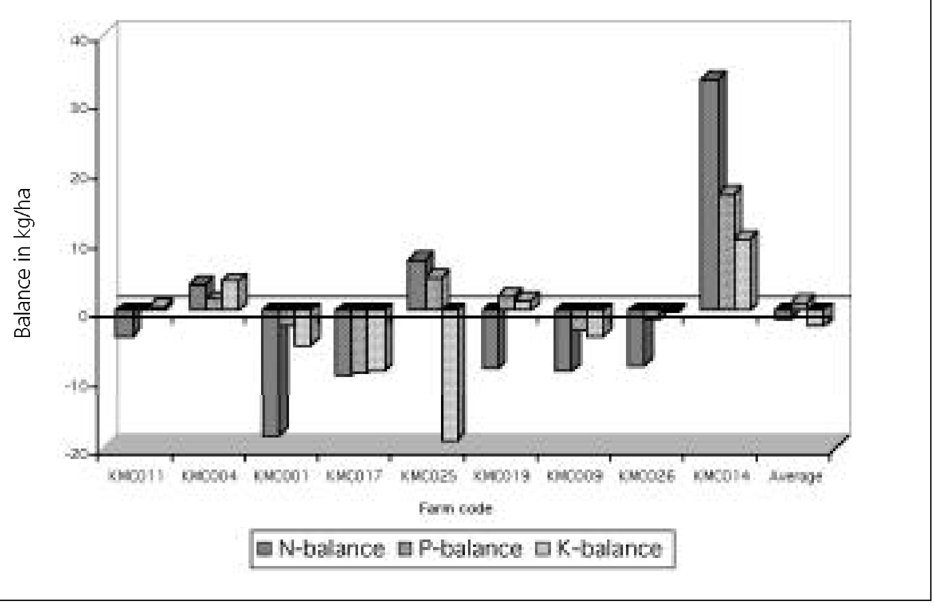
Table 5 and Figure 3 below show that soil fertility management practices directly influence nutrient flows on the farm. Table 5 shows slightly negative average balances for N and P, and slightly positive values for K. As can be expected, there is considerable variation between farms (see Figure 4), and N and P levels are slightly less depleted among the high fertility management group, mainly because they use more inputs. The low fertility management group uses no mineral fertiliser, while the high fertility management group applies a combination of manure and mineral fertilisers, and earns a great deal more from on- and off-farm activities. The two groups thus appear to reflect differences in their resource base as well as their management style.

Farmers met to discuss the reasons for the different parameters of each group, and then split into sub-groups to try to identify the relationship between specific farm management practices and the result of soil samples and nutrient flows. After discussing suggestions for improving soil fertility management practices within existing ecological and economic conditions and constraints, they agreed that technical innovations should focus on practices that make the best use of locally available resources to add nutrients to the soil. These included improving composting techniques and the management of farmyard manure, and using rock phosphate and row and spot applications of manure. It was also concluded that more farmers would be able to apply external nutrients through fertilisers and purchased organic manure, thus protecting the natural resource base, if they could secure better prices for their produce.

Table 5. Nutrient balances and financial performance indicators in the Kionyweni cluster, 1999-2000

	Average	*High fertility management group*	*Low fertility management group*
N-balance (kg/ha, year)	-3.8	-3.8	-6.6
P-balance (kg/ha, year)	-1.2	-0.1	-4.3
K-balance (kg/ha, year)	0.8	-2.9	-0.9
Fertilisers (kg/ha, year)	2.3	5.4	0.0
Organic manure (kg/ha, year)	4.5	3.0	5.3
Net farm income (Ksh/hh, year)	5400	13100	4000
Off-farm income (Ksh/hh, year)	9000	9600	5100

Figure 3. N, P and K balances for farmers in the high soil fertility management group in Kionyweni



4 Conclusions

This study indicates that farmers in the drylands of Machakos are well aware of the precarious condition of their soil resources. Soil sampling and nutrient monitoring activities jointly conducted by farmers, extension agents and researchers in the course of the NUTSAL project have considerably increased their understanding of the causes of soil nutrient depletion, and farmers now recognise that soil quality is gradually declining because current farming systems do not use enough inputs to replenish nutrient stores in their soils.

In our experience, farmers are more willing to participate in research when they receive direct feedback on the results of project activities, and are involved in comparing the different soil fertility management techniques used by their colleagues. This type of exercise, combined with comparisons of the associated differences in yields, nutrient balances and financial returns, proved very useful in identifying promising technical innovations.

At the moment, nutrient balances on the farms studied during the project are only slightly negative. Given the low soil fertility and unfavourable ecological conditions in the locality, poor harvests and total crop failure are generally accepted as a fact of life. However, by increasing the fertility of their soils, farmers will not only be able to make more efficient use of the limited water available, but will also be able to earn more from farming and achieve greater food security.

Although different practices were identified among the three soil fertility management groups participating in the study, they seem to have a very limited effect on selected indicators. The groups thus appear to represent not only different soil fertility management practices, but also differences in the availability and quality of the resource base. These observed differences will be used to develop and test technologies tailored to the resources available to farmers.

The results of this diagnostic phase have been incorporated into a comprehensive programme in which the same group of participants test and evaluate new techniques, which are adapted and changed as necessary. Although it would be unrealistic to expect any spectacular results in the short-term, given the harsh ecological and economic conditions in the study area, we are confident that a slow but steady process of increasing sustainable output, maintaining soil fertility and developing farmer and researcher knowledge is now under way.

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- Examination of the policy context within which soil fertility is managed
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