1 Introduction

There is a growing demand for changes in research and development approaches, so that farmers are involved earlier in the definition of production problems and identification of interventions. Participatory Technology Development (PTD)[1] is one of the approaches that can promote farmers' involvement in the diagnosis and analysis of constraints and opportunities, the development of technology and its dissemination. A PTD approach, using Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA), can also be used to evaluate soil fertility management techniques. Over the last ten years, these tools have become increasingly widely used in Sub-Saharan Africa for identifying farmers' problems, and as a means to plan research and possible interventions.

However, the degree of farmer involvement in the generation and dissemination of new soil fertility management technologies remains very limited in many parts of the continent. This may be attributed to lack of appreciation of farmers' knowledge about soils and soil fertility management, which was until recently much underestimated by soil scientists (Brokensha *et. al.*, 1980; Fairhead, 1992; Richards, 1985). By contrast, some researchers now propose to use farmers' indigenous technological knowledge (ITK)[2] as an approach for assessing rapidly soil fertility and crop performance without the need to conduct field trials (Villiers, 1996; Warren, 1991). However, few studies exist on the correlation between scientists' parameters and indices with farmers' perceptions and indicators of soils and soil fertility (Kanté and Defoer, 1994).

This study is part of a long term programme of monitoring soil nutrients, called NUTMON (see Box 1). It describes experience with using participatory approaches to elicit farmers' criteria and perceptions of soil nutrient management in Kenya and how to correlate these with researchers' knowledge. The main objectives were:

- To explore and compare farmers' and researchers' knowledge on soil management
- To identify constraints in current nutrient management practices and potential strategies for improving and maintaining soil fertility

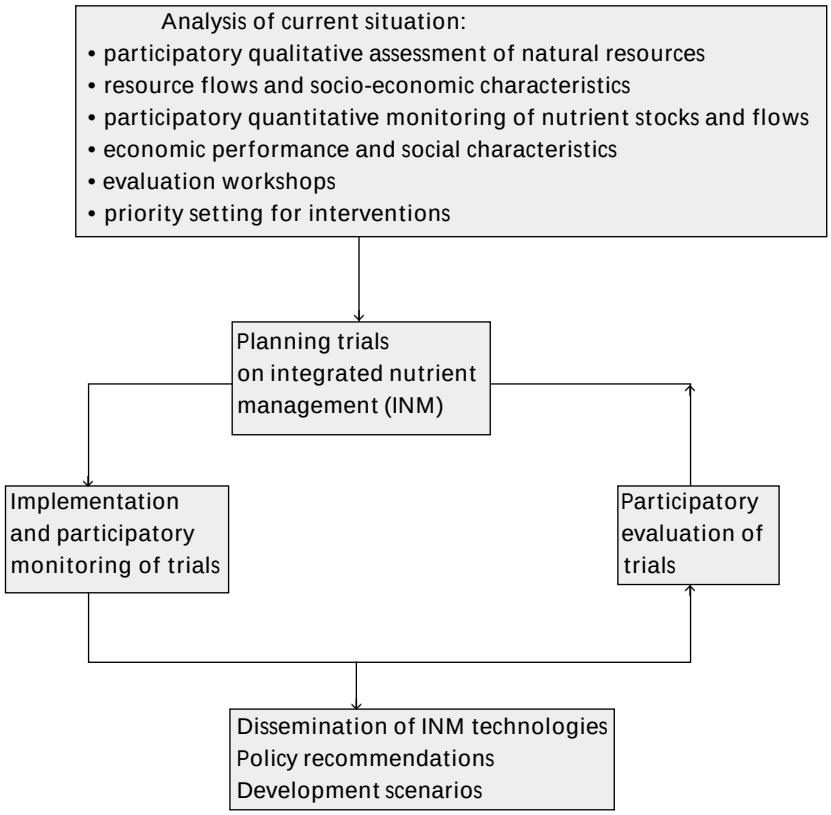
[1] Participatory Technology Development is a process of generating new technologies with the involvement of all stake holders (farmers, researchers and other end users) in priority setting, designing, testing and trying out the new practices, sharing the results and creating favourable conditions for continuous experimentation and sustainable agricultural development.

[2] ITK refers to people's knowledge about their environment and farming systems, including the capacity to expand this knowledge through observation and experimentation (Mettrik, 1993).

Box 1

PTD is one of the tools which is essential in nutrient monitoring. In the Nutrient Monitoring (NUTMON) project in Kenya, a general methodological framework for determining nutrient flows, stocks and balances (Fig.1) has been formulated (De Jager et. al., 1998) and a prototype for collecting and managing data and information on nutrient flows and farm household performance developed (Van den Bosch et. al., 1998). The NUTMON programme involves a multi-disciplinary approach and works with the various actors influencing soil nutrient management at different spatial and time scales. The combination of quantitative nutrient flows and balances, economic performance indicators and farmers' perceptions helps to determine the most appropriate technologies for a specific farming system. NUTMON combines the farming systems approach (Norman and Collins, 1986; Tripp and Woolley, 1989), with more recently developed PTD and farmers learning concepts (Chambers, 1989; Reijntjes et. al., 1992).

NUTMON concept



2 Study approach, methodology and materials

Study sites

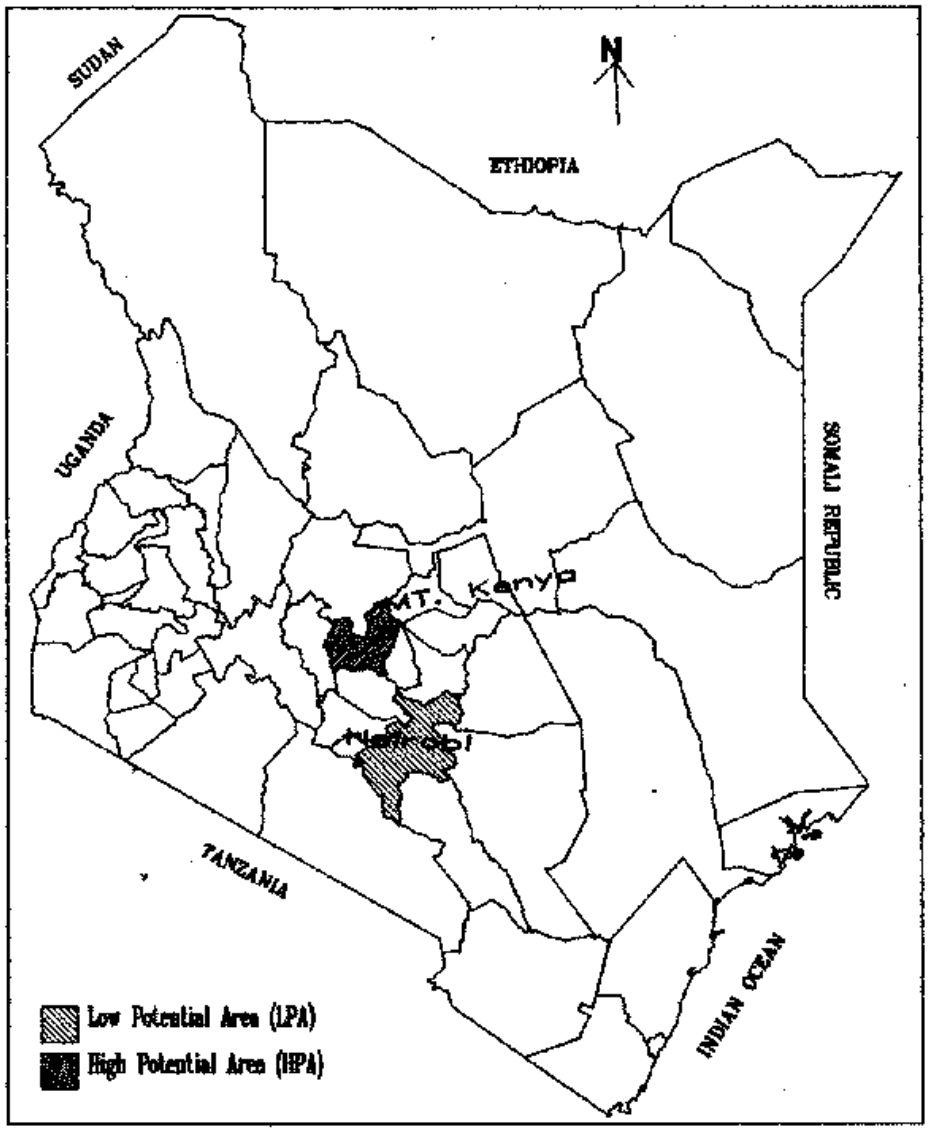
The study of soil nutrient management practices was conducted in a High Potential Area (HPA) in Othaya Division, Nyeri District and a Low Potential Areas (LPA) in Kalama Division, Machakos District (see Figure 1). These areas exhibit distinct agro-ecological characteristics and socio-economic circumstances which influence agricultural potential (Werf *et. al.*, 1997). A study in a LPA was considered particularly relevant for bridging the current information gap on nutrient management practices. It is often argued that substituting for external inputs with internal nutrient recycling is difficult in LPAs since there is less organic matter available due to lower rainfall and lower soil fertility status than in HPAs (Kessler and Moolhuijzen, 1994).

Nyeri District is situated in the Central Province of Kenya and lies between 1220 and 2400 metres above sea level. The area is characterised by a bi-modal rainfall pattern and mean annual rainfall ranges between 700 and 2200 mm. The two growing seasons have a total length of 150-209 days (Kassam *et. al.*, 1991). Approximately 80% of the land is suitable for agriculture. The soils are well drained, extremely deep, dark reddish brown to dark brown, friable and slightly smeary clay with acid humic top soil (ando-humic Nitosols with umbric Andosols).

The District has seven administrative divisions out of which Othaya Division is the selected study site. The Division is predominantly under tea, coffee, maize, dairy and vegetable farming systems (Jaetzold and Schmidt, 1982). The population of the District is about 772,000 persons, in 121,000 farm households with Othaya Division having 101,510 persons. The tenure system is free-hold and farmers have title deeds for their land. Soil and water conservation measures practised include physical measures such as cut-off drains, "fanya juu" terraces[3], bench terraces, narrow based terraces in coffee farms,

[3] Kiswahili term for a ditch of 0.6 M wide and 0.6 M deep dug along the contours to control soil erosion. The excavated soil is thrown uphill, thereby forming a ridge which catches the soil moved downhill by erosion and cultivation.

Figure 1. Location of Machakos (LPA) and Nyeri Districts (HPA) sites



stone lines and infiltration ditches. Cultivation measures practised are crop rotation, planting of agro-forestry trees, mulching, use of buffer strips, infiltration zones, planting with manure, contour planting, strip cropping, trash lines and use of cover crops.

The main problems facing farming systems in Nyeri district are (DAO, 1996a):
- Rapid decline of inherently fertile soil due to inappropriate farming practices resulting in soil mining
- Increased problems of pests and diseases on crops (e.g. bacterial wilt, fungal diseases etc.) especially under low soil fertility conditions
- High cost of farm inputs e.g. fertilisers, seeds and pesticides
- Decreasing per capita arable land
- Inadequate marketing infrastructure

Machakos District is located in the Eastern Province of Kenya, and covers an area of 616,300 hectares of which about 85% is classified as arid or semi-arid. In the centre of Machakos District, hills rise to 1800-2100 metres and are surrounded by an extensive plateau sloping from 1700 metres in the west down to 700 metres in the south-east. Rainfall received in the District has a bi-modal pattern and the average varies from 500-1500 mm depending on location and altitude. The research site has two growing seasons per year with a total length of 90-119 days (Kassam *et. al.*, 1991). The soils are well drained, moderately deep to very deep, dark red to reddish yellow, friable to firm, rocky, sandy clay loam to clay (Jaetzold and Schmidt, 1982), with top soils of loamy sand to sandy loam in many places (Ferralo-haplic Acrisols, ferric Acrisols with Luvisols and Ferralsols).

The population of the District is about 1,050,000 persons. The District has 10 administrative divisions out of which Kalama Division was selected as the study site. It lies in the maize-sunflower zone. Other crops grown include pigeon peas, sorghum, beans and fruit trees. Local breeds of cattle are kept and grazed on common pastures while farmland is held under a free-hold tenure system. Soil and water conservation (SWC) measures coupled with water harvesting techniques are extensively practised in the District to conserve the fragile soils (Tiffen *et. al.*, 1994). These include terraces (mainly bench terraces in the steep slopes), cut off drains, stone lines, trash lines, addition of farm-yard manure, crop residue management including mulching, and use of cover crops.

The main problems facing farming systems in Machakos district are (DAO, 1996b):
- Declining soil fertility due to fragile soils coupled with poor soil management practices, deforestation, etc.
- Decreasing per capita arable land
- Unpredictable and unreliable rainfall
- Limited use of agricultural inputs

Approach and methods

It was decided to compare conventional agriculture and LEISA (Low External Input and Sustainable Agriculture) farming systems in both research sites. LEIA (Low External Input Agriculture) is also used to refer to conventional agriculture in Kenyan discussions on organic farming. The characteristics of LEISA and Conventional Agriculture-LEIA are compared in Table 1.

Table 1. Characteristics of LEISA and LEIA farms

LEISA	Conventional Agriculture/LEIA
• Farm management which optimises the use of locally available natural and human resources and indigenous technical knowledge to enhance diversity, cyclic flow patterns and to build up living soil (ILEA, 1994; IFOAM, 1992; Reijntjes *et. al.,* 1992). • Characterised by a conscious drive towards sustainability • One approach to sustainable agriculture • Low cost input approach; high reliance on re-cycling of on-farm resources	• Farm practices characterised by the use of inorganic fertilisers, low degree of recycling and low degree of optimising nutrient availability. • Lack of conscious drive towards sustainability • Refers to mainstream farming practices carried out by majority of farmers in the research sites. • Spread and adoption facilitated by Government agencies

LEISA farming has been actively promoted in Kenya by NGOs, self-help groups, farmers and other development agencies since the 1980's. The origin of Conventional Agriculture/ LEIA farming systems can be traced back to the 1950's when synthetic fertilisers were introduced. Spread and adoption of these farm practices is facilitated by Government agencies and agricultural input supply companies. There are fewer farmers practising LEISA than their LEIA counterparts. Both Conventional Agriculture/LEIA and LEISA farming systems make use of indigenous technical knowledge. However, there is a conscious effort in LEISA systems towards integrating relevant indigenous technical knowledge into farm management practices. LEISA farming is also perceived as having lower constraints to adoption (due to low costs of inputs) and contributing to more productive and sustainable land use.

Common LEISA farm practices in the LPA and HPA research sites are composting, double digging, natural pest management techniques, crop rotation, liquid manure[4], 5-9 maize seed in a hole, plant tea[5], mulching and use of ethno-veterinary medicine in livestock management among others (Kariuki, *et. al.*, 1994). Some of these LEISA techniques are

[4] Top dressing product prepared from fermented fresh animal droppings in water.
[5] Top dressing product prepared from succulent plants fermented in water.

described in Annex 1. Conventional Agriculture-LEIA practices in the research sites include use of uncomposted farmyard manure, inorganic basal and top dressing fertilisers, use of synthetic pesticides and conventional animal husbandry practices. Practices common to the two farming systems are inter-cropping/multiple cropping, water harvesting, soil and water conservation practices, deep digging and nursery management.

Farms were selected after an introductory workshop with the community followed by field visits. Criteria used for the selection were: household size, location, area cultivated, main crops grown, slope, type and number of livestock, market orientation, mechanisation and contacts with extension/research (see Table 2).

Table 2. Comparative analysis of Conventional Agriculture (CA-LEIA) and LEISA farm households

Farm characteristics	LPA - Machakos		HPA - Nyeri	
	CA-LEIA	LEISA	CA-LEIA	LEISA
No. of farmers per group	10	8	9	9
Female headed households (%)	30	0	22	0
No. of households where women participated in the exercise (%)	80	50	30	30
Education household head (%)				
Non-educated	0	0	33	0
Primary or elementary	50	37	56	34
Secondary	50	50	0	0
Post secondary	0	13	11	22
Average household size	6.6	5.1	7.4	7.3
Labour capacity (family)	2.4	2.6	2.2	2.5
Average land size (Ha)	2.5	2.5	0.9	0.9
Average no. of cattle	2.5	5.1	7.4	7.3
Average slope (%)	17	17	18	22

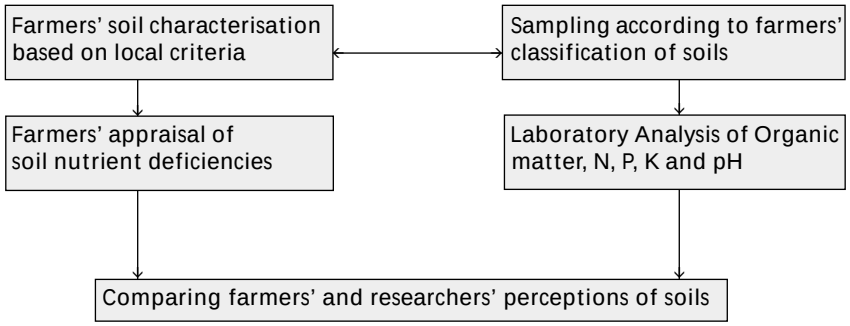
The main cash crop grown by both LEIA and LEISA farmers in the HPA is tea, while in the LPA there is no cash crop. Maize and beans are the main subsistence crops. In both areas the households in the sample are predominantly male headed and have contacts with extension agents. Labour is mainly provided by family members, although some people have sought off-farm employment in urban centres thus reducing access to their labour for the farm household.

Participatory analysis and characterisation of soils

The following four steps were followed during the participatory soil analysis (see also Figure 2):

1. Training of research staff in PRA
2. Making an inventory of farmers' knowledge
3. Soil sampling and analysis, followed by visualisation of the data
4. Comparing farmers' and researchers' perceptions of soil analysis through group discussions

Figure 2. Participatory analysis and characterisation of soils



Training of research staff in PRA

To discuss soil fertility management practices effectively with farmers and to exchange ideas and experiences, scientists need training in the use of participatory tools appropriate for diagnosis of soil nutrient management and the principles underlying such an approach. These include verbal and visual tools to stimulate discussions and to strengthen farmers' own analysis (Chambers, 1991). Visual aids play a crucial role in presenting information about objects, abstract ideas, and system linkages in a readily understandable form (Conway, 1987; Kirsopp-Reed, 1994).

Making an inventory of farmers' knowledge

Farmers' knowledge was explored using soil mapping following a transect walk, with all selected farmers. The resulting maps delineated all soil types that the farmer had identified, which were then analysed using pair-wise and matrix ranking. Criteria used for analysing each soil type were its relative importance in the area, intensity of use for agriculture, main crops grown, and its constraints and potentials. The different soil types on farmers' soil maps were later shaded in different colours by researchers. Each soil type was given a different colour according to a colour chart suggested by both researchers and farmers for each site.

Soil sampling analysis and visualisation of the data

Researchers then drew up their own inventory of soils through soil sampling and analysis. Sampling was done at a depth of 0-30 cm for each of the soil types identified by the farmers. Twelve random sub-samples were taken and mixed together to form a composite sample for laboratory analysis, for major nutrients using methods adopted by Tropical Soils Biology & Fertility programme (TSBF) (Anderson and Ingram, 1993). Organic matter content and soil pH were also analysed, and the results tabled separately for each individual farmer. Soil analytical data were presented visually in the form of numbers and symbols to cater for all stakeholders (farmers, researchers and NGO staff). Using bar charts, soil nutrients were depicted in three ways for each farm:

- Labelling/marking each type of the nutrient on the bar chart. Critical values for each soil nutrient were also depicted in the same chart
- Using designated colours to represent a given soil type, using the same colours as in the soil maps
- Using symbols derived from respective deficiency/sufficiency symptoms to represent nutrient elements

Comparing farmers' and researchers' perceptions of soil analysis

Farmers and researchers took part in joint discussion meetings in each area to share results of the soil analysis, and discuss their implications. First, a summary of colours used for each soil type in each agro-ecological zone was presented to the farmers, as the basis for identifying soil types. Next, each farmer was given a copy of his own soil map with each soil shaded in a different colour. Thereafter, researchers presented each farmer with the results of the soil analysis, visualised in a bar chart. Data were presented for pH, Organic Matter, Phosphorus, Nitrogen, and Potassium contents of all soils that farmers had identified. These soil types which were coloured as on farmers' soil map (see figure 3).

Levels of soil nutrients were presented in such a way that they could be identified using any of the following four methods:

- Comparing the proportion of each bar chart representing a particular soil type with the critical value for that nutrient
- Determining the direction of arrows drawn for each bar chart - a downward arrow was used to show nutrient deficiency while an arrow pointing upwards was used to depict nutrient sufficiency in each chart
- Reading numerical values given for each soil nutrient and soil type in the chart and comparing it with the relevant critical value
- Recognising the following, specific nutrient deficiency symptoms (see Table 3)

Figure 3. Farmer's soil map and visualisation of soil analytical data

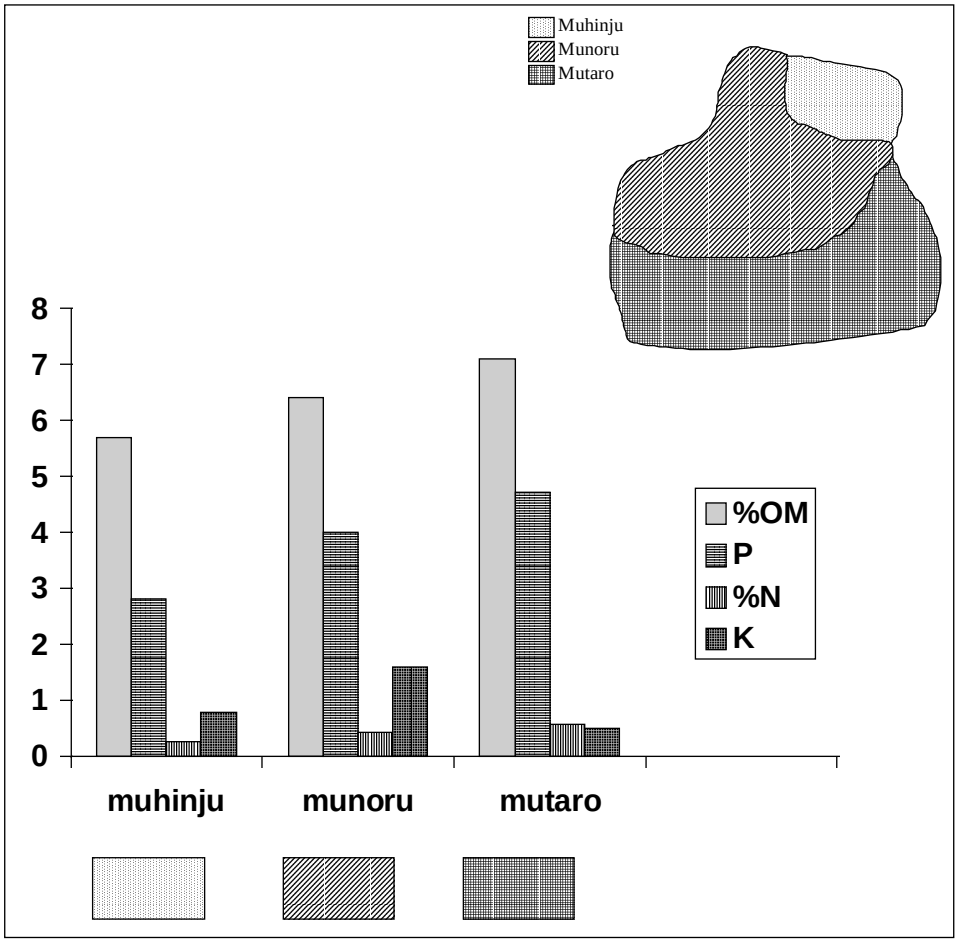


Table 3. Nutrient deficiency symptoms

Nitrogen	Phosphorus	Potassium
Stunted growth	Stunted appearance	Chlorosis along leaf margins
Yellowing	Purpling	Stunted growth
Reduced flowering	Poor root development	Weak stalks, lodging

A discussion then took place between farmers and researchers and amongst farmers on the implications of the soil analysis results and how best to address the nutrient deficiencies identified. A list of proposed materials and interventions was suggested by both farmers and researchers for addressing soil nutrient deficiencies.

3 Results

Matching farmers' soil classification with researchers' analysis

A comparison of farmers' description, classification and evaluation of soil fertility with results of chemical analyses of the same soils sampled from the high and low potential areas is given in Tables 4 and 5 respectively. The description and classification of soils by farmers in Nyeri according to soil fertility status rating runs from *Tiri Muhinju* (poorest) > *Tiri wa ngumba* (poor) > *Tiri Monuru* (fertile) > *Tiri wa mutaro* (very fertile). These categories are consistent with the values obtained from the soil chemical analysis for Phosphorus e.g. 2.76 > 3.36 > 3.96 > 4.70 P (ppm); for Nitrogen 0.25 > 0.41 > 0.42 > 0.58% N; and soil organic matter 5.70 > 5.20 > 6.40 > 7.06% OM. The increasing fertility of the soils was also linked to the increasing amount of silt e.g. 12% > 40% > 20% >32% found in moving from poorer to more fertile soils (see Table 4).

Farmers in the LPAs of Machakos described their soils in terms of colour, but the correlation between farmer categories and soil chemical properties was less clear than in high potential areas. One explanation may be that soils in LPAs are predominantly sandy-clay soils, with phosphorus, nitrogen, potassium and organic matter values at or below the critical level.

The analysis of farmers' perceptions and knowledge provides insight into the criteria they use for distinguishing amongst different soil types and their strategies for soil nutrient management. Furthermore, the results from farmers' soil maps provide information that can help bridge farmer and scientists' knowledge systems on soil fertility management. This study shows that farmers have considerable knowledge of soil types and their constraints and potentials (Table 6), although farmers distinguish soil types and their different attributes based largely on their appraisal of the topsoil. These criteria are mainly qualitative and include soil colour, susceptibility to erosion, moisture retention capacity, 'fertility', 'potential', texture and soil borne diseases.

Table 4. Example of comparing farmers' soil classification with researchers' analysis in Nyeri (HPA)

FARM CODE:	KNL 09, LEISA										
Soil type (Farmers classification)	English translation	pH	% OM	P ppm	%N	K me /100g	P Olsen ppm	% Sand	% Silt	% Clay	Texture class
Tiri muhinju	Poor soil	4.3	5.70	2.76	0.25	0.78		20	12	68	C
Tiri munoru	Fertile soil	4.9	6.40	3.96	0.42	1.58		16	40	44	C/Sic
Tiri wa ngumba	Clay soil	4.6	5.20	3.36	0.41	0.33		16	20	64	C
Tiri wa mutaro	Deposited soil	4.8	7.06	4.70	0.58	0.50		32	32	36	CL

Table 5. Example of comparing farmers' soil classification with researchers' analysis in Machakos (LPA)

FARM CODE:	KMC 08, LEIA										
Soil type (Farmers classification)	English translation	pH	% OM	P ppm	%N	K me /100g	P Olsen ppm	% Sand	% Silt	% Clay	Texture class
Nthangathi	Sandy soil	6.7	1.18	1.07	0.08	0.31	2.13	76	8	16	SCL
Nthangathi na kitune	Red sandy soil	6.8	1.60	1.01	0.11	0.67	0.92	72	0	28	SCL
Nthangathi na yumba	Sandy-clay soil	6.4	0.46	0.86	0.12	0.35	0.65	72	4	24	SCL

Table 6. Farmers' perceived soil constraints and evaluation criteria

Nyeri -HPA	Machakos - LPA	
LEISA & Conventional Agriculture [6]	**LEISA**	**CA - LEIA**
• Soil erosion • Soil borne pests • Reduced soil fertility resulting in poor crop yield • Change in soil structure-loose soils	• Low water holding capacity • Poor crop growth due to low rainfall • Soil erosion/steep slopes • Shallow soils • Reduced workability during dry season • Lack of organic matter	• Soil erosion • Low water holding capacity • Poor crop growth • Reduced soil fertility • Stoniness/shallow soils • Reduced workability during periods of heavy rains/dry season

A similar study conducted in Mali showed that farmers distinguish soil types on the basis of criteria which are often reflected in the local name given to these soil types. Criteria such as topography/geomorphology and presence of coarse elements are used to classify land types while soils are distinguished on the basis of cultivation constraints or their agricultural potential (Kanté and Defoer, 1994). The names given to soils in Kenya follow the same pattern. Thus sand gives its name to sandy soils *(Nthagathi)* and clay to clayey soils (*Ngumba* in HPA and *Yumba* in LPA).

The use of different colours to shade the soil maps allowed farmers to identify specific soil types easily and visualise their location in different parts of the farm. The visual presentation helped them to recognise the relationship between critical soil nutrient levels and measured values of N, P, K and organic matter for each soil type (see Table 7).

Table 7. Farmers' conclusions from the soil analysis data

LPA - Machakos	HPA - Nyeri
• Low levels found of soil organic matter (OM), Nitrogen and Phosphorus • Moderate levels of potassium • The low levels of OM, N, and P explain the poor performance of crops • Farmers' appraisal of nutrient deficiency symptoms corresponds well with the levels of nutrients obtained through chemical analysis	• Moderate levels found of soil organic matter (OM), Nitrogen and Potassium • Low levels of soil Phosphorus and pH • The low level of P and pH explains the poor performance of crops in soils classified by the farmers' as poor and in soils where tea is not grown • Farmers' appraisal of nutrient deficiency symptoms corresponds well with the levels of nutrients obtained through chemical analysis

[6] There was no difference in perception between LEISA and LEIA farmers

The ease of matching each soil type with their characteristics, greatly stimulated farmers' participation and self-confidence in discussing laboratory results from the soil analysis with researchers. Not all participating farmers had the same educational background. This way of presentation therefore played a crucial role in promoting the participation of all farmers in the discussion.

Suggestions for improving soil fertility

Following these joint discussions and learning process, a number of possible interventions for addressing soil nutrient deficiencies were identified and discussed (Table 8). There was almost no difference between the suggestions given by farmers for addressing problems of soil nutrients between the two sites. They differed however between the two farming systems with LEISA farmers emphasising the use of locally available organic inputs for addressing the various soil nutrient deficiencies identified.

Table 8: Farmers' suggestions for improving soil nutrient status

LEISA	Conventional Agriculture- LEIA
• Use of compost • Use of liquid manure • Use of green manure • Use of different types of terraces	• Use of farm-yard manure • Use of inorganic fertilisers • Use of different types of terraces

Researchers' suggested to address soil phosphorus deficiencies by using rock phosphate, improving the quality of compost (using additives like ground-up egg shells, blood and bone meals) and use of *Tithornia sp* as a green manure. For improving soil nitrogen, they proposed the use of green manure, liquid manure, plant tea and 'Biofix' for biological nitrogen fixation. Compound fertilisers can also improve soil phosphorus and nitrogen levels. The use of crop residues, farm-yard manure, compost and other degradable organic refuse was suggested for ameliorating soil organic matter contents, while practices like crop rotation and improved soil and water conservation are also instrumental in maintenance of soil fertility. Researchers proposed liming to correct pH in areas where the soils were very acid except where tea is grown.

4 Conclusion

While farmers use qualitative measures and researchers quantitative data to categorise soils according to their fertility, there is a considerable degree of correlation between the systems. The study showed clearly that farmers understand the types and nutrient status of their soils and use this knowledge to adjust soil nutrient management practices. Crop choice depends on differences in soil types.

Farmers in low and high potential areas manage agricultural inputs on the basis of perceived opportunities and risks associated with their use. Land regarded as fertile receives few inputs (compost, farm-yard manure, fertilisers etc.) or none at all. The limited inputs available are used to fertilise those portions of land which have not received inputs in the previous season. Commercial crops, such as tea, receive higher quantities of inputs than subsistence crops.

In the high potential area, Nyeri, farmers' classification of soils is consistent with the results of soil chemical analyses. However, the correlation between farmers' perception and classification of soils with the results from soil analysis was less clear in the low potential area Machakos.

It can be concluded that participatory diagnosis of soil nutrient management is a useful tool in understanding farmers' and researchers' perceptions of soil nutrient management. Studies of participatory diagnosis of soil nutrient management in Kenya using NUTMON methodology have been used to explore farmers' awareness of soil fertility management issues and to involve farm households, extensionists and research staff in formulating priorities for testing and developing Integrated Nutrient Management (INM) technologies. These studies show that farmers are clearly aware of the risks to soil productivity from continuous cropping on the same field, inadequate supplies of manure where livestock are scarce, and from soil erosion.

The study has shown that the use of participatory tools for analysing soils and soil fertility at farm-level is useful for researchers. These tools were instrumental for involving farmers in a debate with scientists on how to achieve more sustainable management of soils within their own setting.

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Annex 1: Examples of LEISA practices and their contributions to enhancing soil fertility

LEISA practice	Description/concept	Contributions
Composting/ compost	Practical system of mixing, layering and breaking down materials under a suitable environment to give humus end product	• Supply of crop nutrients/nutrient recycling • Moisture retention • Activates soil life • Increases C. E. C. thus improves uptake of nutrients • Improve soil structure and related properties e.g. moisture retention • Buffer material (soil pH management)
Double digging	Creates a deep layer of loose fertile soil (60 cm deep) with favourable root depth for crop growth; breaks hard pan	• Improves soil aeration, drainage, water holding capacity and soil thermo regimes • Supply of crop nutrients • Reduces leaching of nutrients • Increases root depth
5-9 maize in one hole	Holes dug 60 cm deep and well fertilised with compost. Used for gradual fertilisation of land	• Moisture retention • Supply of crop nutrients • Reduces leaching of nutrients • Increases root depth
Plant tea	Nitrogen source prepared from succulent plant remains. Used for top dressing	• Supplies additional Nitrogen
Liquid manure	Nitrogen source prepared from fresh culturally acceptable livestock droppings	• Supplies additional Nitrogen
Organic animal husbandry	Integration of livestock and crops	• Closing nutrient cycles-N and C cycles Provide manure
Fertility trench	Builds up a layer of fertile soil in shallow soils. Suitable forrocky places, murrum areas, etc.	• Supply of crop nutrients • Increases water holding capacity • Increases root depth

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