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Facilitated learning in soil fertility management: assessing potentials of low-external-input technologies in east African farming systems

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Abstract

The paper describes the facilitated learning process of farm households and district policy makers in addressing the problem of soil nutrient depletion. The process is applied in a case study in four districts in Kenya and Uganda during the period 1997–1999, where the potentials of low-external input technologies (LEIA) in addressing the soil nutrient depletion problem were assessed. Working through an inclusive process of dialogue, observation, diagnosis, experimentation and exposure to different types of knowledge, participants made a thorough analysis of the current soil fertility situation and tested various LEIA options for improving soil fertility management. In all four research sites the future agricultural productivity is threatened by soil nutrient depletion. Maximal use of locally available nutrients through LEIA techniques, combined with optimal use of external nutrients appears to be the most appropriate strategy in the existing economic environment. Long-term and intensive collaboration between research institutions on the one hand and extension services, non-government and community based organisations on the other are a prerequisite for a successful and sustainable implementation of a facilitated learning approach. Involvement of stakeholders in the various stages of the research process, including the planning and project formulation is essential for an effective follow-up and implementation of the results. More attention needs to be paid to the development of communication tools to enable an effective interaction between policy makers and researchers.

Keywords: Participatory technology development; Facilitated learning; Soil fertility; Nutrient management; East Africa

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1. Introduction

The number of people falling below the poverty line of US$1/day is estimated above 1.3 billion in the whole world and is still increasing, especially in Sub-Saharan Africa (SSA) rendering most of them food insecure. Many studies and workshops have addressed this issue and tried to identify the major causes and to develop strategies alleviating poverty and food insecurity (McCulloch et al., 1999). A world-wide consultation of relevant stakeholders conducted by IFPRI resulted in a number of emerging issues for food policy research for developing countries (Pinstrup-Andersen, 2000). The continued degradation of the natural resource base is, together with other aspects such as the partly negative impacts of increasing globalisation, the slow technology revolution, the changing role of the state and importance of good governance, the imperfect functioning of agricultural input and output markets, and processes of population increase and urbanisation considered as being a major constraint to achieve the necessary productivity increases in the future. Various publications have addressed the magnitude of resource degradation (Stoorvogel et al., 1993; Van der Pol, 1993; Scherr, 1999; Smaling et al., 1999), and technical solutions to the observed constraints have been proposed (Smaling and Braun, 1996; Mokwunye et al., 1996; Braun et al., 1997). So far impacts have been rather limited since many of these technical options require relatively high capital investments, need a well-functioning infrastructure and a conducive policy and market environment, all of which are constraining factors in most of SSA.

In one response to the low success rate, the research community and development organisations started to shift its focus to developing low external input technologies (LEIA). The effectiveness and impacts of these approaches have been subject of debate. Research results, mostly in the form of case studies, and practical NGO experiences have shown success stories with implementation of LEIA techniques (Reij et al., 1996; Reij and Waters Bayer, 2002). Other authors advocate the inadequacy of these solutions given the growing population and related need for food and economic growth and development (Van Reuler and Prins, 1993; Koning et al., 1998) or describe the limitations (Blaikie et al., 1997). Another line of thought attempts to combine low and high input technologies in an Integrated Nutrient Management (INM) approach, which attempts to maximise the use of local resources and optimise application of external inputs (Smaling et al., 1996; Pretty, 1995). In the search for INM-practices, experiences of low-external input and organic farming at farm-level in SSA have hardly been examined systematically.

The lack of participation of principal stakeholders, such as farm households and policy makers, in technology development processes is considered as another major limitation to success (Defoer et al., 2000; Smaling et al., 2002). Technical options often prove inappropriate for the complex environment of farm households, which have to satisfy multiple goals and are often forced to focus on a short-term planning horizon. Policy makers also have multiple goals and rarely focus on agriculture or natural resource degradation alone. Involving policy makers in the development of the research process is essential to create awareness of the problems of natural resource degradation, to focus research on the needs of the policy makers and to establish linkages between technologies and related required facilitating policies (Scoones, 2001).

The purpose of this paper is to describe and assess the facilitated learning process of farm households and district policy makers in addressing the problem of soil nutrient depletion. The process is applied in a case study where the potentials of low-external input technologies in addressing the soil nutrient depletion problem are assessed. The case study is based upon the experiences and results of a project in four districts in Kenya and Uganda during the period 1997–1999.

2. Methodology

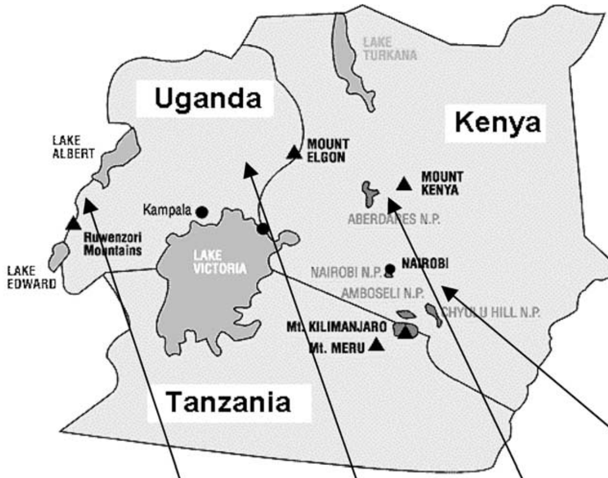
2.1. General approach

The project was implemented in four research sites in Kenya and Uganda (Fig. 1), two with a high agricultural potential (fertile soils, high and reliable rainfall) and two with a medium to low agricultural potential (low soil fertility, low and unreliable rainfall). The nutrient monitoring approach (NUTMON) has been implemented as described in detail by De Jager et al. (1998a, 2001). The approach distinguishes a diagnostic phase where the current soil fertility status, farm management and its influence on resource flows, economic performance and socio-economic environment is assessed. A variety of tools are used such as Participatory Rural Appraisal (PRA), natural resource flow mapping, transect walks and matrix rankings, and a specifically developed quantitative monitoring tool to assess nutrient flows and economic performance indicators. The diagnostic phase is followed by an iterative and participatory technology and policy development phase to address problems identified during the diagnostic phase. During this phase technologies are tested using existing Participatory Technology Development (PTD) methods (Reijntjes et al., 1992) and policy options are explored during a series of workshops with policymakers.

In this project two farm management groups were distinguished and compared:

- 'LEIA management' defined as farm households trained in low-external input technologies (composting, application of liquid manure etc.) and having applied at least three of these techniques on more than 50% of the cultivated area over a minimum of 3 consecutive years.
- 'Conventional management' defined as farm households with similar production resources as the LEIA management group not practising any of the defined LEIA techniques and being representative of the common farming systems characteristics in the catchment.

The differences between the management systems were quantified at the start and monitored during the implementation of the project (Table 1).



	Kenya		Uganda	
District	**Kabarole**	**Pallisa**	**Nyeri**	**Machakos**
Agric. Potential	High	Medium-low	High	Medium-low
Altitude (m.a.s.l.)	1500-1800	1000-1100	1100-2400	500-1300
Rainfall (mm)	1300-1500	800-1200	1200-2000	500-900
Soils (main type)	Andepts	Ferrasols	Andodols, Nitisols (clay)	Luvisols (loamy-sand)
Av. Slope (%)	20	1	21	17
Pop. dens. (n/km2)	400	220	250	100
Av. Land size (ha)	1.6	2.6	0.9	2.5
Crops	Banana, Tea, Maize, Coffee	Maize, cotton, beans Cattle (free-range)	Tea, coffee, maize	Maize, beans, sorghum
Livestock	Cattle (zero-grazing)		Dairy cattle (zero-grazing)	Cattle (corralled at night)

Fig. 1. Research sites and characteristics.

2.2. Farm selection

A representative catchment within each administrative district was selected, after which 14–18 farm households per district were included in the research, divided over two management groups according to the criteria set for LEIA and conventional management. The actual selection process commenced with a workshop for the whole community aiming at discussing the objectives, creating ownership of the project and discussing criteria for participation. LEIA farm households were selected by the community in close co-operation with the NGO-staff. The latter ensured that the formulated selection criteria (representativeness for the catchment, definition of LEIA) were met. The matching group of farms with conventional farm management was selected in a similar process, whereby the NGO-staff assessed the

Table 1
Application levels of LEIA farming techniques of farms with conventional and LEIA farm management in Machakos district, Kenya[a]

Soil fertility management practice	% Farm households applying			
	Conventional		LEIA	
	Year 1	Year 2	Year 1	Year 2
Short-term practices				
Composting	10	100	100	100
Intercropping	90	90	88	88
Crop rotation	80	80	100	100
Double digging	0	20	75	75
Deep digging	0	30	50	50
Natural pesticides	0	20	75	75
Tree nurseries	10	10	63	63
Liquid manure	0	0	63	63
Long-term practices				
Fanya yuu (terracing)	100	100	–	–
Cut-off drains	42	42	37	37

[a] 'Year' refers to year of project implementation.

similarity of production resources with the LEIA group (land, animals, soil type, access to water, etc.). All farms were finally included only after a farm visit by the NGO-staff and further discussions with the farm household members verifying the selection criteria and motivation for participation.

2.3. Participative diagnosis of soil fertility status and management practices

The diagnosis consisted of the following activities: (1) farm households' assessment of natural resources, (2) soil sampling, (3) monthly monitoring, (4) analysis. Farm households' perceptions of the current soil fertility management practices were identified through methods such as farmers' soil maps, transect walks (Reijntjes et al., 1992), nutrient flow maps and group discussions. Based upon the farmer' soil maps, a soil analysis was conducted for N, P, K and organic matter content. Monthly monitoring of the farm management practices was done using structured questionnaires and sampling of nutrient contents of major input and output flows conducted. In order to calculate nutrient flows and balances, additional data were collected to feed the transfer functions, simple models and the background database (Vlaming et al., 2001). At farm household level economic performance indicators such as net farm income, household net cash flow and returns to labour were calculated, while at activity level gross margins and net cash flows for crop and livestock were determined. In addition, a simple environmental analysis was made in which the costs of replacing the lost nutrients were valued at farm-gate fertilizer prices (De Jager et al., 1998b). Analysis of the data consisted of (1) farmers' assessment of natural resource management and economic performance, (2) the quantitative nutrient flows and economic performance using the NUTMON methodology and soil sample results, (3) integration of the two previous steps and discussing results with participating farmers.

2.4. Identification, testing and evaluation of low-external-input technologies

Impact assessment of selected LEIA techniques on the two management groups was done over two seasons through a PTD process (Reijntjes et al., 1992) including the following steps: problem identification, identification of technical options for experimentation, inventory of farmers criteria and indicators for evaluating LEIA technologies, and implementation and evaluation of on-farm trials. A training of the project staff was conducted to facilitate the implementation of the PTD process. The skills gained from the training were used to conduct 'experimentation design workshops' in four research sites, followed by implementation of PTD activities. The workshops commenced with a rehearsal of the results of the problem diagnosis, after which researchers and farmers presented separately potential technologies to address the observed problems. Using various group dynamic tools such as sub-group discussion, visual tools and brainstorm sessions one or more technologies were selected for testing, treatments were designed, data collection procedures agreed upon and action plans drawn for implementation of activities. Simple record sheets were designed for data collection by farmers in addition to quantitative data collected by the research staff. Results were evaluated at three levels: individual farmer's evaluation, joint evaluation among farmers during field days and joint evaluation during group meeting involving farmers, extension staff and researchers.

2.5. Formulation of enabling policies and measures at district level

Based upon the participative diagnosis, the results of the on-farm testing programme, an inventory of historic developments in the district, and an inventory of the existing and relevant policies in the research sites, draft qualitative scenarios for future developments in the areas were formulated. The scenarios described three possible development paths for soil fertility management in the coming 15 years on the basis of identified key indicators: net farm income, productivity of the farming system, nutrient flows and balances, food security. In district workshops in each research area, all relevant stakeholders (Ministry of Agriculture and Rural Development, Ministry of Environment and Natural Resources, provincial administration, development agencies and NGOs, research institutions, extension office and staff, input suppliers, farmers and farmers' representatives, media reporters) discussed these scenarios. Thereafter a vision for a desired situation within 15 years was formulated, the conditions necessary to arrive at this desired situation, the most constraints likely to be encountered and actions necessary by various actors to overcome these constraints.

3. Results

3.1. Diagnosis of soil fertility status and management practices

For all farms, farm soil maps, soil maps analysis and nutrient flow maps were produced jointly by farmers and project staff (Fig. 2). These maps enabled farmers to visualise the nutrient flows on their farms, provided insight in farmers' perceptions of soil nutrient status and flows and contributed, together with the quantitative analysis, to the overall problem analysis of soil nutrient depletion status. Application of the NUTMON model resulted in a quantitative assessment of the soil nutrient status, flows and economic performance indicators of the current farming systems. Only marginal differences were observed between the conventional and LEIA farm management systems (Table 2). The differences between the districts were much more profound. The high potential areas, although different in farming system, both showed a relative high N, P, K nutrient content of the soil, but also more negative nutrient balances at farm level, especially for N (90–125 kg ha^{-1} $year^{-1}$ representing an annual 0.7–1.8% loss of the stock). The latter was mainly due to high erosion, leaching and gaseous losses, and despite relative high uses of mineral and organic fertilizers (Table 3). In the low potential areas the differences in

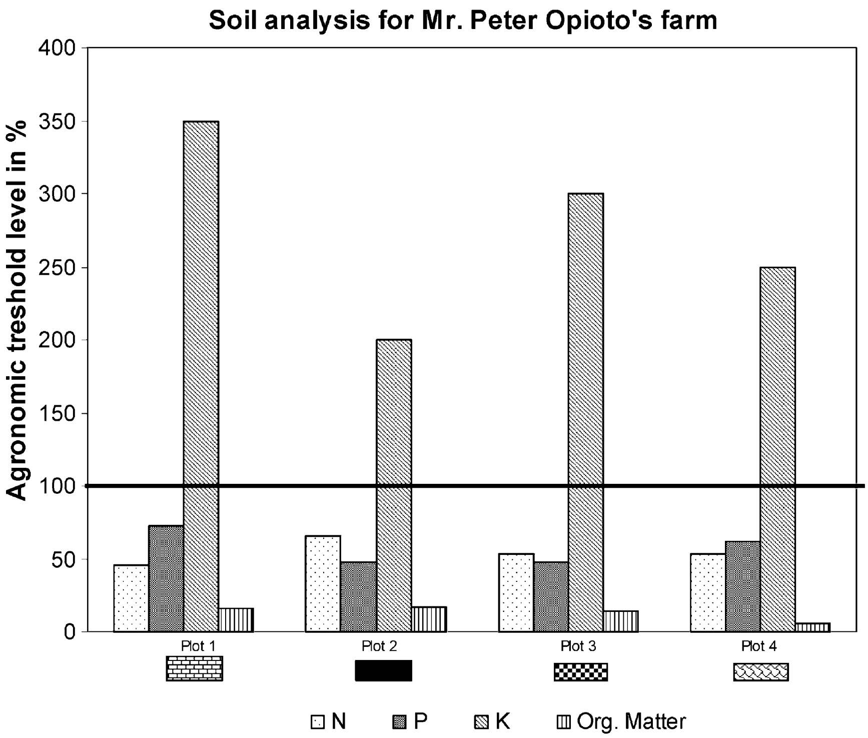


Fig. 2. Example of soil sample feedback report in Palissa district, Uganda.

Table 2
Nutrient stocks and flows in four districts in Kenya and Uganda in the period 1997–1998 (average of 2 years)[a]

	Machakos (LPA)		Nyeri (HPA)		Pallisa (LPA)		Kabarole (HPA)	
	CONV	LEIA	CONV	LEIA	CONV	LEIA	CONV	LEIA
N-stock (kg/ha)	3900	6400	12,200	12,300	3100	3000	6800	8300
N-flow (kg ha^{-1} $year^{-1}$)	−21	−25	−99	−91	−3	−4	−126	−95
N-flow (% of stock $year^{-1}$)	−0.5	−0.4	−0.8	−0.7	−0.1	−0.1	−1.8	−1.1
P-stock (kg/ha)	2000	1700	7900	8000	1000	2500	10,300	9000
P-flow (kg ha^{-1} $year^{-1}$)	2	1	−23	−27	0	0	−70	−57
P-flow (% of stock $year^{-1}$)	0.1	0.1	−0.3	−0.3	0	0	−0.7	−0.6
K-stock (kg/ha)	7800	10,200	10,400	15,300	6100	6300	7800	8400
K-flow (kg ha^{-1} $year^{-1}$)	−9	2	−23	18	2	1	−55	−7
K-flow (% of stock $year^{-1}$)	−0.1	0	−0.2	0.1	0	0	−0.7	−0.1

[a] LPA, low-medium potential area; HPA, high potential area; CONV, conventional farm management practices; LEIA, low-external-input farm management practices; and N, P, K stock measured as N—total, P—total and K—total.

Table 3
Average farm level nitrogen flows per type, research site and management type in Kenya and Uganda in the period 1997–1998 (in kg ha^{-1} $year^{-1}$; average of 2 years)

	Machakos (LPA)		Nyeri (HPA)		Pallisa (LPA)		Kabarole (HPA)	
	CONV	LEIA	CONV	LEIA	CONV	LEIA	CONV	LEIA
Mineral fertilizer	5	2	64	68	0	1	0	0
Organic inputs	5	9	32	74	5	7	20	17
Atmospheric deposition	4	4	6	6	4	4	5	5
Biological fixation	8	10	7	7	1	1	15	12
Crop/livestock products	−2	−2	−38	−30	−1	−2	−3	−3
Crop residues	−2	−5	−8	−6	−2	−2	−9	−7
Leaching	−20	−26	−56	−58	−7	−7	−65	−76
Gaseous losses	−7	−10	−44	−48	0	−1	−18	−21
Erosion	−8	−5	−54	−95	0	0	−66	−18
Human excreta	−4	−2	−8	−9	−3	−5	−5	−4
Total	−21	−25	−99	−91	−3	−4	−126	−95

farming system were clearly reflected in the soil nutrient flows. In Machakos district (Kenya), intensive crop farming on relative poor soils results in negative nutrient balances for N and K of −21 and −9 kg ha^{-1} $year^{-1}$, respectively, mainly due to very low levels of external inputs applied. The low potential area in Pallisa district (Uganda) is characterised by a much more extensive farming system with relatively large numbers of free-ranging livestock. The prominence of free-range livestock in the subsistence oriented farming system concentrates nutrients from the communal lands through grazing into the areas for crop cultivation. At farm level this results into a nearly balanced situation of nutrient flows. However, this situation can only remain stable as long as sufficient common grazing land in the district remains available.

The economic performance indicators showed no clear differences between the LEIA and conventional management systems (Fig. 3). However, analysis of labour data showed that LEIA management required more labour than conventional management. The farms in high potential areas realised higher net farm income both per farm and per unit area. In Kenya off-farm income is of crucial importance to the total family income, reducing the differences in financial resources between the Machakos and Nyeri districts. Huge differences between districts were observed in the replacement cost of nutrients, a method in which the depleted nutrients are considered to have an economic value equal to the market value (at farm gate prices) of an equivalent amount of fertilizers. In Pallisa the replacement cost made up only 5% of the net farm income while in Nyeri these costs were also relatively low (11%). In Machakos and Kabarole a considerable proportion of the net farm income was based upon nutrient mining with respective figures of 25–30% and 60–70%. The economic efficiency of crop activities, expressed in gross margins per hectare, tended to be slightly higher for the LEIA farm management systems. Extrapolating poverty line studies by the World Bank in 1992, the poverty line of an average farm household in Kenya consisting of 5 adult equivalent units was estimated at US$ 1300 per year. In the studied districts the average income from farming alone was far below

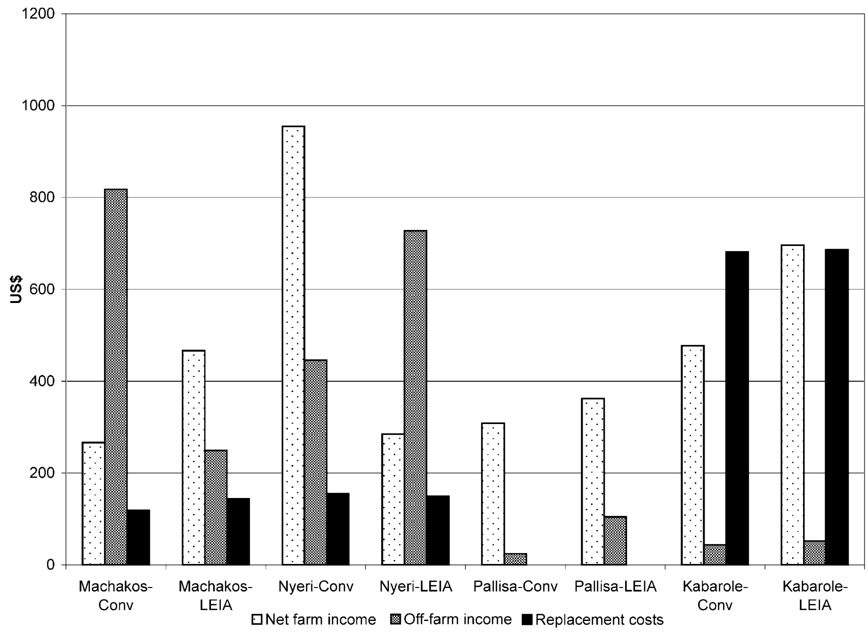


Fig. 3. Average net farm income, off-farm income and nutrient replacement costs per farm per year in four research sites and for two management types in Kenya and Uganda in the period 1997–1998 (average of 2 years). Conv, conventional farm management practices; LEIA, Low-external-input farm practices.

that line (Machakos US$ 390, Nyeri US$ 1050). Only in the high potential area of Nyeri the combined average farm and off-farm income was above this poverty line.

3.2. Identification, testing and evaluation of low-external input technologies

The results of the analysis of nutrient balances in the area were shared during meetings with farmers. Visual aids were used as discussion points, and to explore the possible options for preventing further decline in soil fertility (Table 4). Possible constraints to using the proposed technologies are lack of materials for making compost, shortage of labour for building terraces along contours, and lack of cash for purchasing inputs. Finally, the experiments selected by the group focused on recycling nutrients through composting and liquid manure, while no nutrient adding and hardly any nutrient saving techniques were selected. In general, the results showed that significant increases in yield and economic returns can be realised with relatively high application levels of compost, but that availability of material and labour inputs soon became limiting factors (Table 5). No obvious differences in impact of the tested LEIA techniques between LEIA and Conventional management groups were observed. Follow-up experimentation by farmers give the impression that substantial yield increases with reasonable economic returns can only be realised through combinations of fertilizers and locally available organic resources (Table 6). But for all tested technologies relatively low value–cost–ratio's were found. Apart from yield and economic returns, farmers' assessed the technologies also on aspects such as impact on soil structure, incidence of weeds, moisture retention, leaf colour, seed quality, cash saving or generating and incidence of pest and diseases. Through matrix ranking, scores to each of these indicators were given, compared to the quantitative results and discussed in group meetings.

The PTD process increased farmers' capacity to experiment, and improved their confidence in their own ability to find solutions to different problems. At the end of trial period they were experimenting independently, trying out *tithornia* as a green

Table 4
Suggestions by farmers for improvements in soil fertility management

LEIA farmers	Conventional farmers
• Increasing the quantity of manure and compost	• Covering manure or compost to reduce gaseous losses
• Using additives to improve the quality of compost	• Using additives when preparing compost
• Avoiding the use of compost or manure that is not fully decomposed	• Incorporating crop residues into the soil
• Incorporating compost into the soil as soon as possible to minimize gaseous losses	• Planting leguminous plants, e.g. cowpea
• Covering compost heaps	• Applying liquid manure
• Installing more soil and water conservation structures.	• Applying the correct dose of fertilizer
• Planting leguminous crops	• Rotating crops
	• Taking measures to reduce soil erosion

Table 5
Results of low-external inputs selected, tested and evaluated in four research sites in Kenya and Uganda in the period 1997–1998

Research site, management type and test crop	Technologies tested	Yield (kg/ha)		Gross margin (US$/ha)	
		Year 1	Year 2	Year 1	Year 2
Machakos, conventional, maize	Farmers' practices (17 t/ha manure and 140 kg/ha DAP[a])	2400	–	325	–
	Compost (32 t/ha)	3225	–	400	–
	Compost (32 t/ha) and liquid manure (7 t/ha)	3970	–	443	–
	Farmers' practices adjusted (8.5 t/ha and 140 kg/ha DAP[a])	–	1275	–	207
	Compost (16 t/ha)	–	1575	–	182
	Compost (16 t/ha) and liquid manure 7 t/ha)	–	1700	–	168
Machakos, LEIA, maize	Farmers' practices (17 t/ha compost)	2225	–	325	–
	Compost (32 t/ha)	3225	–	404	–
	Compost (32 t/ha) and liquid manure (7 t/ha)	4325	–	511	–
	Farmers' practices adjusted (8.5 t/ha)	–	1450	–	279
	Compost (16 t/ha)	–	1400	–	250
	Compost (16 t/ha) and liquid manure (7 t/ha)	–	1975	–	296
Nyeri, conventional, cabbage	Farmers practices (42 t/ha manure and 600 kg/ha DAP[a])	30,000	–	857	–
	Compost (42 t/ha)	40,000	–	929	–
	Residual impact of farmers' practices	–	5000	–	–36
	Residual impact of compost application the year before	–	10,000	–	36
	Farmers' practices adj. (21 t/ha manure and 600 kg/ha DAP[a])	–	22,500	–	1143
	Compost adjusted (21 t/ha)	–	15,000	–	643

(continued)

Table 5 (*continued*)

Research site, management type and test crop	Technologies tested	Yield (kg/ha)		Gross margin (US$/ha)	
		Year 1	Year 2	Year 1	Year 2
Nyeri, LEIA, cabbage	Farmers practices (42 t/ha compost)	40,000	–	929	–
	Compost (42 t/ha) and liquid manure (17 t/ha)	42,500	–	929	–
	Residual impact of farmers' practices	–	5000	–	0
	Residual impact of compost and liquid manure application	–	5000	–	0
	Farmers' practices adjusted (21 t/ha compost)	–	12,500	–	464
	Compost (21 t/ha and liquid manure (12.5 t/ha)	–	22,500	–	1071
Pallisa, convenional, maize (Year 1) and groundnuts (Year 2)	Control	1150	–	156	–
	Deep tillage	1600	–	172	–
	Compost (32 t/ha)	1700	–	−188	–
	Deep tillage + compost (32 t/ha)	2125	–	−156	–
	Control (residual impact next year)	–	1225	–	875
	Deep tillage (residual impact next year)	–	1275	–	922
	Compost (32 t/ha) (residual impact next year)	–	1525	–	1125
	Deep tillage + compost (32 t/ha) (residual impact next year)	–	1700	–	1281
Pallisa, LEIA, maize (Year 1) and groundnuts (Year 2)	Control	1375	–	188	–
	Mulch application	1875	–	250	–
	Compost (32 t/ha)	2775	–	−31	–
	Compost (32 t/ha) + Mulch	2450	–	−109	–
	Control (residual impact next year)	–	1050	–	734
	Mulch application (residual impact next year)	–	1375	–	984
	Compost (32 t/ha) (residual impact next year)	–	1025	–	734
	Compost (32 t/ha) + mulch (residual impact next year)	–	1350	–	969

(*continued*)

Table 5 (*continued*)

Research site, management type and test crop	Technologies tested	Yield (kg/ha)		Gross margin (US$/ha)	
		Year 1	Year 2	Year 1	Year 2
Kabarole, conventioanl, maize (Year 1) and Beans (Year 2)	Control	5425	–	859	–
	Manure (150 t/ha)	7625	–	47	–
	Control (residual impact next year)	–	1975	–	500
	Manure (150 t/ha) (residual impact next year)	–	2725	–	688
Kabarole, LEIA, maize (Year 1) and beans (Year 2)	Control	5225	–	938	–
	Manure (150 t/ha)	5850	–	438	–
	Control (residual impact next year)	–	1425	–	359
	Manure (150 t/ha) (residual impact next year)	–	1825	–	453

[a] DAP, diammonium phosphate.

Table 6
Results of farmers' experiments with organic and inorganic input combinations on maize in Machakos District, Kenya in 1999 (averages of two cropping seasons)

	Irrigated		Non-irrigated	
	Yield (kg/ha)	VCR[a]	Yield (kg/ha)	VCR
Farmers' practice	2416 (1857)[d]	–	813 (741)	–
5 t /ha FYM	1978 (1855)	−1.75	613 (606)	−0.80
130 kg/ha DAP[b] + 135 kg/ha CAN[c]	2988 (1674)	0.87	1263 (1024)	0.31
5 t /ha FYM + 135 kg/ha CAN	2634 (1674)	0.40	943 (756)	0.24
5 t /ha FYM + 130 kg/ha DAP + 135 kg/ha CAN	3500 (1999)	1.19	1475 (1038)	0.73

[a] VCR, value cost ratio.
[b] Standard deviation between parentheses.
[c] DAP, diammonium phosphate.
[d] CAN, calcium ammonium nitrate.

manure, testing different doses of compost on various crops, conducting trials with plant density and spacing, and adapting techniques tried out during the PTD phase. Farmers were exposed to a whole range of new soil fertility management options through their dialogue with researchers and extension agents, and many have changed their management practices since participating in the research process. Crop residues were better managed, as they were incorporated into the soil soon after harvest, and as farmers became more aware about soil and water conservation practices in general, they were quicker to repair broken terraces and stabilise terrace embankments. Manure and compost were recognised as important soil amendments, and all 18 participating farmers were producing more compost and used various additives to improve its quality, such as *Tithornia* sp. and wood ash. Manure and compost heaps were no longer left in the open for long periods, but were now shaded with various locally available materials, and only taken to the field just before being incorporated into the soil. As they cannot produce enough compost and manure to fertilise whole fields over a single cropping season, farmers applied these inputs on a rotational basis. They have started using mulches in their kitchen gardens and planted agro-forestry tree species, such as *Sesbania* sp., in scattered stands in fields or along hedges.

A year after the active phase of the study ended, participating farmers continued to meet regularly, sharing their knowledge, experiences and resources, and taking turns working on each other's farms to compensate for labour shortages. They also started contributing financially to local projects, demonstrating that the approach has succeeded in strengthening existing local institutions and establishing horizontal links between various groups. With greater interaction between farmers and extension, visits of the latter to the research site have continued even though the programme has finished. The research process has helped bridge the gap between extension services and farmers and the agency now uses the 'research groups' as its point of contact with farmers.

3.3. Formulation of enabling policies and measures at district level

The four workshops attended by in total 150 stakeholders, gave stakeholders further insights into nutrient balances and soil fertility management in general, which ended with the elaboration of an action plan for overcoming various constraints (Table 7). During the course of the workshops, it became clear to the participants that while community initiatives are a fundamental requirement for change, better targeting and timely implementation of agricultural policies are also needed to facilitate the processes of change. Policies should be designed to encourage farmers to invest in soil fertility. Central government, however, is still seen as the dominant force shaping policies, largely excluding community and civil society groups from the policy process. Most participants agreed that policies are mostly formulated and implemented in a 'top-down' process, and that extension agents and researchers have little opportunity to express their concerns at district or national level. As a result of the workshops in Kenya one local Member of Parliament raised a question on soil fertility related policies in the national parliament, while in Uganda the chairman of the Kabale district council proposed that the proceedings of the workshop should be written in simpler language enabling him to develop proposals for by-laws to improve management of soils in the district.

4. Discussion and conclusions

The participatory approach used in this research demonstrated the potential synergy and complementarity of the knowledge held by farmers, extension agents and researchers. Working through an inclusive process of dialogue, observation, diagnosis, experimentation and exposure to different types of knowledge, participants made a thorough analysis of the current soil fertility situation and tested various LEIA options for improving soil fertility management.

In all four research sites and all studied soil nutrient management systems the future agricultural productivity is seriously threatened by soil nutrient depletion. The cause of depletion however differs considerably between the sites. Soil nutrient analysis revealed that no differences in soil nutrient status could be observed between LEIA and conventional management. Apparently, application of low-external input techniques such as compost, liquid manure etc. did not result in a significantly better soil fertility status (measured in N, P, K and C content) compared to conventional practices such as application of farm yard manure, fertilizers, etc. In general, the nutrient status was considerably higher in the high potential areas compared to the low potential areas. Overall soils were adequately supplied with potassium and deficient in phosphorous. Large variations were observed in soil fertility management, soil nutrient flows, nutrient balances and economic performance indicators between farms within one management group in a particular research area.

In general, rather low and erratic economic returns to agricultural production activities were observed, and moreover a considerable part of these returns are based

Table 7
Summarised results from district stakeholders workshop in Machakos

	Scenarios		
Key indicator	Business-as-usual	Low-input subsistence	INM-commercial
Agricultural production	• Gradual declining crop yields due to reduced manure input/availability • Reduced livestock production at farm level	• Stable yield levels	• Increasing yields; commercial crops • Increased output from livestock; especially milk
Economic performance	• Declining gross margins for crop and livestock	• Remaining relatively low levels of economic return • Increased importance of off-farm income	• Increased gross margins • High capital costs • Agricultural related off-farm income • Soil fertility
	• Negative nutrient balances at farm and plot level and gradually declining soil fertility	• Slightly negative nutrient balances due to limited external inputs	• Higher in and out flows • Soil fertility maintained
Food security	• Food insecure; out migration	• Improved food security; vulnerable to climatic fluctuations	• Food secure for large group of people • Increased gap between rich and poor

Action plan

Soil fertility management

• Use locally available resources to improve soil organic matter content
• Step up water harvesting techniques
• Conduct more training to raise awareness of the range of soil fertility management techniques
• Increase research into alternative technologies

Access to inputs

• Promote co-operative management strategies to enable farmers to pool their resources
• Reduce dependency on government subsidies by promoting the use of local resources

Improving rural development

• Provide artificial insemination services at village level
• Use local processing to add value to farm products
• Mobilise the community to take action on various agricultural development issues
• Facilitate the acquisition of title deeds to encourage investment in short- and long-term soil fertility management strategies
• Credit provision
• Facilitate marketing to improve output–input price ratios
• Improve rural infrastructure

upon nutrient mining. LEIA farm management resulted in similar net farm income levels as conventional farm management. In the low potential areas slightly higher income levels were realised with LEIA management. But in general the current socio-economic environment is not conducive for farmers to undertake short- and long-term investment in soil fertility and soil nutrient management. Off-farm income is an increasingly important factor in family income, especially in Kenya. Therefore a targeted exploration of value-added production alternatives is required to sustain livelihoods in rural areas. Research and development initiatives addressing soil fertility depletion in relation to sustainable livelihood improvement in East Africa should widen its focus beyond the agricultural sector.

Low-external-input technologies alone offered limited opportunities to address the observed problems of soil nutrient depletion in the region. Significant increases in yield and economic returns could be realised with relatively high application levels of compost, but availability of material and labour inputs then become limiting factors. On the other hand, an increased application of external inputs alone is also not a realistic solution. For the vast majority of smallholders this option is economically not feasible, the required infrastructure is lacking and may lead to high losses in nutrients in areas sensitive to leaching and erosion. Appropriate combinations of external inputs and LEIA techniques appear the most appropriate alternative strategy: maximal use of local available nutrients combined with an (environmental–economic) optimal use of external nutrients. More emphasis should be paid to reduction of nutrient losses when using locally available organic resources. Caution in general interpretation of the experimental results is necessary since only results of two seasons were evaluated on a limited number of plots, while some impacts of changes in soil fertility management can manifest themselves only after a number of years.

At farm level, the research process helped establish new and sustainable partnerships between extension agents, researchers and farmers. It raised farmers awareness of declining soil fertility, encouraging them to adopt and adapt new methods of addressing the problem. Farmers' willingness to change their practices, as shown in the changing management practices of the conventional management group, revealed a flexibility and ability to tailor management strategies to changing circumstances and experiences, in contrast to the received wisdom that they simply tend to follow tradition.

Institutional aspects need to be addressed in a more structured way. A smooth long-term collaboration between research institutions and universities on the one hand and extension staff and NGO's on the other is a prerequisite for a successful and sustainable implementation of the approach. In future activities, a structured plan of collaboration needs to be developed beyond the time horizon of projects or activities.

Effective communication between stakeholders is needed to facilitate positive changes in soil fertility management at all levels, which will also require their involvement in a range of decision making processes, from selecting test technologies to targeting capacity building initiatives, improving the infrastructure and designing and implementing policies. In particular the results of the nutrient balance studies have been used to inform policy makers and raise awareness on declining soil fertility. However, it was not possible to initiate effective policy processes within the project time frame, as policy makers were not involved at a sufficiently early stage of the programme. While for participation processes at farm household level a wide array of methods and experiences have been documented (Loevinsohn et al., 2002; Hagemann and Chuma, 2002; Defoer, 2000), relatively limited successful experiences have been gathered on communication tools and participation processes to enable an effective interaction between policy makers and researchers. This is still a major constraint in many research projects and requires urgent attention.

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