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Exploring the Scientific Facts

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Dissemination of Integrated Soil Fertility Management Technologies Using Participatory Approaches in the Central Highlands of Kenya

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Abstract Declining soil fertility and productivity is a critical problem facing smallholder farmers in the central highlands of Kenya. A study to improve soil fertility and farm productivity within the smallholder farming systems in the area was carried out from 2003 to 2006. The specific objectives were to identify farming system constraints, evaluate and disseminate potential integrated soil fertility management (ISFM) interventions using participatory approaches, assess achievements and impacts, and document learning experiences emanating from the methodologies used. The participatory approaches used were Participatory Rural Appraisal (PRA), mother–baby approach (with emphasis on demonstration), farmer groups, stakeholders planning meetings, village training workshops, cross-site visits and participatory monitoring and evaluation. The core problems identified were low crop and fodder yields that were caused by erratic rainfall, soil erosion, low soil fertility and small land sizes. There was high participation of farmers in all the partnership activities, and this possibly contributed to the high uptake of the technologies for testing by farmers whereby after only 2 years a total of 970 households were testing the new technologies. Maize yields at the farm level increased by more than 150% following use of the new ISFM interventions and about half of the farmers within the groups planted close to 500 trees propagated in the group nurseries. We recommend that pathways to reach more farmers should concentrate on demonstrations, farmer training grounds, field days and farmer groups and that a policy framework should be put in place to impart appropriate skills in ISFM to the extension workers.

Keywords Demonstration trials · Mother–baby trials · Field days · Farmer groups

Introduction

Declining soil fertility in sub-Saharan Africa, a phenomenon that has ultimately led to soil degradation and reduced per capita food production, has become a serious issue of global concern (Bationo et al., 2004). Studies indicate that high population growth rates in sub-Saharan Africa, resulting in abandonment of fallow periods and subsequent intensification of agriculture without proper land management and addition of nutrients, is the primary cause of nutrient depletion in this region (Smaling et al., 1997). As population grows, soil fertility continues to be depleted by crop-harvest removals, leaching and soil erosion, as farmers are unable to sufficiently compensate these losses by returning nutrients to the soil via crop residues, manure and mineral fertilizers.

The humid highlands of central Kenya are characterized by high population pressure with growth rate of about 2.9%. To feed this ever growing population, the available land is cropped continuously without adequate external inputs of both organic and inorganic nutrient supplements. This has led to soil nutrient depletion and land degradation evidenced by declining agricultural productivity, soil analytical indicators and soil nutrient balance studies. Use of inorganic fertilizers to replenish the soil nutrients is one of the

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major ways of counterbalancing this nutrient depletion but farmers in central Kenya use insufficient amounts of inorganic fertilizers (Woomer and Muchena, 1996). High costs of fertilizer, lack of know-how about their usage and lack of incentives to use fertilizer have individually or jointly constrained fertilizer optimal use. As a result, soil fertility continues to decrease and has been identified as one of the root causes of declining per capita food production in the area.

Over the years, integrated soil fertility management (ISFM) technologies have been developed by scientists to address the problem of soil fertility decline but the adoption in the farmers' fields remains minimal. Poor research extension linkages coupled with poor dissemination methodologies are some of the causes of low adoption (MoA, 2002). The successful dissemination and adoption of new knowledge-intensive practices such as ISFM technologies requires much more than the transfer of knowledge and germplasm; it involves building partnerships with farmers and a wide range of stakeholders (participatory), ensuring appropriateness of the practice, assisting local communities to mobilize resources and ensuring participation of farmers' groups and encouraging adoption (Franzel et al., 2002). Participatory research methods have been advocated as a means to improve relevance of the developed technologies and adoption by smallholder farmers (Cramb, 2000). According to its supporters, the benefits of this approach are twofold: locally adapted improved technologies and improved experimental capacities of farmers. Practical field experiences reveal that impressive results can be achieved when farmers and outsiders "join hands" (Haverkort, 1991).

Involvement of farmers in selection of soil fertility technologies has proved more problematic, with few successful models (Kanyama-Phiri et al., 1998). Highly variable performance of technologies is one challenge, and local adaptation is one of the ways of optimizing performance in the heterogeneous environment that exists in smallholder farming systems. However, gaps still remain on how this can be achieved as there are relatively few studies with farmer-participatory approaches. The purpose of this study was therefore to use the participatory approach (Chambers et al., 1987; Okali et al., 1994) to diagnose farming system constraints, involve farmers in ISFM technologies development and dissemination and document achievements as well as learning experiences emanating from the methodologies used. Farmers' involvement is essential because they (farmers) understand their complex biophysical, social-cultural and economic environment better than anyone else and are therefore better in adapting new technologies which are crucial in accelerating adoption.

Research in ISFM Technologies

Integrated soil fertility management (ISFM) is now regarded as a strategy that helps low resource endowed farmers mitigate problems of poverty and food insecurity by improving the quantity of food, income and resilience of soil productive capacity. According to Kimani et al. (2003), the ISFM approach advocates for careful management of soil fertility aspects that optimizes production potential through incorporation of a wide range of adoptable soil management practices. It also entails the development of soil nutrient management technologies using inputs that meet the farmers' production goals and circumstances as a way of enhancing adoption of improved soil management options (Palm et al., 1997). According to these authors, there has been a major change in the research and development paradigms over the years, which has led to adoption of the integrated soil nutrient management paradigm.

Integrated nutrient management (INM) is the backbone of ISFM approach, which entails integrated use of organic and inorganic sources of plant nutrients, as well as the entirety of possible combinations of nutrient-adding practices. INM emphasizes on improving the agronomic efficiency of the "external inputs" that are being used (Kimani et al., 2003). Many studies including long-term ones have shown that INM results in more yield and nutrient use efficiency than that expected from mere additive effects of sole applications (Bekunda et al., 1997).

One of the organic resources which has generated a lot of interest among the scientific community is *Tithonia diversifolia* (tithonia). Tithonia is a herbaceous roadside weed which is also commonly used as a boundary hedge and has been shown to improve soil fertility and increase crop yields substantially in western and central Kenya (Jama et al., 1997; Mugendi et al., 2001). The green leaf biomass of tithonia is high in nutrients, in the order of 3.5–4.0% N, 0.35% P, 4.1% K, 0.59% Ca and 0.27% Mg on a dry matter basis (Rutunga, 2000), produces large quantities of biomass and tolerates regular pruning (Buresh and Niang, 1997), which is a favourable characteristic for its use in soil fertility improvement. Application of tithonia biomass has been shown to double maize yields without application of mineral fertilizers in a wide variety of farmer-managed trials (Sanchez and Jama, 2002). In many cases, maize yields were higher with application of tithonia biomass than with commercial mineral fertilizer at equivalent rates of N, P and K.

Fast growing leguminous trees/shrubs have also been identified to have potential to alleviate farmers' problems of soil infertility and soil erosion (Mugwe and Mugendi, 1999). These trees have root nodules that biologically fix nitrogen from the atmosphere, making them available to plants via soil incorporated prunings (Odee, 1996). In addition, when planted on contour hedgerows, they reduce soil erosion through the hedge effect and enhance formation of natural terraces (Mugwe et al., 2004). *Calliandra calothyrsus* (calliandra) and *Leucaena trichandra* (leucaena) are some of the key leguminous trees that have shown positive results in western Kenya and central highlands of Kenya (Jama et al., 1997; Mugendi et al., 1999). For example, results from Embu (central Kenya) showed that the treatment plots that received biomass of calliandra and leucaena (with or without fertilizer) collected outside the plots gave the highest maize yields (Mugendi et al., 1999).

Researchers have also shown that herbaceous legumes, also known as legume green manure crops, are an effective means of sustaining soil fertility (Abayomi et al., 2001). They have been found to contribute significant quantities of N (30–110 kg N ha^{-1}) to the associated or succeeding crops (Constantinides and Fownes, 1994). Notable examples include *Mucuna pruriens* (mucuna or Velvet bean), *Crotalaria ochroleuca* (Tanzanian sunnhemp) and *Lablab purpureus* (Dolichos or Lablab bean) that have successfully been intercropped with maize in many parts of the world with resultant increase in grain yields of the subsequent maize compared to continuously grown maize (Giller, 2001).

Cattle manure is another very important resource that farmers have been using for many years to effectively alleviate the problem of soil fertility decline (Probert et al., 1995). Manures have the advantage of supplying the essential plant nutrients either directly or indirectly (Palm et al., 1997), add to soil organic matter (humus) and improve soil physical and chemical characteristics (Kimani et al., 2004). Manure has also been demonstrated to restock the particulate organic matter fraction better than fresh residues (Kapkiyai et al., 1998) and to exhibit a long-term benefit with its ability to release nutrients slowly, thereby guarding against loss through leaching.

There was a realization however that even after many years of research a large yield gap remained between the yields in the farmers' field and the on-station experiments. Therefore, in 2000, a demonstration trial aiming at offering farmers ISFM technologies for replenishing soil fertility was established in Kirege School, Meru South District. Farmers from Kirege started taking up the technologies and by 2003, about 203 farmers were trying the ISFM technologies in their farms and they indicated that their yields were increasing. With this information it was realized that there was need to expose the technologies to more farmers in the region; therefore, a project aimed at increasing the dissemination and adoption of the technologies to farmers was started in 2003.

Materials and Methods

Description of the Study Area

The study was conducted in Chuka division of Meru South District of Kenya. Meru South District is situated between latitudes 00°03′47″N and 0°27′28″S and longitudes 37°18′24″E and 28°19′12″E. The district covers an area of 1032.9 km^2 and Chuka division covers an area of 169.6 km^2. According to agro-ecological conditions (based on temperature and moisture supply), the area is in the Upper Midland Zone (UM2–UM4) (Jaetzold et al., 2006) on the eastern slopes of Mt. Kenya with an annual mean temperature of 20°C and a total bimodal rainfall of 1200–1400 mm. The rainfall comes in two seasons: the long rains (LR) lasting from March through June and short rains (SR) from October through December.

The area is dominated by farming systems with a complex integration of crops and livestock and smallholder farms that are intensively managed. Land sizes are small ranging from 0.1 to 1.5 ha with an average of 1 ha (GOK, 2001). The main cash crops are coffee and tea while the main staple food crop is maize, which is cultivated from season to season mostly intercropped with beans. Other food crops include potatoes, bananas and vegetables that are mainly grown for subsistence consumption. Livestock production is a major enterprise in the region, especially of dairy cattle mostly consisting of improved breeds. Other livestock in the area include sheep, goats and poultry.

The study was carried out in four sites. These were Muthambi Division (Murugi), Chuka Division (Mucwa and Kirege) and Magumoni Division (Mukuuni). These sites were chosen using GPS coordinates to try to cover the district as much as possible. Kirege (00°20′07.1″S; 37°36′50.8″E) is located in upper midland 3 with an altitude of approximately 1473 m above sea level. Mucwa (00°18′48.2″S; 37°38′38.8″E) is located in upper midland 3 with an altitude of approximately 1373 m above sea level. Mukuuni (00°23′30.3″S; 37°39′33.7″E) is located in upper midland 4 with an altitude of approximately 1287 m above sea level. Murugi (00°23′30.3″S; 37°39′33.7″E) is located in upper midlands 3 and 4 with an altitude of approximately 1287 m above sea level.

The soils in Kirege, Mukuuni and Mucwa are Rhodic Nitisols while in Murugi they are Humic Nitisols. These are deep, well-weathered soils with moderate to high inherent fertility but over time soil fertility has declined due to continuous cropping and minimal use of fertilizers. They have generally low concentrations of organic carbon (<2.0%), nitrogen (<0.2%) and available phosphorus (<10 ppm) and are moderately acidic (pH ranges from 4.8 to 5.4). All these conditions are unfavourable for crop production and result in low crop yields.

Dissemination Approaches Used

Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA) is a growing family of approaches and methods to enable local people to share, enhance and analyse their knowledge of life and conditions and to plan, act, monitor and evaluate their circumstances (Chambers, 1997). The goal of PRA is to implement a project that is socially acceptable, ecologically sustainable and economically viable. PRA helps the community to mobilize its human and natural resources, define prevailing problems, prioritize opportunities, evaluate local institutional capacities and develop a systematic site plan of action for the community to adopt and implement in their farms. This project used the PRA to evaluate the current state of affairs regarding soil management in the target area in a participatory manner. The PRAs were conducted in all the four sites during the month of February 2004 and involved two phases. Phase one involved problem diagnosis while phase two involved the research team providing feedback of the diagnosis phase to the farmers and identification of potential solutions to the constraints.

Mother–Baby Approach

The mother–baby trial model is an upstream participatory research methodology designed to improve the flow of information between farmers and researchers about technology performance and appropriateness under farmer conditions (Snapp, 1999). The methodology was initially developed and implemented to test legume-based soil fertility management technologies in Malawi and was later expanded to Zimbabwe. The trial design consists of two types of trials: mother and baby. The mother trial is researcher-designed and conforms to scientific requirements for publishable data and analysis. A baby trial consists of a single replicate of one or more technologies from the mother trial. Each farmer manages their baby trial on their land. According to Johnson et al. (2003) the mother–baby trial methodology has three goals. The first is to generate data on which to assess the technology performance under realistic farmer conditions. The second is to complement the agronomic trial data with farmers' assessment of the adoption potential technologies. The third is to encourage farmers to actively participate in the trials and is expected to stimulate farmer experimentation with and adoption of new technologies and practices. In this approach, all the farmers within the vicinity of the "mother" sites were given equal opportunities to participate in the study (Franzel et al., 2002). The methods used to disseminate and scale up ISFM technologies included (a) field days and (b) individual farmer visits to the demo sites. The objectives of the field days and the visits were to conduct a field visit for farmers in the demonstration site and to get feedback from farmers concerning the performance of the various treatments.

Training Workshops

The project highly borrowed on the methodology described by Bunch (1982) that advocates a combination of 80% practical training and 20% theory. Trainings were conducted for both farmers and extension staff. The objectives of the trainings were to train farmers and extension staff on the principles of the ISFM strategies; to practically demonstrate on the use of technologies in the mother trial; to train farmers on the best usage and application methods of the different resources into the soil; to advice farmers on research benefits, record keeping and group dynamics; and to train farmers who in turn can train others. Each training workshop was organized into six workstations, (i) Organic materials (*tithonia*, *calliandra* and *leucaena*): sole or in combination, (ii) Manure management, (iii) Mineral fertilizers, (iv) Herbaceous and grain legumes (v) Community mobilization and technology transfer and (vi) Soya bean utilization. In the manure and fertilizer training, appropriate agronomic procedures (timing, rates and application procedures) were emphasized. For example, some of the farmers who had prior experience of using some of the technologies acted as trainers.

Farmers' Groups

With the realization that it would not be possible to reach every individual farmer in the project working area, the farmers were encouraged to form groups in each village. Farmer groups are formed on the principle that when farmers come together, they develop effective working relationships and have synergy, defined as the ability to combine the perspectives, resources and skills of a group of people. Farmer groups or community-based organizations have been used successfully in western Kenya to promote improved fallows technology for soil fertility improvement (Place et al., 2004). In central Kenya, Wambugu et al. (2001) reported success in scaling up of calliandra for fodder using farmer groups.

Stakeholders' Workshops

A strong partnership with stakeholders that includes institutional support has been advocated as an important factor for a successful scaling-up strategy especially with soil fertility-related technologies (Snapp et al., 2002; Sanchez, 1999). The stakeholders included researchers from Kenyatta University, Kenya Forestry Research Institute (KEFRI), Katholieke Universiteit Leuven, Kenya Agricultural Research Institute (KARI), and Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT), extension staff from the Ministry of Agriculture, field technicians and farmers.

Participatory Monitoring and Evaluation

There is often a danger with all new approaches to rural development that this "promising idea" will fall out of favour before its practitioners have had sufficient time to evaluate results and improve on methods (Belshaw, 1997). Now it is increasingly recognized that there is a need for greater attention to the monitoring and evaluation of participatory research projects (McAllister and Vernooy, 1999). With this background a participatory monitoring and evaluation framework was developed where all the different stakeholders developed their own indicators for monitoring and evaluating the project (Mugendi and Mucheru-Muna, 2006). The indicators for technology evaluation that farmers developed include crop foliage colour, height, vigour, inflorescence size and general crop condition.

Results and Discussions

Participatory Rural Appraisal

A total of 1,428 farmers (831 males and 597 females) attended the problem diagnosis meeting while 2,118 farmers (1186 males and 932 females) attended the feedback meetings to rank the problems and suggest solutions. Table 1 shows the problem ranking and their solutions as done by the farmers.

The results indicate that the immediate or core problem is food shortage in all the sites in Meru South District. The farmers associated the food shortage to low yields from their farms. The causal factors for the low yields of both crop and fodder were also outlined as lack of finances to enable farmers allocate adequate resources to food production. Some also argued that sometimes seeds purchased from the local shops are forged and hence did not produce as expected. Low yields consequently led to low finances, and farmers were therefore unable to purchase farm inputs. There was also a problem of inability to connect with extension workers, and this also linked to lack of knowledge on what inputs to apply on the farms for efficient productivity. The farmers also outlined lack of adequate water and rainfall, presence of poor soils, soil erosion and small farms as underlying factors impeding solid production figures. On top of the limited natural resource base, aggravating factors include poor tillage methods, lack of proper knowledge on how to manage soils and lack of finances. Consequently, it emerged that all these problems have a cyclical nature and are all inter-related as shown in Fig. 1.

Since it was not practical to address all the problems identified by the farmers, the project agreed together with the farmers to focus on soil fertility and food security-related problems. During the second phase (feedback meetings), the farmers also identified locations where the demonstration sites (mother trials) would be situated. The farmers agreed that the trials should be (i) on public land, (ii) secure, (iii) accessible to all participants and (iv) at least 2–3 acres in size.

Mother–Baby Approach

Four demonstration trials (mothers) were established in Meru South in each of the study sites (Kirege, Mucwa, Mukuuni and Murugi). They were all situated in public schools except in one site (Mukuuni) where not enough public land was available. Here the farmers selected one farmer who agreed to give land for the demonstration. The mother trials addressed different ISFM themes; in Kirege and Mucwa, the theme was on biomass transfer using tithonia, calliandra, leucaena, manure and mucuna while Mukuuni focused on maize/grain legume intercrops (groundnuts, beans and cowpea) and Murugi on maize and grain legume (soya beans and green grams) rotations.

Farmers were invited to attend joint field days in the mother trials during the grain filling stage every season. The field days were attended by a wide range of stakeholders who included farmers, teachers of the local schools, students from the local secondary and primary schools, local administration, extension personnel from the Ministry of Agriculture and researchers and lecturers from Kenyatta University. The field days involved field visits to the demonstration plots and discussions where farmers interacted with the researchers and extension personnel. Due to the different themes in each of the sites, cross-site visits were also organized during the field days. This enabled farmers to move and share experiences with each other. During the field days, farmers gained knowledge on various technologies in learning by seeing what was being done in the demonstration (mother) plots and then started testing technologies of their choice on their farms (babies).

Four field days were held in Mucwa, Mukuuni, Murugi and Kirege with a total of 1,644 farmers attending. The data shows that more female farmers attended the field days during the 2^{nd} (55%) and 4^{th} (52%) field days compared to the 1^{st} and 3^{rd} field day where there were 35% and 50% females, respectively. Murugi recorded a consistent increase in the female farmers' attendance as time progressed (Table 2). The large number of farmers who participated in the field days can be an indication that they perceive soil fertility as a genuine problem. Versteeg and Koudokpon (1993) also reported an enhanced farmer participation in their study when farmers perceived soil fertility to be a serious problem.

Although the attendance by female farmers (48%) was less than that of males, their participation was relatively high compared to other activities that report poor participation by female farmers due to demanding family chores. Their participation is crucial at enhancing transfer of the ISFM technologies because women usually carry out the bulk of agricultural activities (Adiel, 2004).

Before the start of the project, farmers were using varied vegetative materials such as maize stover, grevillea, banana leaves as bedding material for livestock

Table 1 Problems diagnosed, ranked and suggested solutions by farmers in all the sites during the PRA in Meru South District, Kenya

Problem diagnosed by farmers	Rank by farmers	Solution suggested by the farmers
Poor soil fertility and soil erosion	1	• Practice soil conservation (bench terraces, contour hedges, crop rotation, grass strips and planting trees) • Government to help in the provision of demonstration and training on soil fertility improvement technologies • Practice early planting and mixed cropping • Provision of water for irrigation • Be assisted in soil testing
Animal and crop pests and diseases	2	• Increase extension staff to teach farmers • Use indigenous knowledge to control pests and diseases
Lack of knowledge and extension services	3	• Increase extension staff • Farmers be consulted so as to participate in decision making with extension staff
Inadequate finances to purchase fertilizer	4	• Use of organic materials plus mineral fertilizers • Be provided with credit facilities
Erratic rainfall	5	• Be provided with demonstration and training on soil fertility improvement • Practice soil and water conservation (bench terraces, contour hedges, crop rotation grass strips and planting trees) • Be provided with water for irrigation and practice mixed cropping
Poor markets	6	• Farmers to form marketing groups in order to eliminate middlemen in the marketing of farm produce • Government to ensure that farmers get quality seeds verified through KARI and other organizations • Government to ensure that farmers get markets and good market linkages through formation of marketing groups
Inadequate fodder	7	• Plant more fodder (Napier grass and improved fodder)
Lack of fertilizers and chemicals. Fake seeds	8	• Provide technical know-how through seminars, farmer field days and educational tours, etc. • Government to lower prices of inputs such as fertilizers and seeds • Government to ensure that farmers get quality seeds verified through KARI and other organizations
Small farms	9	• Improve production within small farms • Hire land for cultivation • Offer labour for sale to enable farmers buy food
Food insecurity	10	• Improve production within small farms by improving soil fertility • Use indigenous knowledge to control pests and diseases • Offer labour for sale to enable farmers buy food

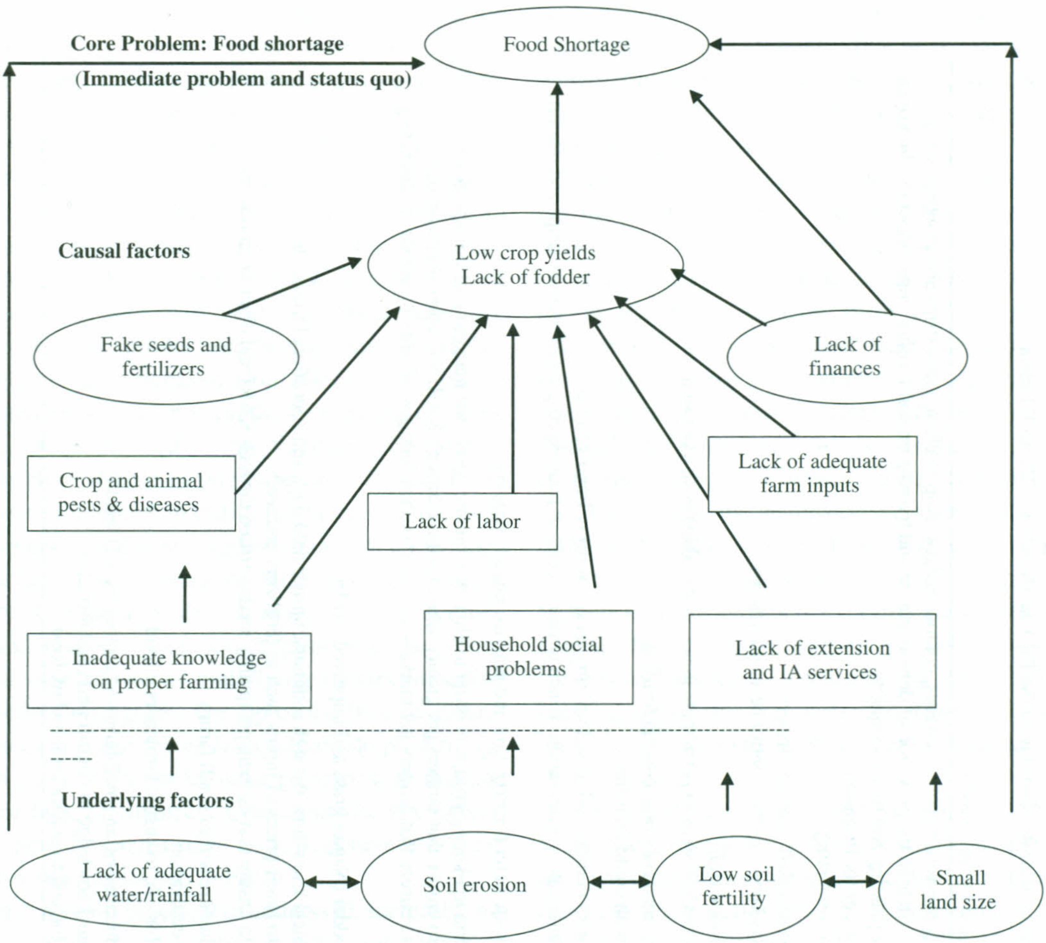

Fig. 1 Diagrammatic presentation of the primary problem status in Meru South District, Kenya, as outlined by farmers during PRA in 2004

and to increase quantity of manure. Manure made from such material was however of poor quality and farmers lacked adequate knowledge on its management and application rates. The use of mineral fertilizer was also common before the project but farmers lacked knowledge on types, dosage and management. During the field days and village training workshops, farmers were trained on proper manure management and appropriate use of mineral fertilizers. Calliandra, tithonia and leucaena were new organic materials introduced to the farmers. A farmers survey conducted during 2005 LR season, involving 563 farmers who

Table 2 Field day attendance by gender in the different sites during 2004 and 2005 in Meru South, Kenya

Site	First field day		Second field day		Third field day		Fourth field day	
	Male	Female	Male	Female	Male	Female	Male	Female
Kirege	64	38	–	–	–	–	–	–
Mucwa	45	37	20	31	46	40	–	–
Mukuuni	145	55	101	114	75	63	80	56
Murugi	81	53	91	109	46	62	77	115
Total	335	183	212	264	167	165	157	171

Table 3 Soil fertility replenishment technologies tested by farmers during 2005 LR in Meru South, Kenya

	Kirege	Mukuuni	Mucwa	Murugi	Total
Technology	$N = 73$	$N = 195$	$N = 62$	$N = 233$	$N = 563$
Tithonia	3	22	11	32	68 (12.1%)
Tithonia + fertilizer	0	10	0	14	24 (4.3%)
Tithonia + manure[a]	2	3	8	5	18(3.2%)
Tithonia + manure + fertilizer[a]	0	1	1	2	4 (0.7%)
Manure	15	63	22	37	137 (24.3%)
Calliandra	1	0	1	2	4 (0.7%)
Fertilizer	27	135	26	78	266 (47%)
Manure + fertilizer	38	69	31	108	246 (43%)
Mucuna + manure[a]	2	0	0	0	2 (0.4%)
Leucaena	0	0	0	1	1 (0.2%)
Leucaena + fertilizer	0	1	0	0	1 (0.2%)
Leucaena + calliandra + manure[a]	0	0	1	0	1 (0.2%)
Calliandra + manure + tithonia[a]	0	0	1	0	1 (0.2%)

[a]Farmers innovated technologies
Percentages add to more than 100% because farmers tried more than one technology

had registered as having tried the new technologies, showed that farmers were testing a wide range of inputs (Table 3). The majority of the farmers tried mineral fertilizer (47%), and a slightly smaller percentage tried manure plus mineral fertilizer (43%).

Most of the farmers tried more than one technology while others tried various combinations of the technologies, modifying them based on their own talent for innovation (Table 3). The modifications of the technologies mainly involved combining different organic materials. At the demonstration site single-type organic materials were solely applied or combined with mineral fertilizer. Farmers indicated that they combined different organic resources because the amount of biomass of an individual kind was mostly inadequate.

Farmers' modification of technologies has been reported by other authors. For example, Franzel and Scherr (2002) noted that small-scale farmers are rarely able to manage any single enterprise in the "optimal" manner prescribed by researchers and therefore adapt the technologies to their circumstances. According to these authors, farmers make compromises in the management of individual enterprises in order to reduce risk, alleviate constraints and increase the productivity of the entire household livelihood system. Modifications of agricultural technologies have similarly been reported by other authors (Adesina et al., 1999; Pisanelli et al., 2000). Adesina et al. (1999) argued that farmers make modifications to fit their managerial and production systems, and these modifications often lead to a final technological package for farmers which is adopted if it is technically feasible, profitable and acceptable to farmers.

Of the total number of farmers who were trying the technologies, 88% had attended field days, while 62% had attended village training workshops. This finding is against our hypothesis where we stated that the village training workshops will be more effective in reaching the farmers than the field days. An explanation for this could be that during the field days farmers were able to see, learn and evaluate technology performance while in the village training workshops, they only learnt how to apply the inputs.

The yields from the farms (babies) varied among the treatments during 2005 SR (Table 4). Maize grain yield from the plots with inputs was significantly higher ($P < 0.05$) than the control treatment during both seasons. However, during 2005 SR, the lowest yields were obtained in the control treatment followed by calliandra and fertilizer treatments. During 2006 LR, the highest yields were obtained from tithonia + manure + fertilizer and tithonia + fertilizer treatments, an indication that sole organic materials, their combinations or a combination of organic materials + fertilizer yielded more than the fertilizer alone treatment. These findings agree with other authors who reported that integration of organic and inorganic nutrient gave higher yield than inorganic fertilizer in the region (Mugendi et al., 1999;

Table 4 Maize grain yield from the different treatments during long rain 2005 and short rain 2006 in Murugi and Mukuuni, Meru South District, Kenya

	Grain yield, mg ha^{-1}			
	Short rain 2005		Long rain 2006	
Treatment	Mukuuni	Murugi	Mukuuni	Murugi
Control	1.2^{b}	0.9^{bc}	0.7^{c}	1.0^{cd}
Fertilizer	2.4^{a}	1.9^{abc}	1.5^{bc}	1.3^{cd}
Calliandra + fertilizer	2.6^{a}	2.0^{ab}	1.8^{ab}	2.1^{bc}
Manure	2.6^{a}	2.0^{ab}	2.2^{ab}	1.4^{cd}
Manure + fertilizer	2.7^{a}	2.1^{ab}	1.5^{bc}	2.3^{b}
Calliandra	2.7^{a}	1.8^{bc}	1.8^{ab}	1.7^{bcd}
Tithonia	3.0^{a}	2.3^{ab}	2.1^{ab}	1.9^{bc}
Tithonia + fertilizer	3.1^{a}	2.4^{ab}	2.3^{ab}	2.9^{a}
Tithonia + manure + fertilizer	3.2^{a}	2.5^{ab}	2.5^{a}	3.6^{a}
Tithonia + manure	3.4^{a}	2.9^{a}	2.6^{a}	2.5^{b}
LSD	1.0	1.0	0.9	0.8

Note: Figures in each column followed by the same letter are not significantly different at $P < 0.05$
LSD, average least significant difference in the means at $P < 0.05$

Mucheru-Muna et al., 2007). It has been reported that a combination of organic and inorganic nutrient sources ensures synchrony between nutrient release and plant uptake, increasing nutrient use efficiency (Vanlauwe et al., 2002).

During the fourth year (2006) farmers shared the experiences in testing of the technologies on their farms (Table 5). The farmers used yields, soil improvement seen through crop responses, soil colour change and labour as their criteria to rank the soil fertility technologies. Tithonia was ranked the best technology followed closely by manure + fertilizer and calliandra and leucaena. The least ranked was fertilizer and as indicated, the major reason was its high costs.

Table 5 Farmers' experiences and constraints in adopting soil fertility technologies in Meru South District, Kenya

Technology	Experiences	Constraints	Score	Rank
Manure	• Requires fertilizer • Must be fully decomposed • Gives high yields • Encourages soil micro organisms	• Labour intensive • Cannot be used directly from the cowshed	5.5	4
Fertilizer	• High yields • Required all seasons • May acidify soils	• Costly • Not readily available	5	5
Manure + fertilizer	• High maize vigour • High yields	• Fertilizer is expensive • No livestock, no manure • Labour intensive • Limited know-how on manure management	7	2
Tithonia	• Crops are not affected by nematodes • Improved soil fertility • High yields	• Biomass not readily available • Labour intensive	8.5	1
Leucaena/calliandra	• Good fodder for livestock • Increase milk production • Increase yields	• Land is limited • Inadequate biomass	7	2

Training Workshops

Village training workshops were held at every site in September 2004 and July 2005 with a total of 1,971 farmers participating (Table 6).

The first village training workshop was well attended, and most of the farmers were males (58%). During the second village training, the number of female farmers attending increased to 55%. The village workshops provided a forum for learning and sharing experiences among farmers and between farmers and scientists. The village training strategy was extremely important in that it was more attractive to women who are not able to attend training venues far from their villages due to their gender roles and relations in the household.

Farmer Groups

A total of 40 farmer groups were formed and trained on tree nursery establishment and management (Mugwe et al., 2007), group dynamics and book keeping. The group membership consisted of 60% females and 40% males. A survey carried out in June 2005 indicated that in Kirege, 43% of the female-headed households who were trying the technologies were group members while they were 42,73 and 78% in Mukuuni, Murugi and Mucwa, respectively. Male-headed households who were group members were 70% in Murugi, 56% in Mukuuni, 55% in Mucwa and 27% in Kirege. This shows that both male- and female-headed households found group membership an important avenue to try the new technologies. In Murugi and Mucwa, most of the farmers who were trying the technologies were group members indicating the importance of groups as far as the uptake of the technologies was concerned.

Table 6 Farmers village training workshops attendance by gender in Meru South District, Kenya

	First training		Second training	
Site	Male	Female	Male	Female
Kirege	337	235	62	50
Mucwa	100	33	68	78
Mukuuni	220	185	107	151
Murugi	96	103	72	94
Total	753	556	309	373

One of the major achievements of these groups was the ability to propagate seedlings in their nurseries and plant them on-farm. During the three seasons that they produced seedlings (2004 SR, 2005 LR and 2005 SR) farmer groups from Murugi produced the largest quantity with 89,631 seedlings followed by Mukuuni farmer groups with 45,196 seedlings. Kirege and Mucwa farmer groups produced the least number with 32,343 and 24,130 seedlings, respectively. Difference in the quantities produced was mainly attributed to the number of groups in each site and membership per group. For example, Murugi and Mukuuni had 10 groups each but had more members per group than Mukuuni, and this could explain why Murugi produced more seedlings than Mukuuni. The use of group nurseries as a means of availing propagation materials to farmers was effective, and considerable success was registered as noted in the number of seedlings farmers received within the short time period. At the end of the three seasons, about a third of all members in the group nurseries received close to 500 seedlings, an amount enough to supplement animal protein for one dairy cow.

Before 2004, only a few farmers had calliandra and leucaena on their farms. An on-farm survey carried at this time showed that Kirege had 8 farmers out of 46 (17%), Mucwa had 7 out of 26 (26%), Murugi had 6 out of 63 (10%), while there was none at Mukuuni who had calliandra or leucaena. In addition, the mean number of trees per farmer was few with Murugi having a mean of 3 trees, Kirege and Mucwa having 11 and 44 trees, respectively. The relatively higher number of trees at Kirege and Mucwa was attributed to past contact of these sites with project activities and other institutions such as the Ministry of Agriculture that promoted planting of calliandra and leucaena. By 2006, the mean number of trees surviving and being utilized had increased to more than 300 trees per farmer, an indication of a positive impact of the group nurseries.

Though the major objective of forming the group nurseries was to enable propagation of calliandra and leucaena seedlings and consequently increase on-farm planting, farmers had an opportunity to interact and know each other better and gained confidence of remaining united. Apart from raising calliandra and leucaena seedlings, and other tree and vegetable species, the groups started other extra activities. For instance, the groups started trying the different technologies in their group farms and also started activities revolving around generating income for the group. Merry-go-round was the most common with more than 50% of the groups having merry-go-round activities as a way of raising funds for the group and also as a group welfare activity. This was reflected by some of the groups transforming themselves to a more formal grouping through registration in the Ministry of Culture and Social Services. These groups are therefore likely to continue even after the end of the project.

Stakeholders' Workshops

The partnerships between the different stakeholders were formalized through the signing of memorandum of understanding (MOU) between the research organizations, farmers and extension personnel. Stakeholders' workshops were held once every year to evaluate and review the progress of the project. For the farmers, each group was represented by two farmers selected by the group, and these representatives were different each year to enhance full participation by the members of the groups. A total of 280 representatives attended the stakeholders' workshops during the 4 years. The stakeholders highlighted the progress they had made during each year and the challenges they had experienced. They also planned together on activities for the coming year and shared responsibilities.

During the second annual stakeholders' workshop (January 2005), farmers suggested another approach of "farmers' training ground" (Fig. 2) to complement the "mother–baby" approach. Farmers indicated that they would be more confident to take technologies to their farms if they first practiced together in small groups (arrow 3, Fig. 2). They indicated that they would be able to confirm whether the good performance they observed at the demonstration site would be transferable to their farms. However, they also indicated that some farmers who were willing to test straight from demonstration were free to do so (arrow 1, Fig. 2). In the "farmers' training ground" approach, the farmers form groups, and one of the farmers avails a piece of land where the farmers practice some of the technologies demonstrated at the mother trial site. The farmers agreed on few technologies to test at the training grounds.

The farmers noted that the approach was more practical and realistic as it gives the farmers a hands-on opportunity to do what is done on the demonstration site. The farmers planned together on which day to come and prepare the land, plant, weed, water and so on. Farmers selected a few technologies from the demonstration trial which they tried within their groups and then eventually started trying the technologies in

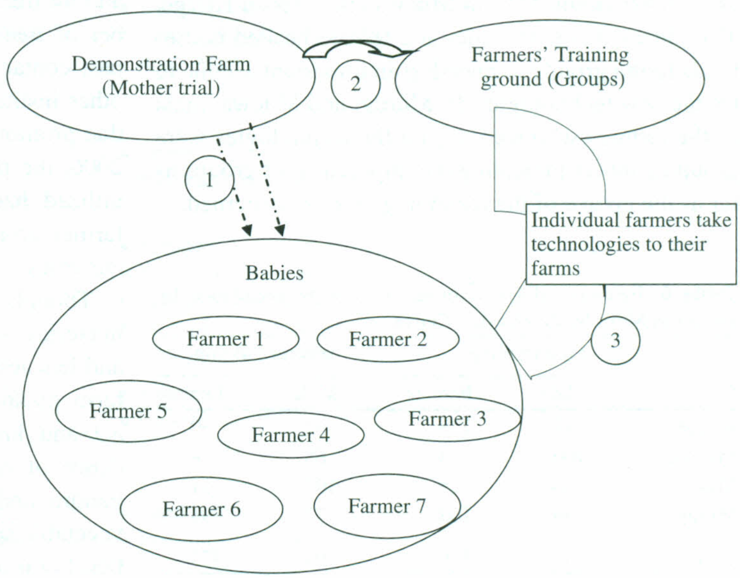

Fig. 2 The adopted new mode of participatory technology transfer by farmers in Meru South District, Kenya

their individual farms. Development of this approach by farmers was one of the major outcomes from the annual evaluation and planning meetings. This is an indication of farmers' interest, full participation and a sense of owning the project activities. According to Franzel et al. (2002) farmers' workshops can be an important means for farmers to discuss issues related to new practices, exchange opinions and lessons, and come to consensus or clarify differences.

Participatory Monitoring and Evaluation

Farmers identified four major outcomes which they expected to achieve by the end of the project and then identified indicators that they would use to measure the extent of progress. The first outcome was higher and better quality yields, and the indicators to measure this were (i) presence of technologies on farms, (ii) increased food supply at household level and (iii) increased food for sale. The second outcome was they gained knowledge on better and improved farming methods, and the indicators to measure this were (i) presence of technologies on farms, (ii) increased knowledge about the technologies, (iii) confidence in teaching other farmers and (iv) confidence in inviting other experts to train them and in asking questions. The third outcome was improved soil conservation, and the indicators to measure this were (i) reduced soil erosion and (ii) formation of bench terraces. The fourth outcome was improved animals, and the indicators to measure this were (i) presence of more healthy animals and (ii) more milk production. The farmers continuously used these indicators to evaluate the progress of the technologies in their farms and the project.

During the third year (2005), farmers in Mukuuni and Murugi sites scored and ranked technologies they were testing in their farms in terms of overall benefits accrued. Results showed that in both sites, the tithonia + manure treatment was ranked highest receiving the highest possible score of 10 in both male and female groups (Tables 7 and 8). Calliandra alone or combined with mineral fertilizer was ranked low in both sites.

Table 7 Farmers scoring and ranking of the technologies on basis of benefits in Mukuuni, Meru South District, Kenya

Technology	Group mean scores				
	Male	Female	*t*-test, *P*	Total mean	Rank
Calliandra	2.0	3.3	0.016	2.7	9
Fertilizer	3.8	2.0	0.038	2.8	8
Calliandra + fertilizer	4.0	4.3	0.768	4.2	7
Tithonia	5.3	5.0	0.768	5.2	6
Manure	6.0	5.3	0.609	5.7	5
Tithonia + fertilizer	8.0	7.3	0.561	7.7	4
Manure + fertilizer	7.3	8.3	0.251	7.8	3
Tithonia + manure	7.67	8.3	0.519	8.0	2
Tithonia + manure + fertilizer	10.0	10.0	Na	10.0	1

Table 8 Farmers scoring and ranking of the technologies on basis of benefits in Murugi, Meru South, Kenya

Technology	Group mean scores				
	Male	Female	*t*-test, *P*	Total mean	Rank
Calliandra	2.7	2.3	0.678	2.5	9
Manure	3.3	4.0	0.374	3.7	8
Calliandra + fertilizer	3.0	4.3	0.116	3.7	7
Fertilizer	6.7	3.3	0.024	5.0	6
Manure + fertilizer	6.7	7.0	0.768	6.8	5
Tithonia + manure	5.3	8.7	0.002	7.0	4
Tithonia	8.3	6.3	0.013	7.3	3
Tithonia + fertilizer	8.3	8.0	0.815	8.2	2
Tithonia + manure + fertilizer	9.7	10.0	0.374	9.8	1

There were significant differences in the scoring of some technologies by males and females.

The results showed that scores allocated to calliandra by the female farmers were significantly higher than those allocated by males (Table 6). This implies that female farmers had a higher preference for calliandra than the male farmers in Mukuuni. This relates to the fact that women are responsible for feeding the animals in the evening, after milking, and calliandra serves as a fodder supplement that is cheap. Since most of the women do not control a lot of cash within the household, this is a better option for them. On the other hand, scores allocated to mineral fertilizer by male farmers were significantly higher than those allocated by female farmers in both Mukuuni and Murugi (Tables 7 and 8), implying that male farmers had a higher preference for mineral fertilizer than the female farmers. This could be because the male farmers can easily afford to purchase fertilizers since they control most of the cash in the households.

Preference for tithonia + manure by female farmers was significantly higher than by the male farmers, while male farmers significantly preferred sole tithonia. This could be attributed to the fact that the female farmers are the ones responsible for collecting and carrying the biomass and would therefore prefer a technology that is not very labour intensive (manure). The male farmers on the other hand being heads of households can be able to solicit for labour from their wives and children.

Stakeholders' workshops are also an important means to find out farmers' views on the technologies, their potential impacts and general project performance in terms of achieving its objectives. Therefore, during the last stakeholders meeting held in March 2007, farmers used the indicators they had developed during the PM&E activities and evaluated the extent to which the stipulated outcomes had been achieved (Table 9). Generally, increased knowledge about the technologies, confidence in teaching others and more healthy animals scored highest (80%). This could be attributed to intensive training that was conducted throughout the project period in terms of field days and village training workshops. Using the knowledge gained, farmers were able to use the technologies on their farms (68%) and consequently increase food supply at the household level to about 68%. Increase in milk production (78%) as a result of improved health of the animals (80%) could be explained by farmers feeding fodder trees to the animals. At the start of the project, farmers had on average less than 10 fodder trees per farmer but after 3 years, the number of trees per farmer had increased to about 300 trees.

Table 9 Expected outcomes, indicators and farmer assigned percentages of achievements in Meru South

Expected outcome	Indicators	(%)
High yields	Presence of technologies on farms	68.1^{ab}
	Increased food supply at household level	68.7^{ab}
	Increased food for sale	33.7^{c}
Knowledge on better and improved farming methods	Presence of technologies on farms	68.1^{ab}
	Increased knowledge about the technologies	80.0^{a}
	Confidence in teaching others	80.0^{a}
	Confidence in inviting other experts and asking questions	74.5^{a}
Improved soil conservation	Reduced soil erosion	63.8^{ab}
	Formation of bench terraces	61.3^{b}
Improved animals	More healthy animals	80.0^{a}
	More milk production	77.7^{a}
	LSD	*16.3*
	P	*<0.001*

Percentage means with the same superscript are not significantly different

Table 10 Farmers' evaluation of the different approaches used in the project in Meru South District, Kenya

Approach	Mean (%)	Rank
Training grounds	77.5[a]	1
Demo farms	76.2[ab]	2
Nurseries	71.2[abc]	3
Field days	68.7[abc]	4
Groups	58.7[abc]	5
Training workshops	55.0[bc]	6
Cross-site visits	50.0[c]	7
LSD	*22.2*	

Percentage means with the same superscript are not significantly different

The farmers also evaluated the participatory approaches that the project had been using in disseminating the technologies using a score of 10 for most effective and 1 for least effective. Training grounds were ranked the best overall followed by demonstration farms with 77.5 and 76.2%, respectively, while the least scored were cross-site visits (50%) and village training workshops (55%) (Table 10). The training grounds were significantly more effective in the dissemination of the technologies than cross-site visits and village training workshops (Table 10).

Possible explanation for this could be the fact that cross-site visits only involved a few farmers due to transport costs. The reason why the training grounds were significantly more effective than the village training workshops could be due to the fact that the farmers could see the crop growing and they were also involved in the actual management of the technologies, while in the village training workshops they were observers and not doers. In addition the farmers were the inventors of the training ground concept indicating that they actually owned the idea. We had earlier anticipated that the village training workshops would have a higher contribution to dissemination compared to the field days, but this was not the case as far as the farmers were concerned. This agrees with Franzel et al. (2002) who noted that whereas in many cases the information provided by farmers in such workshops is what the researchers might have anticipated, it is possible that new information may be obtained.

Lessons Learnt

A number of lessons were learnt during the project, and this agrees with Franzel et al. (2002) who noted that participatory research offers researchers, extensionists, policy makers and farmers themselves an opportunity to learn important lessons about achieving effective dissemination of agricultural technologies, as well as feedback on further research priorities. Some of the lessons learnt include the following:

(i) The use of "mother–baby" approach to scale up the technologies may not be very effective for all technologies. The use of "farmers' training ground" approach where the farmers form groups and one farmer avails a piece of land where they practice some of the technologies from the "mother trial" is a better option. This gave the farmers a hands-on experience to do what is done on the mother trial. The farmers plan together on which day to come to carry out various activities on their plot like prepare the land, plant, weed, water.

(ii) Working in partnership is very constructive and enhances sustainability as well as impact. For instance, the project activities have awakened some retired agricultural officers who are now being invited by the groups to come and discuss agricultural matters with the farmer groups. In this way there is a renewal of synergy and recognition and appreciation of the knowledge of other professional community members. In other areas, the farmers have made an effort to forge links with the Department of Forestry and are being taught various other methods of handling seedlings. This is an interesting experience given that only 3 years ago the very farmers were accusing the Ministry staff for not being available to assist them.

(iii) The framework of participatory interaction has enabled farmers to view the "outsiders" as partners in development and with whom they do engage in development discourse. This indicates that they are in a position to interact very well with other partners who use the participatory approaches used in this project.

(iv) The use of participatory monitoring and evaluation has been a major eye opener for all stakeholders on how the farmers would like to direct the course of a project for their optimal benefit.

(v) Keeping a vibrant and an effective working partnership is very challenging and more expensive than had been anticipated. Constant meetings and regular field team visits must be put in place.

Conclusions and Recommendations

The farmers' participation was quite high in most of the joint activities, and this possibly contributed to the high rate of farmers' acceptance to test the technologies. The immediate problems identified by the farmers were low crop yields and lack of fodder which were caused by inadequate finances to purchase inputs, inadequate knowledge on farming and inadequate extension services among others. The underlying constraints to the causal factors were erratic rainfall, soil erosion, low soil fertility and small farm sizes. The current study, however, addressed only two of them (low soil fertility and soil erosion) and realized positive impacts. The problem of erratic rainfall is critical and there is need to address it through exploration of strategies to conserve moisture and optimize its usage. As for the problem of small farms, options of optimizing efficiency in agricultural production need to be sought.

Adoption of the introduced ISFM technologies has potential to increase crop yields by over 100%, and the high yields observed from innovations of mixing organic materials developed by farmers is a reflection that farmers are modifying the technologies to fit their needs and circumstances. This is a lesson that researchers should facilitate the process of farmer learning, experimentation and modification of technologies as what is likely to remain on the farmers' fields is what farmers have modified to suit them as this is what they can cope with. In addition, the gender differences observed in the participation of project activities and preferences of technologies is also a lesson that gender issues are critical and need to be put into consideration in dissemination of ISFM technologies.

This study has provided pathways for future scaling up of ISFM activities. It is recommended that future efforts aimed at reaching farmers should concentrate on demonstrations, farmer training grounds, field days and farmers' groups. Farmer groups are particularly effective in activities that involve bulking of planting materials as revealed by the success in propagating seedlings. Since ISFM technologies are management and information intensive and require skills, there is need to build capacity for field extension workers. A policy framework should therefore be put in place to impart appropriate skills to the extension workers.

It was evident that income generation activities among the groups were instrumental in keeping the groups cohesive and individual members interested in the group activities. Researchers and the other stakeholders should therefore channel their efforts towards empowering farmers to engage in income-generating strategies as these are likely to improve resilience of the groups.

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Success Stories: A Case of Adoption of Improved Varieties of Maize and Cassava in Kilosa and Muheza Districts, Eastern Tanzania

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Abstract The project of Eastern Zone Client Oriented Research and Extension (EZCORE) was designed to improve the capability of researchers to better respond to the needs of the farmers and empower the districts to obtain and implement relevant research results for the benefit of the rural populations. In the process, farmers in Mkobwe village of Kilosa district reported that they were getting very low maize yields due to problem which was later identified as maize gray leaf spot. Similarly, farmers of Tongwe village in Muheza district had a disease problem in cassava which was later identified as cassava brown streak disease. Researchers were commissioned to solve these two problems which were severely limiting crop yields. In Mkobwe village, a maize variety called TMV-2 was tested and found suitable, while in Tongwe village, a cassava variety *Kiroba* was the best. The maize Var. TMV-2 and cassava Var. *Kiroba* were then provided to the villagers of Mkobwe and Tongwe, respectively. The monitoring and evaluation of project activities for the last 3 years indicated that all the farmers in Mkobwe village and more than 50% of the farmers in the nearby villages are growing TMV-2. With regard to *Kiroba* variety, the variety is planted by all the farmers in Tongwe village, and now the variety has spread to over eight villages in Muheza district. Apart from Muheza district, it is also planted in many villages in the nearby districts. The source of cassava cuttings in all the villages planted with variety Kiroba is Tongwe village.

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Introduction

The Eastern Zone Client Oriented Research and Extension (EZCORE) Project was established in 1999 and aimed at improving food security and livelihood of the rural poor and reducing poverty through policies and programmes which empower the beneficiaries. The programme strives to attain improved food security and sustainable management of natural resources, therefore contributing directly to national goals of poverty reduction and hence improving livelihoods. In Tanzania, client-oriented research (COR), sometimes also referred to as client-oriented research and management (CORMA), has been adopted as a strategy for delivery of research services in future. Until now, COR has been implemented in the northern and lake zones. Basically, COR strives to forge closer links between the demand side (farmers, governments, NGOs, traders and businesses) and the supply side (research stations, NGO and training institution). But in the case of EZCORE, the supply side included extension services, which include government and service providers from the private sector.

EZCORE made deliberate efforts to forge links with extension services by involving district councils on behalf of the beneficiaries to manage the research resource as well as manage the entire research process, from problem identification to contracting out and using the outcomes of research findings.

In order to achieve the set objectives, EZCORE had to support many activities which eventually changed

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the mindset of the farmers. Farmers were organized into groups and they were trained on group dynamics and on skills to interact with local government authorities on various matters related to their development initiatives and were eventually able to identify their problems, formulate researchable issues and forward to the district level. On the other hand, village extension officers (VEOs) were trained on participatory extension methods so that they can be able to assist the farmers in identifying the problems using participatory approaches.

Through such skills, farmers in Mkobwe village, Kilosa district were able to identify a problem mentioned as drying off of maize leaves. This problem was causing yield decline of up to 90% (Mbiza et al., 2002). Similarly, in Tongwe village, Muheza district, farmers identified cassava root rot problem, which caused yield decline of up to 74% (Muhana and Mtunda, 2002). In Mkobwe village, farmers reported that maize yields used to be about 1250 kg ha^{-1} but gradually declined to less than 500 kg ha^{-1} in January 2002. After infection, the yields of both maize and cassava could not support the family for food even for 3 months after harvest. Most families were therefore food insecure and poverty levels kept on increasing because they could not get cash by selling maize and from cassava produce.

These two disease problems were forwarded to the respective district office, and then to researchers. The solutions to these two diseases were not available and therefore researchers were commissioned to solve these two problems. Different maize and cassava varieties were evaluated in the farmers' fields by researchers in collaboration with farmers and identified tolerant varieties of TMV-2 for GLS and *Kiroba* for CBSD, and thereafter the varieties were adopted by farmers. This chapter explains the extent of adoption of maize variety TMV-2 and cassava variety *Kiroba* after being found to resist grey leaf spot and cassava brown streak disease, respectively.

Materials and Methods

Mkobwe village is in Kilosa district, found in Uluguru mountain ranges of eastern arc mountains, and located at an elevation of about 1700 m above sea level (m.a.s.l.), while Tongwe is found in Muheza district coastal area at an elevation of 500 m.a.s.l.

Commissioned researchers from Ilonga Agricultural Research Institute and Kibaha Sugarcane Research Institute collected samples from affected plant parts of both maize and cassava plants for identification of the diseases. The plant parts collected were affected leaves from maize plants and leaves and tuber from cassava plants. After identification, seven maize varieties were compared for resistance/tolerance against GLS in Mkobwe village. The varieties used were Tuxpeno, TMV-1, TMV-2, Staha, Kito-ST, Kilima-ST and Ngida. The plot size used was 10 m × 10 m and assessed for severity of GLS using scores of 1–5. The lowest score represented less affected, and highest score represented most affected plants. This was then followed by establishing four demonstration plots, each located in one sub-location using three varieties. These were TMV-2, Kilima-ST and Ngida. These varieties were chosen because of being more tolerant to GLS than were the other varieties. The basic seed obtained from seed farms was used in all cases. The demonstration plots were laid in farmers' fields, and farmers were involved in the GLS assessment and in the field days. Two field days were conducted, the first at vegetative phase and the second at physiological maturity. The evaluation was administered by researchers of Ilonga Agricultural Research Institute in close collaboration with farmers and extension staff of Kilosa district. It was important to conduct the second field day at physiological maturity because the GLS-infected plants normally have dry leaves as if the crop has matured, but if examined, the cobs are still green and if husks are removed, grain filling is poor. Normal maize physiological maturity starts with the maize cob by drying of the husks.

In the case of cassava, eight varieties were compared in Tongwe village. These include Kiroba, Namikonga, Kitumbua, Naliendele, Kigoma-red, Kikombe, Kibaha, Mahiza and Kibanda-meno. In the first year of 2003, the varieties were planted on four farmers' fields on a plot size of 15 m × 15 m. In the second year of 2004, the varieties were planted on 14 farmers' fields. The plot size used was the same as that of the first time. In each of these two plantings, farmer field- and cassava days were conducted and attracted more farmers, were also used to make some assessments. Apart from assessing the resistance of these varieties to CBSD, farmers also evaluated other qualities which are important in cassava industry. These qualities include yield level, taste and time to maturity. Farmers gave scores starting from 1 to 5 for each quality. Apart from evaluation, cassava day was used to popularize the variety by distributing the cuttings to the farmers who showed interest. The evaluation was administered by researchers of Root and Tuber Programme based at Kibaha in close collaboration with extension staff of Muheza district.

Results and Discussion

Table 1 gives the scores of severity of maize varieties to GLS as scored by farmers. Maize varieties which were most susceptible to GLS were TMV-1, Kito-ST and Tuxpeno with the highest score of 4.0, followed by Kilima-ST and local variety Ngida with comparable scores of 3 and 3.5, respectively. The most resistant variety to GLS was TMV-2. Similar observations were obtained in the southern highlands of Tanzania, which include Mbeya, Iringa and Ruvuma regions. In these regions, Mbiza et al. (2002) reported that TMV-2 was also found to be resistant to GLS.

Table 1 GLS severity score of maize varieties in Mkobwe village in year 2002

Maize variety	Score
Tuxpeno	4.0
TMV-1	4.0
TMV-2	1.0
Staha	4.0
Kito-ST	4.0
Kilima-ST	3.5
Ngida	3.0

Score scale 1–5, where 1, clean leaves; 5, severely affected

Initial symptoms of GLS disease can be observed as small lesions surrounded by a yellow halo confined between the veins, which are easily visible when the infected leaf is held against light. In severely infected maize plant, leaves are completely blighted and cob filling is very poor or there is no formation of seeds. The GLS pathogen (*Cercospora zeae-maydis*) causes extensive leaf blighting. Reduction in green leaf area of the upper leaves may cause significant yield reduction of 75–90% of the photosynthates required by the ear during grain filling (Ward et al., 1997).

The scores given by farmers with regard to tolerance of different cassava varieties to CBSD are given in Table 2. With the exception of *Kiroba*, the other varieties which were evaluated were susceptible to CBSD at varying degrees. The local varieties (Mahiza and Kibanda-meno) were more susceptible than those which were introduced by researchers. Apart from being less susceptible to CBSD, *Kiroba* variety had better qualities than did other varieties. For instance, the yield per plant was 12–18 kg, which is equivalent to 76–115 t ha^{-1} of fresh cassava, and matures only within 9 months. These qualities made most farmers prefer planting variety *Kiroba* in Tongwe and later in neighbouring villages.

In the year 2003, the variety which showed resistance to GLS started to be demanded by many farmers

Table 2 Farmers' assessment of cassava resistance to CBSD

Varieties	Scores: CBSD susceptibility	Yield	Taste	Time to maturity
Kiroba	1	1	2	1
Namikonga	2	2	1	1
Kitumbua	3	3	1	3
Kibaha	2	3	3	4
Naliendele	2	3	2	3
Kigoma-red	3	3	2	4
Kikombe	2	3	1	1
Mahiza	5	3	3	3
Kibanda-meno	3	3	2	4

Scoring: CBSD susceptibility: 1, not susceptible; 5, very susceptible. Yield: 1, 12–18 kg $plant^{-1}$; 2, 10–14 kg $plant^{-1}$; 3, 6.5–12 kg $plant^{-1}$. Taste: 1, very sweet; 5, very biter. Time to maturity: 1, 8–9 months; 2, 9–12 months; 3, 12–18 months; 4, 18–24 months

Table 3 Adoption of maize variety TMV-2 by December 2006

Village	Farmers planting TMV-2 (%)	Average grain yield (t ha^{-1})
Mkobwe	70	3.2
Masenge	55	3.0
Lufikiri	50	3.2
Nongwe	60	3.8
Mandege	62	2.9
Rubeho	65	3.0
Kisitwi	40	2.6

of Mkobwe village, and in the following year, the farmers from the nearby villages also showed interest of planting TMV-2.

Monitoring and evaluation mission of year 2006/2007 indicated that maize variety TMV-2 has been adopted by other villagers in the villages found along Ukaguru mountain ranges. These villages include Masenge, Kisitwi, Rubeho, Mandege, Nongwe and Lufikiri. Most farmers in these villages have adopted the variety (Table 3). The adoption rate of this maize variety ranged from 40 to 70%. This was possible because the seed was available from the farmers who were commissioned to produce quality-declared seed and sell the seed at affordable price equivalent to US $0.3. The seed is still demanded by more farmers, as the seed produced in the village has not satisfied the demand of all the farmers. It is worth noting that the problem of GLS has disappeared in these villages. Apart from tolerating the disease, maize yield obtained from this variety was in the range of 2.6–3.8 t ha^{-1}. This is equivalent to 420–660% increase if compared to the yield of 0.5 t ha^{-1} obtained by GLS-infected maize varieties.

With regard to *Kiroba*, the variety has spread very fast. Within 2 years, *Kiroba* cuttings were sold and adopted by farmers in eight different villages within Muheza district (Table 4). This figure is according to the village records, but it may be higher since some farmers may have given the cuttings to their relatives without reporting to the village authority. The selling of the cuttings was also to six districts within the same period.

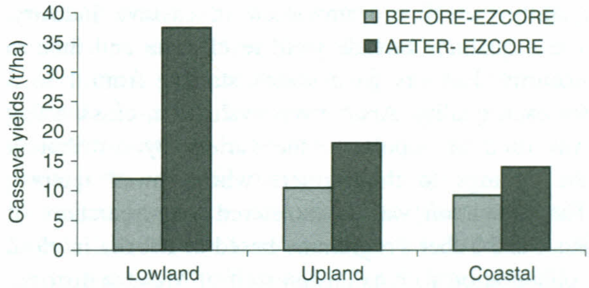

Fig. 1 Changes in cassava production (t ha^{-1}) in different zones of Muheza district

According to the monitoring and evaluation report of year 2007/2008, cassava production in Muheza district has increased by 40–60% due to the introduction and adoption of high-yielding *Kiroba* variety (Figure 1). The increase in cassava production varied from 68% in the lowland, 41% in the upland, to 34% in the coastal zone. This high cassava production has improved food security and the surplus was sold and improved farmers' income. Some farmers revealed that increased income from selling of cassava cuttings in Tongwe village enabled them to pay school fees, purchase radio, mobile phones and iron sheets.

At district level, the adoption of *Kiroba* variety featured high compared to other technologies extended within the same period (Table 5). This could be due to the fact that farmers are best rewarded by planting this variety compared to other technologies.

Table 4 Purchases of Kiroba variety from Tongwe village

Year	Villages within Muheza district	Districts
2005/2006	Mtimbwani, Mavovo, Maramba, Amani, Bombani	Tanga, Handeni, Kilindi
2006/2007	Kwemhosi, Nkumba, Ubembe	Same, Pangani, Korogwe

Table 5 Overall adoption of technologies in Muheza district

Types of technologies	Adoption (%)
Maize production technologies	18
Orange improvement technologies	9
Cassava improvement technologies	36
Chicken improvement technologies	36
Milk improvement technologies	18
Cashew nut improvement technologies	27
Soil and water conservation/soil fertility improvement	5

Conclusions

Empowering small-scale farmers with knowledge can improve their participation in technology testing and adoption of improved technologies. This approach normally leads to the change of the mindset of the farmers and can be used to break with business as usual syndrome, and contribute to green revolution in Africa.

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