Fertile Ground?

Soil fertility management and the African smallholder

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Dedicated to Victoria and Davies

Abstract

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The focus in this thesis is to form a view of how well soil fertility research performs within the ever shifting smallholder contexts. This study examined application of agro-ecological knowledge for soil fertility management by smallholder farmers, with the view to enhancing the utility of research among resource-deprived farmers of western Kenya.

A *realist* methodological approach to the study of soil management was applied. It is shown that soil fertility management operates under the assumption that consequences (soil management) are to be explained not just by contextual states (in this case farmer knowledge) but by "mechanisms" of decision making and soil management that need to be uncovered. Knowledge is nothing unless it engages with real soil management processes.

Between 2003 and 2005, participatory experimentation, monitoring and evaluation of technologies and concepts were explored. Those experiments involved: (i) cereal-legume rotations; (ii) screening new soyabean varieties for selection among smallholders; (iii) organic resource quality concepts and biomass transfer; and (iv) mineral fertiliser response. Farmers' practices following these experiments were investigated, with particular focus on their underlying justifications and livelihood objectives.

Participating farmers selected experimental plots to ensure that the soils were representative in terms of type, fertility status and history of cultivation. These farms were classified as infertile during the participatory soil characterisation. Farmers deliberately selected the infertile plots to "see if the new technologies worked", and as part of their wider objective. These experimental plots were researcher-designed.

Researcher notions of organic resource quality was interpreted and amended by farmers based on existing knowledge, experiences and cultural constructs. For instance, *Tithonia* was perceived as a "hot resource" that could be added to composts to increase the "speed of cooking". Amendments to this concept, and to new soil fertility management technologies, were based on "ordinary" applications and reflected perceptions of *inconvenience;* meaning especially labour constraints, land shortage, uncertain yield and economic returns. Alternative (i.e. not-for-soil-fertility-management) uses of the different technologies were prominent. For example, legume varieties with utility beyond soil fertility management were preferred which resulted in readily observable gains when applied under variable local conditions. Those local conditions demanded the use of mineral (P) fertiliser in the successful implementation of the cereal-legume rotation scheme or adoption of new promiscuous soyabean varieties. Farmers selected varieties primarily on the basis of yield, rate of growth and appearance.

Poor yields when mineral fertiliser was not applied, or unsteady crop responses after its use, cost - coinciding with priority expenditures and association with particular technologies such as hybrid maize - complicated the use of fertiliser.

Limited understanding of fertiliser functionality, soil nutrients or soil fertility mechanisms is clarified in terms of the context-mechanism-outcome paradigm of "realist" explanation. The farmer paradigm refers mainly to context and outcomes, which we interpret as a kind of positivism. On the one hand, scientists' focus on mechanisms (to the apparent exclusion of context and outcome) does not match the highly variable local social, physical and economic contexts made more difficult by poor (implementation of) policy. Both farmers and researchers, it is argued, need to enhance their capacity to modify their knowledge sets by engaging in well-designed joint research drawing on the context-mechanism-outcome configuration. Experimentation is seen as one way to expand farmers' knowledge sets on soil fertility and to make mechanisms (e.g. nutrient availability) more visible, so that farmers can engage in soil fertility improvement activity in ways that are both more effective and more meaningful.

This thesis also concludes that to increase the utility of research requires a shift from component research to research at subsystem or whole-farm system level to address broader household objectives. The chances of sustainable application of scientific innovations by smallholders will be greatly enhanced if field research embraces and embeds social science methods of engaging the farmer sustainably as a partner in technology development and not simply as a client.

Key words: *smallholder farmers, soil fertility, experimentation, "inconvenience", realist.*

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Tribute to all the farmers who toil on soil, keep the glow on. Surely, “soil is mother”. Let us not abandon her health. There are honest researchers and devotees to your welfare. Only that it takes longer.

Mola Asifiwe!

Michael Misiko

Wageningen, May 2007

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CHAPTER 1

General introduction

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Soil fertility management and the African smallholder

Soil fertility management among smallholder farmers will only be effectively targeted by embracing the complexity of interactions among social, bio-physical and economic factors (Scoones, 1997; Zingore, 2006). Scientists should therefore seek to improve soil fertility through development of concepts and technologies that can be amended to suit such interactions while at the same time maintaining the validity of core scientific concepts. For over twenty years agro-ecological knowledge and information on organic resource quality, legumes, fertiliser equivalencies, soil-limiting nutrients and soil biota have been generated by the Tropical Soil Biology and Fertility Institute (TSBF) of the International Centre for Tropical Agriculture (CIAT) and partner institutions. Currently, researchers focus on a paradigm of Integrated Soil Fertility Management (ISFM). ISFM is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation – biological, physical, chemical, social, economic and political (CIAT, 2006:2, see also InterAcademy Council 2004). This widening of focus of soil fertility research is intended to offer broad solutions that, for instance, prove socially acceptable, while at the same time remaining fit for purpose. ISFM comes in the wake of numerous technological advances which have not, in spite of concerted efforts, been widely used by smallholder farms. The scientific basis for these concepts and technologies is valid, so it is not clear what exactly their variable application within an ever-shifting smallholder context conveys. The present study seeks to throw light on this puzzle by focusing on soil fertility management as a goal among smallholder farmers, paying specific attention to how soil science concepts and technologies are actually understood and translated by farmers in western Kenya.

The concept of soil fertility does not have a single universally agreed definition. Most definitions seek to reflect the nature or functionality of soil; this will be revisited at greater length in the last chapter on the conceptualisation of soil fertility. Suffice it to say here that many authors generally imply or refer to the concept of soil fertility as the capacity of a soil to provide plant nutrients to crops, the physical and biological properties which allow appropriate growth of plants and ensure preservation and recycling of nutrients over a substantial period of time (cf. Brady, 1974:10; Cooke, 1967:351). There is, however, much greater agreement on soil fertility decline as a real and serious challenge to food security, and something which needs urgent attention (e.g. Vanlauwe *et al*., 2002; Bationo; 2004). Soil fertility management is therefore widely seen as an important goal to underpin sustainable crop production (Woomer *et al*., 2002:313; Sanchez and Jama, 2002:23). To succeed in improving crop production through soil fertility enhancement requires a thorough understanding of the underlying climatic, edaphic and socio-economic factors involved in determining and controlling the process of soil fertility regeneration (de Costa and Sangakkara, 2006; InterAcademy Council 2004). Soil fertility decline is often blamed on poor smallholder practices, such as continuous cultivation, lack of soil erosion prevention structures, low use of available technologies, and also exogenous factors such as cost of fertiliser, etc (Vlek *et al*., 1997; Hartemink, 2003). Household contexts and exogenous and biophysical factors interact in a complex way.

This study grows out of earlier attempts to tackle this complexity of interactions through improved communication of research-based agro-ecological knowledge to farmers, especially through seeking a vocabulary that fits local systems of ideas while still conveying information of scientific and ecological validity. It is worthy of remembering that the local system of ideas has been nurtured by sets of qualitative interactions between local land users and their ecosystem. These interactions are governed by social, cultural, political and economic contexts (Scoones and Thompson, 1994). But given ecosystem changes, farmers may need infusion of new concepts to "top up" knowledge and allow appropriate adaptation of local practices. It is assumed here that it cannot be other than useful to equip farmers with expertise so that they can better interact successfully and sustainably with their soils.

Between 2001 and 2004, TSBF-CIAT developed interactive learning tools to incorporate scientific insights generated by scientists into ecological and practical knowledge for farmers' decision-making and choices. The approach used in that process is referred to here as the Folk Ecology Initiative (FEI). FEI forms an important background to the present study, which attempts to probe some of the relationships between science, local practices and farmers' understandings, in regard to soil and soil fertility, further.

The specific study context

The present study was embedded in a project entitled "Strengthening 'Folk Ecology': community-based interactive learning with specific application to integrated soil fertility management (ISFM) in western Kenya". "Folk Ecology" was terminology adopted by the anthropologist, the late Patrick Sikana,[1] for what was in effect a participatory project entailing partnerships with farmer groups and other local partners of TSBF-CIAT in western Kenya. The FEI exploited participatory tools, especially joint farmer-researcher demonstrations, dialogue, and participatory monitoring and evaluation (PM&E) to facilitate exchange of knowledge. One of the specific themes of the initiative was to disseminate generic scientific principles, and not empirical prescriptions or technology packages, while intervening to extend farmers' knowledge rather than to change specific farmer practices (Misiko, 2002). An underlying idea was to provide farmers with a sound framework for future adaptive behaviour based on grasp of principle, not "rule of thumb". This is why the present thesis seeks to understand whether farmers and scientists have indeed aligned their ideas at a foundational level, or whether participation reflects (only) rhetorical agreement. Put bluntly, can the FEI be considered science, and are farmers agreeing with scientists only to secure short term project benefits? This theme is part of a broader objective within TSBF-CIAT, to improve the livelihoods of people

[1] I acknowledge the contribution of Patrick, the former social science officer of TSBF Programme, who wrote the first phase proposal for the FEI. His ideas were foundational, and were sustained and developed by Joshua Ramisch through his subsequent leadership of the project.

reliant on agriculture by developing profitable, socially acceptable and resilient agricultural production systems based on ISFM (TSBF-CIAT, 2005).

The FEI as implemented

The FEI was first introduced to farmers in western Kenya in 2001 through open community interviews (open question and answer sessions, i.e. Q&A with no pre-set agenda). These sessions were held in four sites where TSBF-CIAT had worked earlier. The interview sessions were designed to establish dialogue with communities about soil fertility management and their participation in such activities. Several misconceptions concerning TSBF-CIAT were addressed at this level. Further meetings were conducted to discuss farmers' real-life situations, to establish personal rapport with representatives from all sections of the community, and to ensure their subsequent support. This necessitated choice of neutral venues, like churches, community grounds, or schools. In these neutral venues participants (not necessarily farmers) were free to bring up all sorts of issues related to ISFM (whether involving soils directly or other related areas of concern). Expectations' management was initiated at this stage, to avoid false expectations. This process created detailed understanding on the root causes of local agricultural productivity problems, while TSBF-CIAT explained itself to the farming community, and outlined its core research findings and how and why they were thought to be "promising".

The FEI core participatory team included the leader, Joshua Ramisch (human ecologist), John Mukalama (agronomist), Isaac Ekise (economist) and myself (anthropologist). The team consulted regularly with technical experts, especially Bernard Vanlauwe (soil scientist), and took care to consolidate efforts and not mislead farmers about project activities, amid a welter of competing vested interests. The team worked closely with communities to analyse sets of related problems and identified what might constitute in local perceptions an overall solution. It was at this point that farmers demanded a hands-on "action" towards the identified solution.

(a) Partnerships for "action"

Once some rapport had been established, appropriate groups were sampled from lists of groups previously gathered. Among this set of groups there were four Farmer Field Schools and six farmer groups with diverse objectives, but engaged in agriculture. Working with well-established groups with strong community ties was considered crucial for interactive research. The identification and involvement of trusted, accessible members of rural communities gave the FEI team a good level of local legitimacy, ensured adequate participation and effective data collection, and permitted access to many homesteads in the communities[2].

The process of dialogue, partnership initiation and initial community studies took six months. Then farmer collaborators decided that a hands-on interactive process should be established. They expressed a preference for demonstrations and open field events to ensure inclusive participation and plentiful attendance. Four major demonstrations on key

[2] But on drawbacks associated with working only with pre-formed groups see Isubikalu (2007).

technologies and concepts were proposed by TSBF, and future plans of action were made collectively.

(b) Demonstrations

Beginning in the first rainy season of 2003, four main demonstrations were established in all sites. These demonstrations were:

(i) cereal-legume rotations;
(ii) the organic resource quality concept illustrated through biomass transfer;
(iii) mineral fertiliser responses (most limiting nutrients N and P were chosen);
(iv) mineral fertilisers and organic manure (i.e. FYM) combinations.

Parallel learning experiments/plots were also established, to meet a researcher-perceived need for such facilities, and following farmers' requests after exchange visits and tours. These took the following form:

(i) screening (for selection) of new soyabean varieties;
(ii) *Striga* eradication (a collaboration of many projects and institutions);
(iii) soil nutrient test strips – adjacent to all demonstrations.

(c) Farmer trials

These were experiments by farmers to try out demonstrated technologies and concepts. Several were selected for illustration and to boost knowledge exchange among farmers themselves and between farmers and scientists.

(d) Exchange visits and feedback seminars

Mineral fertiliser and FYM demonstrations were established only in Chakol and Emuhaya. Visits were arranged to these sites to expose farmers from sites without demonstrations. Additionally, farmers visited same-type demonstrations in other sites (and on TSBF on-station trials) to record differences, to learn from the experiences of host farmers and to engage in feedback debate.

(d) Participatory Monitoring and Evaluation (PM&E)

Participatory monitoring and evaluation refers to participation of willing farmers in the following FEI initiatives:

(i) to identify key themes to be tested, and to decide on which hands-on tools for interactive learning would be used jointly by farmers and FEI researchers;
(ii) to exercise responsibility for deciding on the location of demonstrations. Interestingly, this aspect turned into a test of sincerity of the project. Exercised the initiative they were granted farmers selected severely depleted sites – ones heavily infested with *Striga* – as part of their experimentation. In other words, they had decided not only to join the project to learn, but also sought to test TSBF-CIAT's knowledge, to assess whether it was worthy of their participation. This was not known[3] to TSBF at the beginning of the demonstrations.
(iii) to design, set up, and wholly manage (including harvest) the demonstrations in consultation with the FEI team
(iv) to decide independently upon criteria to be used to assess the demonstrations, and

[3] Studies showed that farmers had long-held doubts about outside interventions. So, they applied secret *tools* according to a *hidden agenda* to experiment on researchers' trustworthiness.

(v) to collect and analyse information and generate suggestions.

(e) Resource farmers
Farmers' elected representatives mobilised the 'people' to participate. These elected representatives were called resource farmers because they were considered knowledgeable, trusted and able to "serve", socially "stable" (e.g. married), amicable, not criminals on the run, and considered to be better soil fertility managers. Resource farmers were responsible for the day-to-day active linkage between FEI team and other farmers in the respective sites. They were later entrusted to lead the group umbrella forum. This forum was initiated to market produce, seek external funding or credit and other links, and facilitate seed exchange and information sharing.

(f) Song and performances as learning tools
The FEI drew on indigenous styles of knowledge sharing to reach as many farmers as possible. Songs, drama, drumming and dance were all commonly used. Though undertaken for learning about soil fertility, music and other performance idioms proved effective cultural vessels for communicating appreciation of, and requests in relation to, or disguised ironical messages about, soil fertility research.

(g) Interactions on demonstration plots
Dialogue was largely unstructured, but followed a general trend to (i) explain the concepts behind the demonstrations and (ii) understand differences in plot performances where necessary (iii) verify whether or not the technologies and concepts were being appreciated. Most of the visits to these demonstrations were done regularly by farmers alone, to carry out independent monitoring and evaluations, and to record observations in their own language, free from FEI researchers' influence. Notes from these meetings were usually shared and analysed by farmers, with me, in open seminars.
This thesis documents *(a)* agronomic findings from the demonstrations useful to the farmers *(b)* outcomes of the PM&E processes *(c)* application of tested concepts and technologies at the farm level. The study pays close attention to why farmers applied certain aspects of technologies, and how they amended others. It is worthy emphasising that experiments were designed by scientists, but largely managed by farmers to reflect their local situation. PM&E farmer notes were mainly taken independently. While the present study is not integral with FEI, the author took part in both activities. I was involved with the farmers in two roles - first as a TSBF-CIAT 'agent' and later as an anthropologist 'investigator'.

Farmer-researcher social relationships

The process of knowledge sharing was never fully neutral, and led to diverse farmer interpretations, translations and representations of lessons or facts, which can to some extent be considered subjective. One of the causes of this subjectivity was the researcher. It was not possible to neutralise my effect as an outsider. I was largely perceived as a zealous intervener. Notwithstanding, the FEI process created a common language and good level of trust enabling farmers to express themselves openly, for instance, by actively declining certain processes or "opting out" altogether. I was involved by farmers in community processes and in events that were considered both routine and priority events by individual farmer. For instance I participated in weeding, brick-making, ploughing, funerals, fund-raising drives, harvest and beer parties, community-driven development projects, and village elders and chief's meetings. There were many times when the project vehicle was used in emergencies as an ambulance, meals were shared, life stories told, spouses introduced from both sides, gifts exchanged, etc. In the end, many farmers probably recall these social episodes above the technologies and concepts they were observing and absorbing.

Geographical location of the study sites

This study was conducted in villages in Butula, Chakol, Emuhaya and Matayos Divisions (Table 1). It was from these villages that informants were selected for in-depth interviews, participants were observed and focus group discussions (FGD) were conducted.

Table 1: Sites of the study; their villages and participation

Site (District)	Main Villages	*Frequent participants
Chakol (Teso)	Akites, Osorit, Aludeka, Elu, Soromit	35
Butula (Busia)	Bumakunda, Emamba, Siguli, Agola, Enduru	46
Emuhaya (Vihiga)	Emanyonyi, Mukhombe A, Mukhombe B, Wobaria, Mwilonje, Emukangu	34
Matayos (Busia)	Muyafwa, Mundalira, Syamakhanga, Nandere, Nang'oma	42

*Frequent participants defined as those who attended one in four of all possible village meetings. These took place at an average of 1.4 meetings per month between January 2002 and December 2003

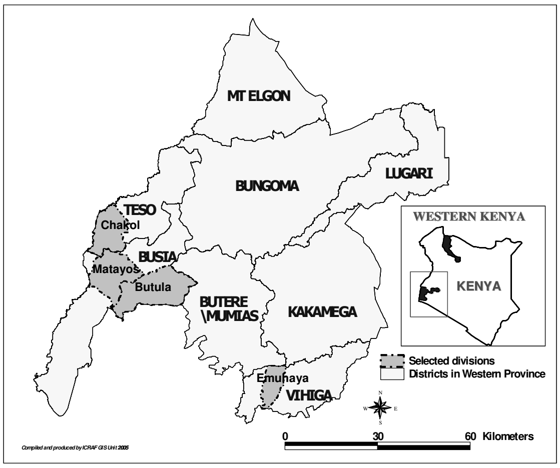

Fig. 1. A map of Kenya (inset) and Western Province: indicating the locality of selected administrative Divisions of Butula, Chakol, Emuhaya and Matayos

Source: ICRAF, Nairobi (June 2006) – adapted by author.

The conclusions and suggestions emanating from the present study mainly derive from and apply to community studies (Table 1) in each of these four divisions.

Household types from which informants were sampled

Wealth ranking exercises at eight sites (including the FE ones) show that the majority of farmers are belonged to wealth categories 2 or 3 (i.e. they were medium or poor farmers) Groups 2 and 3 are the most heterogeneous groups. Many households were hard to classify. The clearest difference was livestock keeping, highly sought after and largely inaccessible to group 3, who also only used fertiliser rarely. Group 1 was quite distinctive and readily separated on a range of criteria from Groups 2 and 3.

Table 2: General characteristics and percentage of different social classes from wealth ranking exercises in 2004

Indicator	Class 1	Class 2	Class 3
Land hire	Hire in land (3-5 parcels)	Hire out only in financial crises, or in some seasons	Hire out land (part of it) to 1, 2
Fertiliser	Use it regularly	Use in long rains, on selected sections	Generally none, or intermittent use
Labour	Hire-in	Family, hired-in during peak season	Family, hire out labour
Certified seed	Regularly	Yes in long rains, but use 'local' seed in second rains	Sometimes, mainly depend on 'local' seed
Farm tasks	Early/punctual	Timely to late	Late to very late (scanty weeding etc)
Harvest security	Secure (or can afford to buy food)	Lasts 4-8 months – not quite secure	Lasts for about 3 months (food insecure)
Income – on-farm	e.g. tea, tobacco, sugar cane, milk.	Few (or less acreage of) cash crops, limited milk production.	Generally no cash crop, rely on selling Napier grass, stover, firewood etc
Income – off-farm	Yes – includes pension, rents, salary, remittance, business income.	Few, or low: pension; salary, remittance, business (e.g. retail shop).	Wage labour, few children are herds boys, maids, manual labour in urban centres, etc
FYM	Enough, can sell surplus	Have some, sometimes buy	Do not have (any or enough)
Average	10%	55%	35%

Source: "Folk Ecology" and "Soil Fertility Gradients" Projects (2004)

Broader context: soil fertility decline as a problem

Improving soil fertility is an important issue because it is held to be central in the quest for food security among small-holder farmers in Africa (Bationo, 2004:1-2; Savala *et al*., 2003:13; Sanchez *et al*., 1997). Improvement and sustenance of soil fertility management among the rural poor is proving to be an elusive target, however. The past decade has seen concerted research and development initiatives targeted on management of natural resources (TSBF, 2001), and results have been reported (e.g. Harwood and Kassam, 2003; Critchley *et al*., 1999; Defoer, 2000:130-2; Werner, 1993). Many of these results can be classed as promising technologies, while others have been referred to as "best bets" (Dyck, 1997; Kanyama-Phiri *et al*., 2000; FAO, 2004). Promising technologies have usually been rated highly in terms of their chances of adoption when participatory consultations were undertaken. Many researchers have therefore argued for an intensification of the participatory research approach (Blackie and Gibbon, 2003; DFID, 1998; Pretty *et al*., 1995). Advocates of reliance on valued farmer-knowledge and expertise have been active for more than two decades in Africa (e.g. Richards 1985; Scoones and Thompson, 1994; Chambers, 1992; IDS, 1979; Brokensha, Warren and Werner, 1980). Yet despite all this activity positive changes in agricultural productivity on smallholder farms have been hard to find (Practical Action and Pelum, 2005:10; Zingore, 2006:2). Rural communities still live on less than one US dollar a day. There are many explanations for this persistent poverty, including the *complexity* of interactions among biophysical, social, economic and technological factors, and stubborn adherence to top-down approaches and hierarchies in agricultural extension and even research (e.g. Zingore, 2006:2-3; TSBF, 2000:66). An issue to be addressed in this study is not complexity as such, but rather that complex situations are also highly changeable, which means that research has to hit a moving target. At the farm-level, situations are always shifting due to changing knowledge and technologies (e.g. from hoe to plough), labour re-organisation, and social re-arrangements affecting or affected by changing gender relations, income sources and patterns of access to land (Scoones, 1997). At any given time therefore, every smallholder farmer has to find an equilibrium point on an ever changing farming situation. Sometimes, farmers address unique sets of circumstances with emergent properties only partially knowable (even through participatory research). It is therefore clear that while soil fertility decline is identifiable among smallholder farmers, targeting to reverse it through research needs a highly dynamic approach.

Progress along this dynamic path has been elusive to both the farmer and the researcher. While Richards (1985), Waters-Bayer and van Veldhuizen (2005) and others demonstrate the value of indigenous knowledge, dependence upon it by smallholder farmers has not sustained soil fertility due to some of this contextual dynamism just mentioned.

Problem focus

The foregoing analysis shows that there is an inherent difficulty in filling the gap between research efforts and their application. Researcher knowledge about smallholder-soil interactions is always incomplete. Even with scientific advance and declarations of "best bets", researchers are always aiming at a moving target. There seems to be no way that smallholder management of ecosystems can be known in their entirety by researchers, and thus strategies for embedding actions and knowledge need to be both dynamic and robust in relation to heterogeneous social contexts.

Overall goal and objective of the study

The focus in this study is to form a view of how well soil fertility research performs within this ever shifting context. The main approach has been to try and identify the main underlying drive beneath the selection and/or application of scientific agro-ecological knowledge as shared with farmers through the FEI. The overall *goal* was to study interpretations or translations of technologies and concepts in farm-level application, thereby evaluating the utility of soil fertility management research among smallholder farmers in western Kenya in terms of its actual outcomes.

The general *objective* of the thesis can thus be stated as an attempt "to study and examine application of agro-ecological knowledge for soil fertility management by smallholder farmers, with the view to enhancing the utility of research among resource deprived farmers of western Kenya".

Specific objectives

Specific objectives were to:

(i) Explain farmers' amendments to cereal-legume rotation technology, promoted for soil fertility management by researchers. This also involved evaluating farmers' perceptions of the potential of different legumes within their farming systems;

(ii) Trace species selection for soil fertility management by analysing the influence of agronomic performance, participatory evaluations, and farm-level experiences with new soyabean varieties among local farmers;

(iii) Study how well the research concept of organic resource quality was integrated into local practices in western Kenya, following an interactive learning process;

(iv) Illustrate smallholder perceptions underlying use of mineral fertiliser by examining results from a participatory learning initiative and community studies in western Kenya;

(v) Illustrate and discuss, in relation to previous objectives, the gap between soil fertility conceptualisation by scientists and smallholders, with a view to contributing to improvement of utility of research results for smallholder farmers.

Rationale of the study

Relevance of agro-ecological knowledge is perceived differently at different times and places by farmers and researchers. Usually, the perception of the farmer counts last, yet it is decisive for land use. This study shows that the selected agro-ecological research knowledge was interpreted and applied disparately, due to variations in farmers' goals, and that this variation conveys insights about the utility of research for farmers. These findings count as feedback around which research interventions for smallholder farmers can be reshaped.

Realism as methodological foundation

Soil fertility is affected by non-linear dynamic and complex interactions of factors mediated by a variety of social, economic and political institutions (Scoones, 1997; Giller et al., 2006). To transform soils, therefore, there is need for a more embedded, context specific, adaptive and learning-based approach to intervention that rejects simplistic, aggregated assessments of people-resource relationships. Instead, research should be prepared to encounter and adapt to uncertainty, complexity and non-linear change factors in smallholder operations. Smallholders address ecological problems through a multiplicity of meanings and understandings. Historically, technological invention and scientific discovery have not been the crucial causal factors in the course of agricultural intensification (Netting, 1993:57), and this study tends to align with that position. Soils research needs to align with wider social and economic processes if it is to have much chance of successful application.

While studying farmer-soil interactions, it became clearer that a holistic model or approach to research for change is a useful way forward. The systems-analysis model was used only partially to guide this study during its inception. Moran (2000:58) defines the systems approach as a "holistic model of components and interrelations of an ecosystem, essentially a qualitative and descriptive process…". It simplifies complex interactions so that these can quantitatively address the behaviour of both the whole and particular parts of the ecological system. By way of limitation, systems theory still has to rely on other theories to devise tools, make measurements and explain phenomena. As a qualitative study oriented towards ecological anthropology the present thesis makes use of a *realistic* approach.

Realism argues that there are entities with causal efficacy beyond and irrespective of the conceptual systems of investigators. Realism as a research methodology is oriented towards analysis in terms of a context-mechanism-outcome (*CMO*) configuration (Pawson & Tilley 1997). In this thesis we will seek to understand how agro-ecological knowledge works as mechanism to bring about adaptations (i.e. outcome patterns) under the complex circumstances encountered by farmers (i.e. context). The *CMO* as a paradigm provides a framework within which causation can be examined across social and biological strata according to the formula:

$$\text{mechanism } (m) + \text{context } (c) = \text{outcome } (o)$$

This $M+C=O$ equation forms the conceptual backbone of *Realistic Evaluation* (Pawson and Tilley, 1997), i.e. attempts to understand the ways in which social or development programmes bring about transformations.

A realist approach to soil management operates under the assumption that consequences (soil management) are to be explained not just by contextual states (in this case farmer knowledge) but by "mechanisms" of decision making and management that need to be uncovered. In effect to pump in knowledge does nothing unless it engages some actual (real) management process. This management process is by no means obvious on the surface, but must be uncovered through hypothesis formation and empirical testing among alternatives.

One way plausible mechanisms can be first identified, Pawson & Tilley (1997) suggest, is by rendering informants complicit in the research. Here, inputs were sought from informants about their own awareness of agro-ecological processes affecting soil fertility, as people who are deeply knowledgeable about conditions within the targeted sites (western Kenya) and who undertake their own experiments in soil fertility management. Sampling was predicated on the issue of what was known, and who knew it.

During the FEI we had documented villages in which participants were doing trials or applying the tested agro-ecological knowledge through snowball procedures. This gave me *ten* key informants from each site selected for close personal working relationships (*participant observation*). Participant observation allowed me to tailor efforts closely to each personality or household involved, and to understand action and beliefs within a wider "model" of causes and consequences they helped articulate. Since the overall approach in the FEI was to disseminate generic knowledge, a major concern in this study was how then to get these informants to lead me, through their working practices, to some understanding of how they responded to demonstrated concepts and technologies, and how they determined what would be useful amid the many competing knowledge claims and practical pressures facing smallholder cultivators in the region.

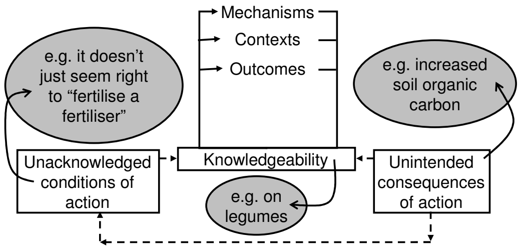

Figure 2 A (partly) knowledgeable farmer as an actor according to the realism paradigm (adapted from Pawson and Tilley, 1997)

As a realist evaluation of soil fertility management actions and interventions, therefore, this study is charged with demonstrating aspects of the agro-ecological concepts and technologies that are relevant (according to the *CMO* approach) to the isolation and testing of causal mechanisms, and to get the informants to contribute their own knowledge to this process, according to the realist interviewing process suggested by Pawson & Tilley (1997), as shown in Figure 3.

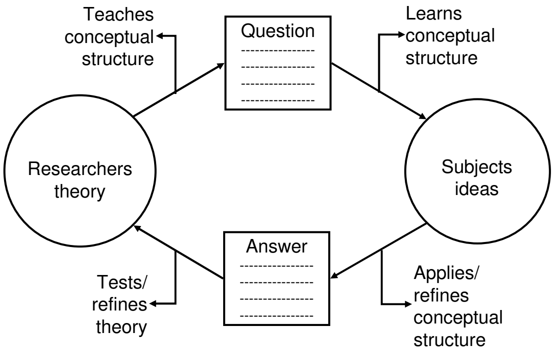

Figure 3 Basic structure of the realist interview (Pawson and Tilley, 1997)

The *C+M=O* could not equip me to target surprises before they happened. Rather it positioned me to understand problems as real and holistically grounded in a larger context. The structure in Fig. 3 allows for subjects' ideas to play upon the question and answer process. Realistic interviews under conditions of participant observation, are in effect two-way discussions or feedback interactions. And in many interviews I invariably became the subject or informant. In any case, this was applied research. In real life, it involved paying protracted attention to explanatory stories and narratives, and linking them to 'flow paths' and answer sequences, which resulted in more follow up. The C-M-O configuration, as Pawson & Tilley (1997) conceive it is a corkscrew (C-M-O-C-M-O-etc) of recurrent enquiry. Hypotheses about mechanisms are never fully confirmed because the context can change so fast.

My own study format was largely conversational, working on short lists of broad themes, while farmers responded according to their (often more detailed and situational) understanding of the subject matter in hand. This proved to be an effective way of homing in on what works for a smallholder farmer, and getting to know why. During *in-depth interviews* and *FGD*, informants progressively opened up their own questions about who I was, what I was after, especially given my association with TSBF-CIAT, and why I needed it from them and not other farmers. After all, many questions had been asked in the villages by other researchers. Questions on key themes were therefore framed or posed and explanatory cues offered to position the farmer to think (e.g. Pawson and Tilley, 1997: 167) and I was subjected to many "why-that-question" rejoinders. This was complementary to *notes* from PM&E processes, in which farmers had their own say on the agro-ecological concepts or technologies being demonstrated, or expressed through opting out (a silent means to disagree with the utility of research itself and the processes involved). This therefore calls for keen observance to how and why agro-ecological knowledge can result in better livelihoods. It necessitates an understanding beneath manifest farmer actions, and digging for alternative (or latent) causal mechanisms or triggers of outcomes specific to local contexts. Such an outlook allows (eventually) for projects to fine-tune interventions to local circumstances, through closer engagement with and understanding of the smallholder farmer.

Of course this somewhat challenges recent debates about the need for scaling up/out of participatory research, under the assumption that a well-worked method is being implemented. It is perhaps better to think of the kind of research dialogue in which the present study engaged as a tool of change in itself, and as a catalyst for the mechanisms being researched. Researchers need to acknowledge that farmers toil on soil within a changing and permeable social world. Research may thus be undercut, nullified or even augmented in significance through the unforeseen incursion of new contexts and occurrences. Applied research should therefore always encompass intellectual craft. Applied social research, engaging social mechanisms within the farmers' grasp, should be the constant intellectual travelling companion of bio-technical enquiry.

Thesis structure and key themes

The present section offers a brief schematic summary of the structure of the thesis.

Chapter 1: Introduction.
This chapter has delineated the background, context, methodology, study objectives and structure of the thesis.

Chapter 2: Smallholder amendments to cereal-legume rotations in western Kenya.
This chapter assesses the underlying reasons for farmers' amendments to cereal-legume rotation technology. It examines the nature of adaptations to this technology, and discusses why in general terms soil fertility is a secondary objective for the smallholder farmer.

Chapter 3: Integrating new soyabean varieties for soil fertility management in smallholder systems through participatory research: lessons from western Kenya.

Grain legume species have been found to be better for smallholder conditions because they address many needs. This case study shows some of the compromises farmers make in selecting new soyabean varieties introduced for soil fertility management. It shows that embedding new species within a local system is a delicate search for balance.

Chapter 4: Farmers' evaluation of biomass transfer technologies and the concept of organic resource quality: *integrating knowledge brands for soil fertility.*
This chapter explains how and why local expertise and knowledge overrode a research based agro-ecological concept.

Chapter 5: Strengthening perceptions of mineral fertiliser among smallholder farmers in western Kenya.
This offers an in-depth evaluation of long-held farmer perceptions of mineral fertiliser and the influence of these perceptions on its use (and lack of use)

Chapter 6: Soil fertility: concept-context gaps.
This argues that while soil fertility phenomena and mechanisms are real, there is a disconnection between scientific and smallholder paradigms. It draws on the preceding chapters, and literature, to show that soil fertility is tangled beneath more manifest goals of smallholder farmers

Chapter 7: General conclusions.

CHAPTER 2

Smallholder amendments to cereal-legume rotations in western Kenya

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Chapter 2

Smallholder amendments to cereal-legume rotations in western Kenya

Abstract

Between 2003 and 2005, a scheme of cereal-legume rotations was tested through an interactive learning process to manage soil fertility by farmers in western Kenya. The learning process included demonstrations that were collectively planned and designed by farmers and researchers from the Tropical Soil Biology and Fertility Institute. The main objective of this process was to illustrate the potential of multipurpose grain legumes both as crops and as a means of improving yields of subsequent cereal crops when used in rotations. Yield data were collected by researchers, while farmers carried out regular participatory monitoring and evaluation and managed the demonstrations. Participant observation, in-depth interviews among forty households, and focus group discussions were carried out to document the extent to which farmers adopted and amended or adapted the proposed rotation scheme. Results show that alternative (i.e. not-for-soil-fertility-management) uses of legumes, need for mineral (P) fertiliser in the implementation of the rotation scheme, cultural aspects, and perceptions of *convenience* were key factors underlying farmer amendments and soil fertility impact. The paper concludes that it is important for crop rotation schemes to include legume varieties with utility beyond soil fertility management alone. Such schemes should result in readily observed gains when applied under minimum local conditions.

Keywords: soil fertility, cereal-legume rotations, amendments, farmer knowledge

Introduction

Continuous mono-cropping, especially of maize (*Zea mays* L.), and lack of, and/or inappropriate use of available soil management technologies contribute considerably to the chronic problem of poor soil fertility in western Kenya, a region of agrarian poverty. The fertility and health of soils influence agricultural productivity, and therefore food security and quality of livelihoods. Thus the soil fertility problem is broader than that of soil's ability to supply plant nutrients. Although soils and their management options are context specific (e.g. influenced by farming systems) soil fertility status is also determined by the socio-economic and policy environment.

Poor soil fertility occurs within a context of many other interconnected challenges. In addition to the widespread N and P deficiencies reported for western Kenyan soils (TSBF, 2004; Jama *et al.*, 2000), agrarian populations face crop pests and diseases, weeds such as *Striga hermonthica,* and marketing problems as manifested in low commodity prices and poor post harvest handling capacities (CGIAR, 2002). Since 1984, scientists at the Tropical Soil Biology and Fertility Institute (TSBF) and elsewhere have partnered with farmers in western Kenya to research, discuss, learn and adapt soil fertility management technologies to the local ecological conditions (Misiko, 2003). One such partnership was realised under the Strengthening Folk Ecology Project (FE), which facilitated a dynamic learning process among local farmers over soil fertility management technologies. One of the key technologies illustrated through participatory engagement was cereal-legume rotation.

Field demonstrations carried out within the FE project were based on the logic that testing a wide range of legumes would allow farmers to custom-fit the most appropriate legume for various soil, climate, seasonal and cropping conditions. Certain legumes fit well into local cropping schemes and can improve soil conditions, compared with further continuous cereal cropping, thus bringing within reach of smallholders some of the multiple benefits of crop rotation, such as breaking crop pest and disease cycles. Prominent legumes already present in western Kenyan farming systems include groundnut (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* (L.) Walp.), common bean (*Phaseolus vulgaris* L.), edible crotalaria (*Crotalaria ochroleuca* G. Don.), Bambara groundnut (*Vigna subterranea* (L.) Verdc.), yellow/golden gram and green gram (different types of *Vigna radiata* (L.) R. Wilczek). Other legumes such as peas (*Pisum sativum* L.), soyabean (*Glycine max* (L.) Merr.), velvet bean (*Mucuna pruriens* (L.) DC.), jack bean (*Canavalia ensiformis* (L.) DC.)*,* pigeon pea (*Cajanus cajan* (L.) Millsp.) or lablab (*Lablab purpureus* (L.) Sweet)*,* etc are not commonly grown by small-scale farmers in western Kenya.

The attraction of legumes rests on their multiple potential uses (for food and fodder, biomass incorporation, and nitrogen fixation). These multiple aspects imply reduction in cost of investment in soil fertility (Giller 2001), soil structure improvement and erosion control, and income generation through marketing and seed production. Both green manure and dual-purpose grain legumes have a potential in management of N in legume-cereal rotations (Bationo, 2004; Sakala *et al*., 2004). Long-established grain legumes in western Kenya such as *P. vulgaris* and *A. hypogaea* have a relatively large N harvest index as compared with multi-purpose crop types such as soyabean and cowpea, and thus most of the N fixed is removed in the harvest and not added to the soil when these established crops are used. TSBF's longer-term experiments have shown evidence that certain species of short-duration herbaceous legumes and dual purpose grain legumes (especially soyabean and cowpea) have potential to improve soil fertility while providing immediate benefits to farmers in the form of food and fodder for self consumption or the market (*ibid*.). However, the beneficial effect of legumes on succeeding crops often depends on a variety of other factors, such as management of the crop and its stover, disease incidence, and *Striga* infestation, as well as other changes in soil fertility factors (Giller, 2001).

The Folk Ecology project entered into dialogue with farmers over the potential of selected legumes in rotation with cereals to improve soil fertility. In this article we present an analysis of the outcome of that dialogue. Our main objective was to assess the underlying reasons for farmers' amendments to cereal-legume rotation technology, when promoted for soil fertility management by researchers. Additionally, farmers' notions concerning the potential of different legumes within their systems were evaluated.

Materials and methods

Site description

Participating farmers originated from several villages of Chakol Division (Teso District), Butula and Matayos Divisions (Busia District), and Emuhaya Division, (Vihiga District), western Kenya. They were purposively selected to follow up the FE participatory initiative implemented earlier. The soils of study villages in Emuhaya are ferralo-orthic Acrisols (FURP, 1987:0.31), developed on an undulating topography with slopes ranging between 5 and 16%. The experimental farm was 1556 m above sea level (study data). The site receives annual rainfall ranging from 1800 – 2000 mm with a bimodal distribution. Butula, Chakol and Matayos have a mean annual rainfall of 1500 mm (Republic of Kenya, 1997). In the villages studied in Chakol Division the soils are spatially heterogeneous in the landscape, and include dystric and humic Cambisols, ferric Acrisols and petroferric Lithosols (FURP, 1987). The experimental farm was 1225 m above sea level (study data). In the study villages in Matayos, soils are generally ferralic Cambisols, lithic or petroferric phase and Lithosols, with rock outcrops (*ibid*.). The experimental farm lies 1225 m above sea level (study data). Soils in the study villages in Butula can be characterised as chromic and orthic Acrisols and rhodic Ferralsols, with partly petroferric phases and dystric phases, and dystric Nitisols (*Ibid*.). The host farm for the experiments was 1310 m above sea level.

Cereal-legume rotation demonstrations

Each site had demonstration plots located on farms of participants. They were central in each location to facilitate interactive learning. Host farms were selected by farmers to ensure they were representative in terms of soil type and history of cultivation (host farms had been cultivated continually from as far back as between 1951 to 1980), and host farmers were classified as popular and well-integrated. The study farms were classified as infertile during the participatory soil characterisation preceding demonstrations, and were deliberately selected by farmers to "see if the new technology worked". On the day of planting, composite soil samples from each of the plots used for demonstration were taken, air dried, ground and sieved through 2 mm and analysed for soil organic C, total N, extractable P and K, and pH following standard methods for tropical soils (Anderson and Ingram, 1993). Analytical results are given in Table 1 for Butula, Chakol and Matayos; reference soil data for Emuhaya were derived from secondary sources and not used in the analysis of the soil quality-crop response relationship.

Table 1: Average soil properties for the different plots (n = 15) sampled at each demonstration site. Values between brackets indicate standard deviation

Site	Soil organic C ($g\ kg^{-1}$)		Total soil N ($g\ kg^{-1}$)		Extractable P ($mg\ kg^{-1}$)		Exchangeable K ($cmol_{(+)}\ kg^{-1}$)		pH (water 1:2.5)	
Chakol	4.8	(1.2)	0.5	(0.10)	2.6	(0.8)	0.18	(0.06)	5.9	(0.1)
Butula	9.0	(0.7)	0.8	(0.16)	6.1	(5.3)	0.14	(0.03)	4.8	(0.1)
Matayos	14.5	(1.9)	1.2	(0.15)	3.9	(4.5)	0.17	(0.05)	5.8	(0.2)
Emuhaya*										
Home field	15.0		1.6		19.8		0.54		6.1	
Poor outfield	9.5		1.0		2.1		0.14		5.3	

*Reference data from Tittonell *et al*., (2005)

Plots were located in gently sloping landscape positions, on reddish clay loam soils except for Chakol, where they were sandy. The demonstrations consisted of single replicates of each treatment combination, because having many replicate plots per site had proved confusing during an earlier participatory monitoring and evaluation (PM&E) exercise conducted during 2002, and because it was not easy to get sufficiently large areas of adequate land protected from theft or grazing and easily accessible to all farmers. Dual purpose grain and herbaceous legumes were planted on 6 x 6 m research-designed plots during the long rains seasons of 2003 to 2005 (Figure 1). The main treatments consisted of:

(i) continuous maize (HB 512 in 2003, Western Hybrid 502 – in 2004 and 2005);

(ii) soyabean [SB20 (TGX 1448-2E)] in the long rains and maize in the short rains;

(iii) *Mucuna pruriens* L. (DC) (white type) in the long rains and maize in the short rains; and

(iv) a legume of farmers' choice in the long rains and maize in the short rains.

Farmers chose to try yellow grams in Emuhaya and groundnuts (Uganda Stripe) elsewhere. These legumes were selected because they were preferred, and were widely known and sold on all local produce markets. Soyabean on the other hand was identified by researchers to have high potential for soil fertility improvement, nutrition and marketing, especially if new varieties yielded well. *Mucuna* was introduced solely for soil fertility, i.e. as a green manure. The main assumption was that even though it was not highly edible, it would increase legume choices if it contributed significantly to increased crop yield.

Each of the demonstration plots was split into four sub-plots receiving or not receiving mineral N (urea) and P (triple super phosphate) fertilisers, as follows:

(i) –P –N: control treatment without mineral fertilisers;
(ii) +P –N: 100 kg P ha^{-1} during the first season of 2003 and 50 kg P ha^{-1} in subsequent seasons;
(iii)–P +N: 0 kg P ha^{-1} and 45 kg N ha^{-1} throughout the experiment;
(iv)+P +N: 100 kg P ha^{-1} during the first season of 2003 and 50 kg P ha^{-1} in subsequent seasons and 45 kg N ha^{-1} throughout the experiment.

Maize -P -N	Maize –P +N	Farmer choice -P -N	Farmer choice -P +N	*Mucuna* -P -N	*Mucuna* -P +N	Soybean -P -N	Soybean -P +N
			1m				
Maize +P-N	Maize +P+N	Farmer choice +P -N	Farmer choice +P +N	*Mucuna* +P -N	*Mucuna* +P +N	Soybean +P -N	Soybean +P +N

Figure 1. Plot lay outs in the cereal-legume rotation and continuous maize with and without fertiliser demonstrations conducted in Butula, Chakol, Emuhaya and Matayos Divisions. Legume crops selected by farmers: yellow gram in Emuhaya and groundnut elsewhere.

There was a distance of 0.5 m between main plots and a 1 m-separation between +P and –P sub-plots (Figure 1). Farmers managed and evaluated plots, and took notes during a three-year span of an interactive learning process. Farmers and researchers jointly harvested each demonstration. Harvested plants were weighed at the plot, and grain and stover sub-samples were taken, weighed, sun dried at Maseno Research Station and weighed again to determine dry weights. During the on-farm weighing, yields were evaluated by farmers for quality. Legume residue was incorporated into the farm. Some or all of the maize stover was usually taken away by farmers to be fed to livestock.

Participatory Monitoring and Evaluation (PM&E)

Visits to these demonstrations were regularly held by both farmers and researchers. Dialogue were organised with farmer groups mainly to assist researchers to verify whether or why the treatments were appreciated. Visits to plots were also regularly undertaken by farmers alone to carry out independent participatory monitoring and evaluations (PM&E), i.e. to record observations free from researchers' influence. Before the ranking of treatments, farmers identified key criteria commonly used locally to explain crop performance (*kufanya*, in Swahili). Observable performance especially during the cereal phase of the demonstration formed a key aspect of the assessment criteria given below (Section 3.2). These criteria were used to infer "which legume would be better for soil fertility enhancement". This ranking was qualitative, with certain criteria being more important, for instance colour of leaves, size of cobs and size of stalks. Farmers' notes were presented and discussed in focus group discussions, and during community participant observation and focus group studies. At the end of the exercise, yields of cereals and legumes were presented to participants for final rankings and concluding discussions.

Community studies

Participant observation and in-depth interviews were conducted among 40 households selected because they had 'try-outs' (*kujaribu*, in Swahili), i.e. households testing for themselves some of the options related to the demonstrations. During participant observation notes were taken describing and explaining male and female farming activities. These notes were later organised along with photographs. Participant observation was especially used in case studies to gain an *emic* (i.e. insider) perspective on selected legumes, and to understand how local logic influenced interpretations or application of knowledge on legumes. Focus group discussions and in-depth interviews pursued four key themes, namely the type of try-outs or practices, how and why they were done, and main lessons or conclusions drawn by farmers. Open ended in-depth interviews were undertaken, and used concurrently with participant observation to further understand the PM&E results, to elicit farmer suggestions, and to verify findings (cf. Frankfort-Nachmias and Nachmias, 2005). Interviews were undertaken at repeated intervals, and involved both husband and wife together, or both partners at different times. Lead respondents were regular participants in the Folk Ecology initiative.

Results

Productivity of the legume-cereal rotations

Legume yields and their response to mineral fertilisers did not show a consistent increasing or decreasing trend from the first to the third year of the rotations (Figure 2 A-D), but may have followed the rainfall pattern in most cases.

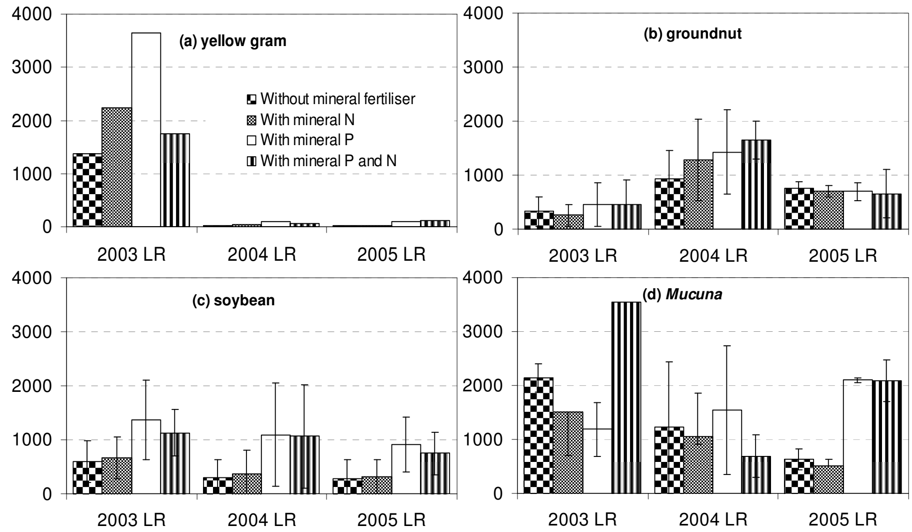

Figure 2. Legume grain yield on rotation plots on farmers' fields in western Kenya during the long rains (LR) over three years (means of four trials; vertical bars indicate Standard error of the mean).

Yield of yellow gram grown in Emuhaya during the long rainy season (LRS) of 2003 were the greatest in sub-plots receiving mineral P fertiliser, while a yield increase of c. 1 t ha^{-1} with respect to the control was obtained with application of mineral N fertiliser (Figure 2 A). The combined N and P fertiliser treatment did not improve yellow gram yields substantially. During subsequent years of rotation with maize, yellow gram yields plummeted to almost zero due to crop failure (mainly caused by heavy loss of seed due to shattering and also pest attack).

Groundnuts grown in rotation with maize in Butula, Chakol and Matayos produced the highest yields during the LRS of 2004, more than doubling the yields obtained during the LRS of 2003 (Figure 2 B). Poor yields were obtained in all sites in 2005 due to lower rainfall. A yield increase of c. 1 t ha^{-1} with respect to the control was obtained with combined applications of mineral N and P fertilisers in the best yielding season of 2004, whereas no responses to fertilisers were observed in 2003 and 2005. Soyabean grown in rotation with maize in all sites responded positively to mineral P applications and to N and P combinations in all seasons, but showed a decreasing trend in yields from the first to the third year of the rotation (Figure 2 C). Yields of *Mucuna* increased substantially with combined N and P applications in the LRS of 2003, showed some response to P in the LRS of 2004 and responding well to sole P and to combined N and P applications in the LRS of 2005 (Figure 2 D).

In general, legumes tended to respond to mineral P applications and not to sole (or additive) N applications, presumably due to their capacity to fix atmospheric N_2. However, the feasibility of P fertilisation should be analysed in the light of the current price ratios between inputs and outputs in western Kenya. For example, the average prices for soyabean, groundnuts and yellow grams in 10 local markets in Vihiga district, western Kenya during 2006 was 45, 70 and 62.5 KSh kg^{-1}, respectively, and the average price for P fertilisers was 84 KSh kg P^{-1} (1930 +/-160 KSh per 50 kg-bag of TSP – Tittonell *et al.*, 2006:94). With these prices, the threshold yield increases necessary to break even should be 187, 120 and 134 kg ha^{-1} for soyabean, groundnuts and yellow grams, respectively, when 100 kg P ha^{-1} is applied (as in the LRS of 2003), or 93, 60 and 67 kg ha^{-1} when 50 kg P ha^{-1} is applied (as in subsequent seasons).

However, the benefits of applying mineral P should not only be considered in terms of the short-term, seasonal response of legumes to applied P, but also by accounting for the residual effect of P fertilisation on the subsequent crops in the rotation. Such an effect could be observed in the yield of maize grown in rotation with these legumes during the short rains seasons (SRS) of 2003 to 2005 (Figure 3). Larger maize yields were obtained in plots where the previous legumes received mineral fertilisers, in spite of the variation in average yield levels across seasons. Yields tended to be greatest in sub-plots in which the legume received combined N and P fertilisers, followed by those receiving only P (presumably due to an increased N availability resulting from N_2-fixation by the legume). Maize yields in the rotation with yellow grams of Emuhaya were greater in the SRS of 2004 and 2005, following the seasons of crop failure.

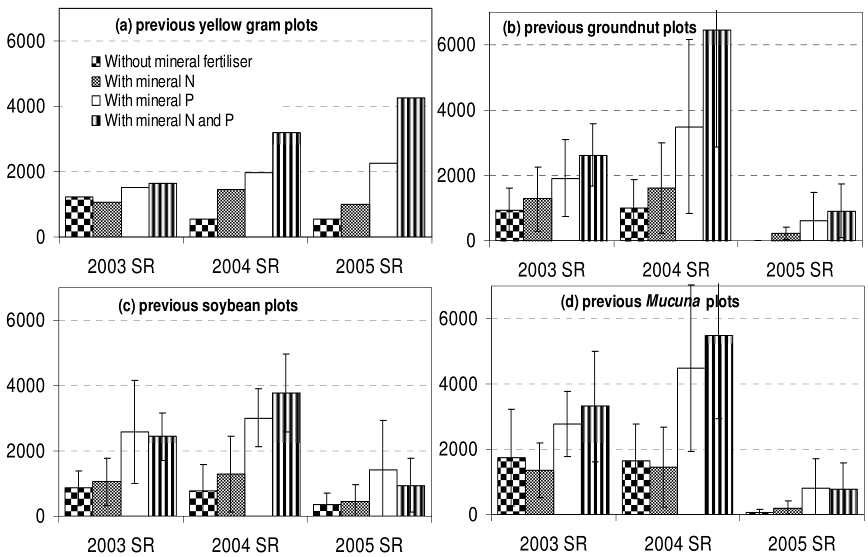

Figure 3. Maize grain yield from rotation plots on farmers' fields in western Kenya during the short rains (SR) over three years (means of four trials; vertical bars indicate Standard error of the mean).

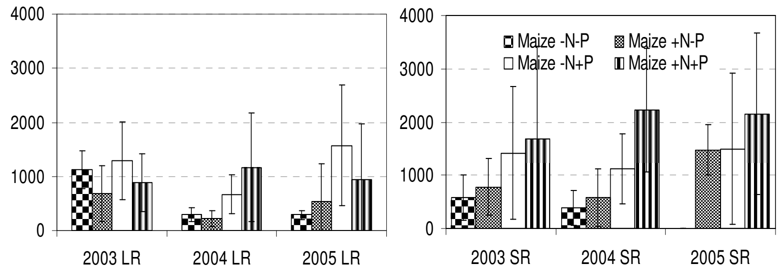

Figure 4. Maize grain yield from continuous cereal plots on farmers' fields in western Kenya during the short rains (SR) over three years (means of four trials; vertical bars indicate Standard error of the means).

Maize yields in rotation with legumes were about twice as large as those grown under continuous cultivation (Figure 4). This implies, in principle, that the annual production of maize under continuous cultivation could be realised in just one season when maize is cultivated in rotation with legumes. No apparent changes in yield levels of maize under continuous cultivation were observed over the three years; yields in the SRS tended to be larger than those of the LRS, and some degree of yield response to P and to combined N and P applications was generally observed. However, the drought experienced during 2005 reversed the upward trends in maize yields rotated with legumes in most treatments, and notably in the SRS of 2005 continuous maize plots performed on average better than in the rotation plots, a result undermining farmers' appreciation of the benefits of cereal-legume rotations.

Participatory monitoring and evaluation outcomes

The process of participatory monitoring and evaluation (PM&E) involved organised farmer groups, farmer field school groups and other interested farmers. Farmers' reports shared in regular farmer group discussions indicated that P was important for better yield in this rotational scheme. They also noted that external sources of N were essential due to extremely low fertility in the sites. The rotation of cereals with legumes was said to 'work' by farmers in terms of increasing cereal yields compared with continuous cropping of maize, the previous common practice. However, farmers noted that improved yield on rotation plots was subject to common yet important intervening factors beyond their control including (i) crop diseases such as groundnut rosette virus, which reduced groundnut biomass, (ii) erratic rainfall and drought, and (iii) infestation by *Striga hermonthica*. Although participating farmers were requested to get *Striga*-free fields, they deliberately offered *Striga* infested and seriously depleted plots to test the versatility of the new technologies in highly hostile local circumstances. Their starting point was to learn from the worst possible sites. If potential solutions could be arrived at here then they would have the answer to problems of agricultural productivity on other, less difficult plots.

Table 2: Collective farmer ranking of rotation plots' *performance*

Site	Continuous maize	Soyabean Plots	*Mucuna* plots	Farmer practice	
				Groundnut	Yellow gram
Butula	4	2	1	3	-
Chakol	4	2	1	2	-
Emuhaya	4	2	1	-	3
Matayos	4	3	1	3	-

Source: local farmer field schools and groups, 2003 – 2005
Legend: 1 – best, 4 – worse. Impressions are general, they include plots with mineral P and N.

'Performance' (*kufanya* – Swahili, the word most commonly used in this context) was the main farmer-generated criterion referring to a combination of appearance and yield of maize. According to farmer notes and discussions, good performance meant: (a) dark green leaves, (b) long, wide leaves, (c) tall stalks relative to the variety in question, (d) rate and uniformity of crop growth in a plot, (e) size of grain (useful in selecting planting seed) and cobs, (f) number of lines of maize on every cob, depending on variety, (g) number of cobs on every plant, (h) colour of seed ('pure white' was considered a sign of a well-fertilised hybrid maize), and (i) weight or quantity of maize at harvest. These criteria were applied sequentially, meaning that opinion shifted as seasons progressed.

PM&E was a *deliberate* attempt to make clear-cut inferences with special emphases on soil fertility. PM&E was sometimes influenced by common farm-level factors such as:

i) The occurrence of hotspots due to charcoal burning sites and incidence of termites (especially during low rainfall periods).
ii) Results in 2005, which influenced farmers to believe that under drought circumstances, maize, or millet and sorghum, grew better as repeated mono-crops rather than in a rotation scheme.

Farmers' notes showed that they now believed that their soils were more fertile by reason of project interventions. For instance, pre-study discussions with farmers in 2002 in Chakol showed that their farms were naturally fertile, and needed no mineral fertiliser. However, other perceptions persisted: for instance millet, sweet potatoes and cassava were strongly believed to improve soil fertility. Participants said that they gained some understanding on how legumes contribute to soil fertility, through biological processes and biomass production for incorporation in the soil. Research is needed to address some of these long-held perceptions, such as low-fertility and *Striga* tolerance by millet. These beliefs were some of the key bases for continued rotation of maize and millet or sorghum.

Community studies

Commonly practiced crop rotation schemes

Previous community studies show that maize is a dominant crop in local cropping schemes as shown in Table 3.

Table 3: Common rotation schemes on the main farm-plots in the study sites

Site	Most likely crop Year 1		Most likely crop Year 2	
	Season I	Season II	Season I	Season II
Emuhaya	1. Maize and beans 2. Sorghum	1. Maize and beans 2. Sorghum 3. Sweet potato	1. Maize and beans 2. sorghum	1. Maize and beans 2. Sorghum 3. Sweet potato
Chakol, Butula, Matayos	1. Maize and beans 2. Sorghum/millet	1. Maize and beans 2. Sorghum/millet 3. cassava	1. Maize and beans 2. Cassava 3. Sorghum/millet	1. Cassava 2. Maize and beans 3. Groundnut 4. Tobacco/sugarcane 5. Natural fallow

Legend: order of crops shows likelihood of crop to be planted in the season.
Source: study data (focus group discussions)

Although these rotation schemes describe the larger (mainly maize) plots on the farms, most farmers in western Kenya have intercrop-rotations (i.e. a mixture or sequential and simultaneous systems) on all plots (e.g. Giller 2001). For instance, many varieties of vegetables are intercropped with bananas, or maize. A few (richer) farmers maintained regular cash-crop-only plots, generally for several seasons. Schemes in Table 2 were not strictly based on seasons, more so in Chakol, Butula and Matayos, where farm sizes are bigger than in Emuhaya. Cassava varieties that took longer than one season would be on one plot for up to two years. Maize hybrids grown in the long rains would be "rotated" with local varieties considered to be tolerant of drought and low fertility, and competitive against weeds.

Explaining amendments

Participant observation and in-depth interviews showed three broad types of amendments or try-outs: (i) validation of demonstration findings, e.g. "testing one's luck"; (ii) finding new uses; and (iii) streamlining the scheme, e.g. the sequence of seasons. Validation or trying one's luck under farm level conditions involved 'doing on the farm as on the demonstration'. Five out of 40 farmers planted *Mucuna* as a rotation legume. Ten farmers planted soyabean in rotation with maize. New uses included planting soyabean (20/40) or *Mucuna* (8/40) partly to smother weeds (especially *Striga*); burning soyabean leaves and using the ashes to produce traditional salt (*musherekha, abalang'a*). A clear majority (37 out of 40 farmers interviewed), 'streamlined' the rotation scheme by: (i) varying cropping density (mostly increased), (ii) applying low or no mineral fertiliser on legumes, (iii) incorporating "high quality" residues into compost, and (iv) trying different types of intercrops, especially soyabean and maize, but also using "trusted crops", or substituting other known legumes, e.g. *Crotalaria ochroleuca.*

Discussion

Farmers amended the demonstrated rotation scheme depending on the performances of the different treatments and local contextual logic (e.g. family or land tenure situations, need for cash crops, rain patterns, *Striga*, etc). Amendments enhanced compliance with vital conditions in the view of farmers, besides targeting soil fertility (see also Werner, 2000). This section explains the logic behind amendments to the research rotation scheme.

Performance of the different plots

All interviewed farmers said the demonstrated cereal-legume rotation scheme was generally convincing, especially given the cereal yield increase of 2004. However, the minimal differences of grain yields of groundnut from +P and –P sub-plots of inadvertently strengthened a long-held perception that this crop does not require fertilising (see Table 4). The very low yields of legume contributed to the decision to drop yellow gram in Emuhaya. Residual fertility, or lack of it, and drought effects were intertwined, however. Drought was a known factor causing variability, and poor performance attributed to it resulted in strengthened preference for "trusted crops", especially cassava in all localities. Farmers' evaluation of the rotation concept was often done with reference to other crops. In drawing such conclusions, cassava and millet (seen as crops capable of withstanding low fertility) were often referred to in Chakol, Butula and Matayos. Farmers observed that "although cassava did not have nodules, the *performance* (kufanya) of maize planted in rotation with it usually improved" (Professor, Butula). Farmers report this belief from West Africa also, and it may have some basis not yet fully understood (cf. Saidou 2006). Focus group discussions brought forward claims that farmers had experienced better yields in fields with such traditional rotations than with continuous maize. Some of the 'rotation effect' is not just due to improved N availability, but also because of the effect of breaking the continuous maize monoculture, crop disease reduction, addition of root systems to the soil improving soil structure, etc.

Performance of the demonstration plots must be seen in light of the poor state of the host farms. Farmers deliberately selected the worst fields for experimentation, and the results of the rotational schemes may therefore be 'misleading' and probably far below the typical potential for each agro-ecological zone. This was a widespread yet covert goal of participating farmers; to learn what they could from researcher interventions on the most depleted (and most severely *Striga*-hit) sites, an intention not known to researchers before the demonstrations were established.

Legume manure stand-alone qualities

There was clear increase in maize grain yield on the rotation plots in 2004. However, the performance and yield on +P sub-plots were significantly higher than that on –P sub-plots (Fig. 2, 3, 4 and 5) for both cereal and legume harvests. These portrayed the legumes as less than sufficient options for soil fertility improvement. The legumes were not a stand-alone option for soil fertility. Farmers needed to invest especially in mineral P to attain good legume and subsequent cereal yields (see also Giller, 2001; Kihara *et al*., undated).

Figure 5: Maize during season II, 2004 in Butula. Differences between the various rotation plots were less obvious compared with the differences between +P and –P rows. See Figures 2, 3 and 4.

In view of this, poor farmers intermittently applied varying quantities of mineral fertiliser on maize and soyabean, but not on groundnut. Awareness of mineral fertiliser had a positive bearing on farmers' decisions over which fertiliser to opt for whenever they could meet the expense of some. However, in 2005, most studied farmers observed K deficiency signs for soyabean (variety TGX14482E, commonly referred to as SB20), and so future emphases on mineral fertiliser may have to be broadened.

Latent functions for legumes

Other than the manifest function of legumes in improving soil fertility – the main goal of the demonstration - one possible response expected by farmers from selected legumes was "to exterminate *Striga*". This was partly due to the observed reduction of *Striga* incidence, especially on previous *Mucuna* and soyabean plots. In-depth interviews showed that the majority of farmers held out this hope. There were 25 observed farmer try-outs of legumes targeted to smother *Striga*. In-depth interviews suggested that the aspiration was usually masked from researchers, but a message began to gain momentum within local knowledge networks that *Mucuna* smothered *Striga*. Since *Striga* was not the target in the exercise, there were no scientific observations to verify this impact. However, scientists have observed that as legumes make the soil more fertile, they may cause the seeds of the parasitic *Striga* weed to germinate without the means to survive (i.e. suicidal germination increases). *Striga* attacks the roots of cereals and extensively devastates crops. *Striga* seeds are triggered to germinate by chemicals from the roots of crops. However, its seedling has only few days to attach itself to a host root and start drawing nutrients and water. Because legumes such as soyabean, *Mucuna* and groundnut are not hosts, germinated *Striga* cannot find a suitable host and dies. Over time, more *Striga* seeds might be expected to lose viability and the weed's incidence might then decrease.

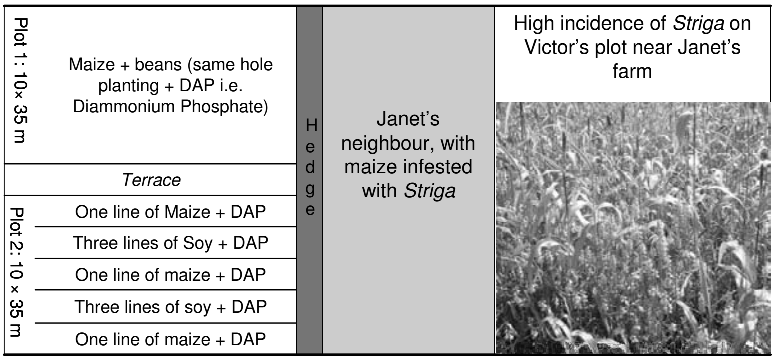

Figure 6: An amended 'try-out' by farmer Janet, Matayos in 2005.
(With consent of Janet and Victor, Matayos (November 2005).

Figure 6 represents Janet's try-out. Plot 2 had high incidence of *Striga* in 2004, where she planted a soyabean-maize "intercrop-rotation" to suppress *Striga*. This "intercrop-rotation" comprised intercropped soyabean and maize, during which Janet marked clearly where each crop was, and secondly, interchanged their positions in the following season. With *Striga* a major problem, targeted plantings of soyabean (often intercropped with maize) was planned by three-quarters (30/40) of the studied farmers. Targeted planting aids complementarity in growth and competition as well as gaining benefits associated with soyabean (see Giller 2001:95). Janet predicted that if this dynamic practice reduced *Striga* incidence substantially (e.g. by +75% as she thought) then the practice would be applied not just by herself, but also by her mother in-law, various neighbour(s), and other local farmers (she named Victor, a neighbour). Further participatory work specifically targeted on legumes and *Striga* elimination would seem to be called for.

Soyabean leaves and stover were also tested for novel and competing uses, such as green vegetable (3/40 farmers), fodder (10/40), traditional slat making, etc. These are traditional uses of legumes e.g. common beans (*P. vulgaris)*, limiting the incorporation of residues for soil fertility. Even when used as fodder, the resulting cattle manure needs to be managed well. All interviewed farmers incorporated legume residue to make "high quality compost" or directly into their farms. This has a positive soil fertility role because of the large content of N and because this N is likely to become readily available for uptake by crops.

Convenience of existing and new practices

By *convenience* farmers referred to relative low or uncomplicated labour demands, low input requirements and ease in selling produce. Farmers tend to reject labour intensive crops. However, a crop may be labour demanding, but is accepted where it generates immediate higher or relatively assured returns, as is the case with sugarcane in some neighbouring districts. Such a crop would be seen as being *convenient* by local farmers, despite its labour demands.

All studied farmers with cattle preferred shorter term natural fallows as an option instead of buying *Mucuna* seed and mineral P and paying for extra labour. Socially, natural fallows are considered more convenient for most individual smallholder households than planting *Mucuna.* This was ranked as the best in terms of improving the “soil’s physical appearance” but lacked all-important ‘direct’ value in terms of food.

Figure 7: Farmers incorporate *Mucuna* residue on the cereal-legume rotation demonstration plots in Chakol. *Mucuna*’s positive qualities were mainly associated with its nodules, incorporated residue and “good root system” (focus group discussion results).

Mucuna’s application looked promising during the demonstration due to collective labour and its promotion by researchers. On individual farms, it was generally ‘disowned’ as *inconvenient* by farmers. Convenience was the primary determinant for preferences as shown in Table 4.

Table 4: comparative *status* of legumes based on key farmer criteria

Legume	Soyabean (SB20)	groundnut	Yellow gram	*Mucuna*
Soil fertility	2	3	3	1
Marketability	2	1	1	3
Processing or edibility	3	1	2	-
Work load	3	1	2	3
Storability	1	2	1	-
Pests & diseases	3	3	2	1
Theft while in the farm	2	3	2	1
Local Price	2	1	1	3
Taste	3	1	1	-
Need for P	2	1	1	2
Striga/weed control	2	3	3	1
As an intercrop	1	2	1	3
Staggered harvesting	3	1	3	2
Overall status	2	1	2	3

Source: farmer groups, focus group discussions of March 2005

Legend:

1. 1- best 3 –worst. Ranks were based on farmers' perceptions, observations and experiences.
2. yellow gram was only ranked in Emuhaya, where groundnut was not planted.
3. Processing refers to cooking time, threshing e.g. SB20 was found to be so dusty and caused coughs.

Table 4 reveals that preferences were influenced more by certain qualities than others. Mainly, *A. hypogaea* was: (i) not as laborious as *Mucuna* or soyabean, (ii) *easy* to sell on local produce markets, (iii) very edible, even when raw, (iv) fetched relatively higher prices, e.g. KSh.75/kg compared to KSh.50/kg for soyabean, in March 2006, and iv) suffered smaller price oscillations. Participant observation and focus group discussions showed clearly that if soyabean was going to be as favourably perceived as groundnut, then it would have to be a convenient answer to smallholder priority problems, and above all its price on the local produce market would have to be as high or higher than groundnut and stable. If it met farmers' convenience criteria it would then (theoretically) induce more application of mineral P (and perhaps also K) by smallholder farmers.

Clash of cropping and hardship seasons

Researchers hoped that selected legumes (especially soyabean), besides enhancing soil fertility and providing food, would also enhance smallholder cash flow and health (nutrition). The purchase of inputs, and sowing and weeding of crops, coincided with seasonal hardship peaks, such as the peak malaria season, seasonal labour constraints, seasonal hunger urgent annual demands to pay school fees. Some thought the new might replace the old. For instance, soyabean was sometimes planted in the same hole as maize by a few farmers seeking a "replacement for *P. vulgaris* varieties that were failing". Such approaches did not guarantee good yield or soil fertility improvement (see also Kansas Rural Centre, 1998). Conservatism with respect to maintaining cropping systems that incorporate new varieties or practices into traditional high intensity tillage systems (e.g. in Emuhaya) with low or no P addition may not provide the increased gains that researchers were hoping for. In such systems, sustaining or improving nitrogen levels through crop legumes is an essential but not sufficient requirement for sustainable fertility. The need to balance such systems by meaningfully elevating legumes to a dominant role in intercrops and rotations, especially in the least fertile fields, remains a crucial requirement.

Cultural facets

Figure 2, 3 and 4 show higher cereal yield on previous *Mucuna* plots than those of continuous maize. If a farmer planted *Mucuna*, he or she would regain maize harvest foregone during that season, within one further season. But this remains hypothetical. In the words of one discussion participant, farming is about edible plants (*sisi Wateso hatupandi vitu visivyoliwa,* i.e. "we Ateso do not usually plant resources that cannot be eaten"). So then they would rotate maize+beans with millet or cassava "to improve soil fertility". Farming is a deeply rooted tradition in western Kenya. It comprises a routine growing of certain crops which everyone else in village also grows. Growing maize, even when it performs badly, is not as odd as growing *Mucuna*. One needs good reason to be the odd one out, planting a crop that no relative or friend may ask for. A farmer grows food not only to feed the household but to have the means to reciprocate. As anthropologists have long argued, to give or to share is to sustain one's place in a social system. Lack of reciprocal demand is one of the reasons why three years on the idea of *Mucuna* remained largely alien. A sense that *Mucuna* had no established part to play in creating a social order through exchange played a negative role in deterring try-outs or experimentation with new usages such as fodder and composting.

Participant observation showed that *Mucuna* fallows had been planted in rotation with maize by only eight (out of 40) studied farmers on small portions. The other 32 informants did not plant it. They stated explicitly that fallows were less salient to to the social sustainability of cropping systems on their farms. In the words of one farmer, "a fertiliser should not be fertilised, unless it confers tremendous benefits" (Silvestre, Chakol). Like Silvestre, other typical smallholder farms in Matayos, Chakol and Butula preferred cassava, which was seen as reliable in its social purposes, as well as being good for soil fertility. Natural fallows (some with infertility indicator plants), were common in these three sites. Although local knowledge recognised fallows as '*rest*' for depleted fields, crop-free zones may not be as beneficial as some farmers assumed, especially if the type of plants left to grow were not legumes. It would be worth continuing to press the idea of planted fallows, but there remains a challenge to make such fallows seem socially as well as biologically productive.

Shortcomings of participatory research and scaling up

Although participatory knowledge sharing had been achieved, the FE project was not mandated to carry out household level extension and provide detailed technical guidance to farmers. Participation rarely manages to support information flow to guide participants' post project knowledge sharing and application. Even during the project, there was a limitation to how much science could be divulged to participants, and whether any of that knowledge might spread spontaneously. For instance, the conditions under which N is fixed and removed from the environment can indicate whether there are net benefits to the system of growing a legume (Giller 2001:96). Such understanding can be a useful guide for any amendments, yet it is not easily accessible to most participants, nor is it even commonly shared knowledge among different scientific disciplines.

Symbolism: "experimenting for recognition"

Three cases of try-outs by regular participants were said:
"…to show a good example and vision. …who knows, *Mucuna* could be tomorrow's gold" (Musa, Butula).
These try-outs were special sections on farms, applied with mineral fertiliser and worked by these participants to showcase their farms as good examples. For instance, five farmers had opted to "do it as was on the demonstration" by trying out a *Mucuna*-maize rotation. *Mucuna* was a researcher's idea, and showing 'loyalty' to researchers was a way of getting social recognition. Usually, 'good' try-outs were jointly identified by farmers and researchers and used as learning fields. Visitors (especially from outside Kenya) were taken to such farms by project staff, to illustrate the 'success' of the learning process. However, such try-outs were few and usually not sustained for several seasons. This implies that the motive for such try-outs may have been mainly to show 'solidarity' with the research process, and in turn enhance the social standing of the farmers in question.

Suggestions for future participatory research

Most of the cropping systems with herbaceous legumes currently grown in western Kenya by smallholder farmers could be improved even without introducing exotic species. For instance Giller *et al.,* (1987) and Giller (2001:165) show that groundnut residues can have additional benefits that were either not due solely to their provision of N or were due to a more efficient use of the N by maize. This was largely evident in the demonstration results from all sites. By contrast, new soyabean varieties (especially SB20) that were good for soil fertility had a longer growing season, and were beginning to show susceptibility to (rust) disease. Achieving a balance between local and introduced leguminous materials is a critical issue. For the new legume varieties to get a meaningful foothold in western Kenya, there is a need to strengthen farmer preferences, for example, via intercropping with cereals (maize) and even cassava, and to work out ways of maximising the net benefits of such legumes on soil structure and fertility. This can be through what farmers called "high quality composts", i.e. incorporated with legume residue. Composts were a likely option for the labour constrained farmers, who were unable to carry soyabean and groundnut residue back to the farm for incorporation. Maximisation of net benefits is an important step for soil fertility improvement objectives. Mumias Sugar Company introduced soyabean in early 1970s as a sugarcane intercrop in Butere Division (next to Emuhaya), yet it was abandoned by smallholder farmers because of its promotion as part of a sugarcane-based system, which was characteristically labour intensive. The future adoption of cereal-legume rotations requires legumes that: (i) can, for instance, be used as alternatives to *P. vulgaris* e.g. as intercrops, (ii) are highly promiscuous in nodulating with indigenous rhizobia in the soil,

(iii) are tolerant of the poor P availability that prevails, and (iv) therefore result in easy-to-see increases in yield of crops in subsequent seasons, even when legume stover is removed. The new soyabean varieties being tested in western Kenya by TSBF were not low-P tolerant, although they would meet the other criteria with further germplasm improvement? If these varieties became easily marketable and profitable especially on local produce markets this might (as already noted) lead to more widespread purchase of mineral fertiliser, especially P.

Conclusions

Farmers' amendments to the demonstrated cereal-legume rotation scheme signified that soil fertility was enmeshed with other equally pressing issues; soil fertility is not perceived as *the problem*, rather as one avenue to solve the urgent (albeit linked) priorities such as hunger or school fees, or comparable problems of *Striga* and fodder. Besides latent functions and benefits, when increase in yield of a subsequent cereal was attributed to legumes, the role of soil fertility management was strengthened among smallholder farmers. However, some amendments to the original scheme, such as low use of mineral P, compromised chances to improve and sustain harvest gains. The main challenge, therefore, is to reshape the rotation scheme or concept, and move further to strengthen residue management and cereal-legume simultaneous systems for soil fertility. Any new rotation or intercrop scheme to be successfully adopted, has to directly result in easy-to-see increases in yield under the minimum-input local conditions shaping local farming systems.

CHAPTER 3

Integrating new soyabean varieties for soil fertility management in smallholder systems through participatory research: lessons from western Kenya

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Chapter 3

Integrating new soybean varieties for soil fertility management in smallholder systems through participatory research: lessons from western Kenya

Abstract

Soybean (*Glycine max* [L.] Merr.) promiscuous varieties were screened and evaluated in western Kenya through participatory approaches. Farmers selected preferred varieties and explained their reasons (criteria) for making the selections. Seven promiscuous varieties had better yields than a local one on the 2.5m × 3m plots that were managed according to farmers' practices. Farmers' selection criteria fell into three broad categories relating to yield, appearance and labour. Selection criteria were not primarily aimed to improve soil fertility. This created a challenge to embed the new varieties within the local farming systems for soil fertility improvement. This study shows that farmer criteria for selecting varieties overlapped with scientific procedures. We propose co-research activities targeted to strengthen farmer experimentation skills, their understanding on N addition, and the role of P.

Key words: selection criteria, variety screening, farmer experimentation**.**

Introduction

In addition to their direct food provision, grain legumes are an appropriate way of targeting soil fertility improvement on smallholder farms due to their capacity to fix atmospheric N_2 in symbiosis with rhizobial bacteria (e.g. Muhr *et al*., 2001; Snapp and Silim, 2002; Ojiem, 2006). In response to rapidly declining soil fertility and resultant low crop yields in sub-Saharan Africa, breeders have focused on developing improved soybean (*Glycine max* [L.] Merr.) varieties that fix a high proportion of nitrogen from the atmosphere. These cultivars have the capacity to fix N_2 in symbiosis with rhizobia occurring in the natural soil flora without inoculation with specific strains, and are known as promiscuous varieties (Giller, 2001). Promiscuous varieties can also produce large amounts of biomass and are often referred to as dual-purpose because they do not only provide grain and/or cash but also leave a net amount of N in the soil that can benefit subsequent crops (Mpepereki *et al*., 2000; Sanginga, 2003).

Soybean grows well in tropical climates; it constitutes a source of high quality but inexpensive crop protein and can be used to produce cooking oil. In addition to improving soil fertility through biomass and N_2-fixation, promiscuous soybean can contribute to balanced diets. Thus soybean has a major potential to benefit smallholder farmers in Sub-Saharan Africa where soil fertility is extensively depleted due to a combination of increasing population, poverty and inherently poor soils (Vanlauwe and Giller, 2006). In Sub-Saharan Africa soybean is mostly manually produced by smallholder farmers either as a sole crop or intercropped, with little or no nutrient inputs applied. Soybean is a recent introduction in much of Africa and therefore has fewer disease and insect problems than other grain legumes, and its average[4] yields in Africa (Sanginga *et al*., 1999), fluctuate around 990 kg ha^{-1} (IITA, 2006). Lack of market for the grain, restricted skills in processing for home consumption, poor moisture and P availability in the soil comprise important constraints to wider adoption of soybean.

Variability in local physical and socioeconomic contexts necessitates appropriate adaptation of plant and bacterial genotypes if they are to be successfully grown (Giller, 2001). Thus, participatory variety screening becomes an important step prior to wider dissemination for adoption of new soybean genotypes. Since 2001, the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT) has tested several dual-purpose soybean varieties for their nodulation, biomass production, and grain yield in western Kenya to identify varieties that are productive under smallholder conditions (Vanlauwe and Mukalama, 2003). These tests showed that promiscuity of most of the tested varieties was retained under western Kenyan conditions, even though these soybean varieties were not specifically been bred for these environments. These varieties produced prolific biomass while grain yield was maintained, and there was generally good nodulation. However, in aiming to embed new crops/ varieties within a rural community, such researcher-designed screening tests needed to be complemented by farmer analyses and assessments via participatory variety screening.

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[4] Under on-farm research conditions.

Participatory screening processes give farmers the research role in all major stages of the breeding and selection process. Farmers become co-researchers as they can: help set overall goals; determine specific priorities; make crosses; take charge of adaptive testing; and lead the subsequent seed multiplication and diffusion process (Sperling and Ashby, 1999). The main advantage is that involving farmers can deliver more than when researchers work alone (Almekinders and Elings, 2001; Sperling *et al*., 2001). Participatory variety screening is a qualitative assessment of experimental treatments by farmers. It is useful in quickly explaining smallholder criteria for preferring and/or selecting one variety over another (Reijntjes *et al*., 1992). Screening is also useful to understand the conditions under which outbreaks of certain pests and diseases occur and what can be done to avert failure (e.g. Barker, 1979). To complement researchers' screening tests in western Kenya, a network of demonstration plots with the most promising soybean varieties was established and managed jointly with local farmers as part of a wider design of interactive learning for soil fertility management (Misiko, *et al*., 2003). Participating farmers select new varieties based on disease tolerance, yield, taste, etc. However, they are less likely to adopt new crops/ varieties if, for example, appropriate methods of processing and utilisation are unknown to them (IITA, 1992). Since soybean is a relatively new introduction in western Kenya, this activity sought also to identify different utilities of a range of soybean varieties (cf. Richards, 1979).

Selection of promiscuous varieties is only a first step in the process towards wider adoption. If they satisfy the most important criteria, then they are more likely to be widely accepted in smallholder farming systems. In 2004, participatory screening exercises were conducted through partnerships between TSBF-CIAT and smallholder groups on farmer-selected plots. The underlying logic was that, however promising, a technology should only be recommended for wide-scale adoption by farmers after it has been rigorously evaluated in local fields under realistic conditions. These rigorous evaluations must involve typical smallholder farmers (Giller, 2001). This study was part of the process of evaluation and observation of smallholder preferences, and how they selected from these varieties and planted them in subsequent seasons.
Our overall objective was to trace variety selection by smallholders, by analysing agronomic results from screening plots, participatory evaluations and farm-level experiences with new soybean varieties.

Materials and methods

Site description

Participating farmers originated from several villages of Chakol Division, Teso District and Matayos Division, Busia District all found in western Kenya. They were purposively selected as partners within a participatory learning initiative under a project called Strengthening Folk Ecology, which is implemented there. In the villages studied in Chakol Division the soils are spatially heterogeneous in the landscape including dystric and humic Cambisols, ferric Acrisols and petroferric Lithosols (Jaetzold and Schmidt, 1982). The site receives an annual rainfall ranging from 1270 – 1500 mm with a bimodal distribution. In the villages of study in Matayos, soils are generally ferralic Cambisols, lithic or petroferric phase and Lithosols; with rock outcrops (*Ibid*.). The site receives an annual rainfall ranging from 1020 – 1270 mm with a bimodal distribution.

Commonly grown legumes in the sites

Prominent legumes already present in western Kenyan farming systems include groundnut (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* (L.) Walp.), common bean (*Phaseolus vulgaris* L.), edible crotalaria (*Crotalaria ochroleuca* G. Don.), Bambara nut (*Vigna subterranea* (L.) Verdc.), yellow/golden gram and green gram (different types of *Vigna radiata* (L.) R. Wilczek). Soybean has been known to local farmers for long, but only recently is more widely grown

Screening plots

Two screening sites were chosen and fully managed by participating farmer groups in the research localities during the first season (long rains) of 2004. In these sites seven varieties from a "20 best-bet" (i.e. Vanlauwe and Mukalama, 2003) dual-purpose soybean set obtained originally from IITA, plus the local variety SB21 (included as reference), were tested on farmers' fields with and without application of mineral P fertiliser.

Table 1: Soybean varieties included in the demonstration plots and their maturity group

Variety (IITA* code)	Local identifier	Maturity
TGX 1889-12F	SB15	Late
TGX 1893-10F	SB17	
TGX 1448-2E	SB20	
TGX 1835-10E	SB3	Medium
TGX 1876-4E	SB5	
TGX 1740-2F	SB19	
X-Baraton	SB21	Early
J499	SB22	

IITA: International Institute of Tropical Agriculture

Host farms were selected by farmers as representative in terms of soil type and history of cultivation (host farms had been cultivated continuously from start dates ranging from 1951 to 1980). Host farmers were selected to be socially well-integrated and willing to host the trials. Soils were classified as infertile during the participatory soil characterisation preceding the demonstrations, having been consciously selected by farmers to test the new varieties under typical local conditions. In Matayos, screening plots were located on gentle slope, with reddish clay loam soils, while in Chakol soils were sandy. Composite soil samples from these fields were taken, air dried, ground and sieved through 2 mm and analysed for soil organic C, total N, extractable P and K, and pH following standard methods for tropical soils (Anderson and Ingram, 1993).

Table 2: Average soil properties for host fields (n = 15) sampled at each farm. Values between brackets indicate standard deviation

Site	Soil organic C (g kg^{-1})		Total soil N (g kg^{-1})		Extractable P (mg kg^{-1})		Exchangeable K ($cmol_{(+)}$ kg^{-1})		pH (water 1:2.5)	
Chakol	4.8	(1.2)	0.5	(0.10)	2.6	(0.8)	0.18	(0.06)	5.9	(0.1)
Matayos	14.5	(1.9)	1.2	(0.15)	3.9	(4.5)	0.17	(0.05)	5.8	(0.2)

Data from Misiko, *et al*., (2007, unpublished)

At each site, single plots (no replications) were planted with each of the 7 soybean varieties plus the local one. Each plot was divided into two sub-plots receiving or no mineral P at a rate of 50 kg ha^{-1}, as triple super phosphate (TSP). The different soybean varieties were planted 2.5 m by 3 m plots during the long rains of 2004 and the central area discarding a border row was harvested. The demonstration plots were used by farmers to check if there were indications of N_2-fixation. There was a distance of 0.5 m between variety plots and a 1 m paths between +P and –P sub-plots.

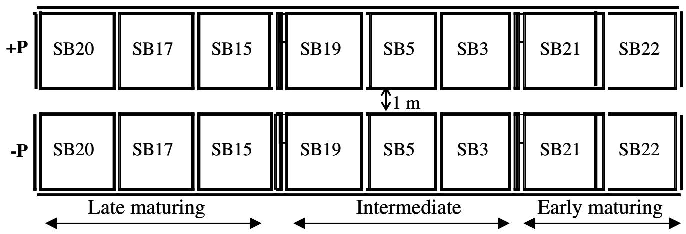

Figure 1: Schematic representation of the on-farm demonstration plots, indicating soybean varieties (main plots) and mineral P applications (sub-plots). The design of the layout in the field was not random: the first to the third plots (from the left) were planted to late maturing, fourth to sixth medium maturing, and seventh to eight with early maturing cultivars (ninth plot planted to the local variety SB21).

Seed was sawn at spacing of 45 cm between rows and 5 cm within the row and weeded twice. Participating farmers managed the crop, evaluated it, and took notes for each variety at planting and germination at intervals of two weeks, then at 50% flowering (bloom), at 50% podding, at maximum height and leaf area, rapid leaf yellowing or fall in lower canopy, and at harvest when 95% of pods had changed to brown colour. Biomass (leaves, stems and pods) sampling was done by researchers at 50%-100% podding and at full seed. Farmers and the researcher jointly harvested the screening plots. Harvested varieties were weighed at the plot, and grain and stover sub-samples were taken, weighed, sun-dried at Maseno Research Station, and re-weighed to determine dry weights. During the on-farm weighing, yields were evaluated by farmers for quality of the grain.

Participatory Monitoring and Evaluation

Visits were mostly done regularly by farmers alone to carry out independent PM&E, i.e. to record observations free from researchers' influence. Collectively designed forms were also used to enable organised data collection. Before the ranking of varieties, farmers identified key criteria seen as most critical locally to assess performance (*kufanya*, in

Swahili) at different stages. Distinguishable performances during the different growth stages (under 'screening plots'), formed a key basis for ranking. These criteria were used to judge farmer preferences. Preferences shifted from stage to stage, and ranking was aggregative (i.e. it did not reflect only a single stage). Ranking was therefore qualitative, with certain criteria – yield, rate of growth - being more prominent, but including the amount and colour of leaves etc, at different stages of growth. Some varieties were judged as resembling each other (*zinakaribiana sana*, Swahili), e.g. they shared similar growth rates, or were bushy. Farmers' notes were used in focus group discussions, and during community studies (see below). At the end of this process, yield of the different varieties were extrapolated to hectare basis and presented to participants for final ranking and discussions. During the previous year farmers had been trained in basic skills to evaluate nodule 'performance'. The procedures involved careful uprooting of representative plants from inside each plot, counting and dissecting nodules and examining their colours. This process was guided by farmers. During this evaluation process, the researchers (i) observed the PM&E process and kept notes, (ii) assessed screening plots' management by farmers, (iii) kept notes on pest and weed influences, and (iv) assessed other irregularities during the screening implementation.

Community studies

A rapid comparative "adoption" assessment of 80 randomly sampled households with soybean was carried out in 2005. Participant observation and in-depth interviews were carried out on 20 of these households. These 20 households were purposively selected because they participated in the screening exercise and had tested more than three varieties on their own plots. Participant observation was used in these case studies to allow lengthy and focused observations to corroborate how soybean varieties were planted, managed, assessed and the reasons behind the process. Participant observation therefore enabled better understanding of *emic* (i.e. informant) notions shaping actual selection of varieties, rather than relying only on what was reported in the rapid assessment or PM&E. Four focus group discussions were used to further understand the PM&E and rapid assessment results, analyse them and elicit farmer suggestions. Analyses broadly focused on understanding farmer selection criteria i.e. conditions each variety met or did *not* meet and participants' key reasons to/not to plant the screened varieties.

Initial lists for interviews were made through a snowball sampling exercise undertaken by local resource farmers, possessing prior interview skills, and in-depth knowledge on the study villages. These lists were used to randomly sample 80 informants. This exercise did not seek to count all farms with soybean. Rather, the purpose was to document smallholder reasons for planting soybean, and their experiences, as conveyed in their own words. It also involved estimating the area under soybean, and determination of the variety grown and the source of seed.

Results and discussion

Screening plots

In general, biomass production and grain yields of all varieties were larger in Matayos than in Chakol due to inherent differences in agroecology and soil quality across sites (Table 2).

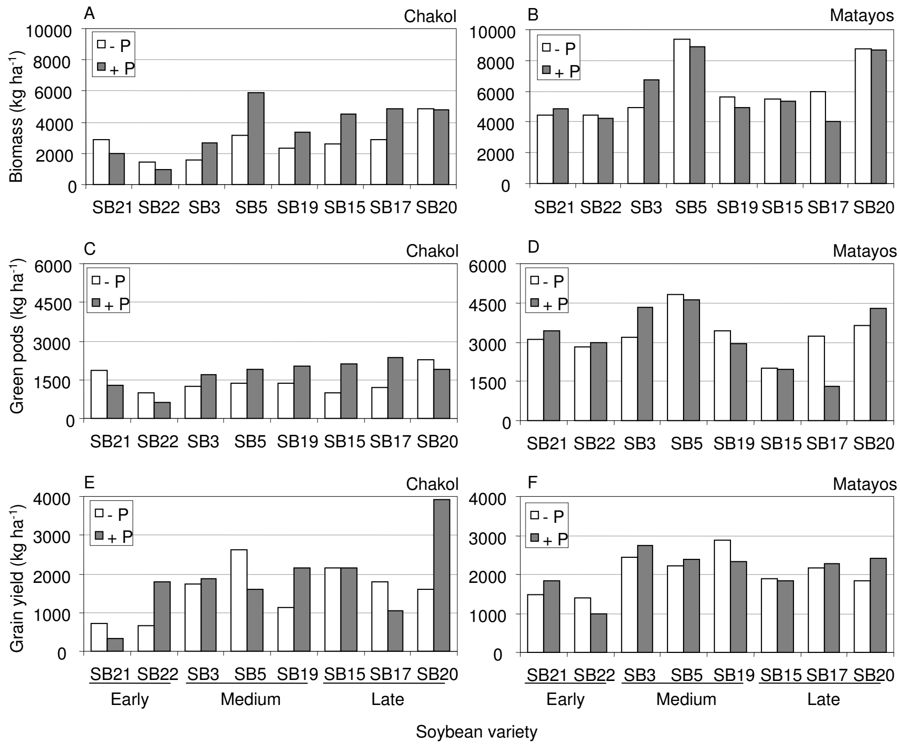

Figure 2: Total biomass production (A, B), green pods biomass (C, D) and grain yield (E, F) of the screened soybean varieties at Chakol (Teso district) and Matayos (Busia district), western Kenya, receiving or not 50 kg P ha-1 as TSP, during the long rains season of 2004. Biomass and pods were measured at full-seed stage, and grain yield at harvest maturity. **NB**: Farmers were interested in detecting any links between biomass and grain yields, and grain and pods yields as key tools to predict productivity of the different varieties.

In both sites however, intermediate and late maturing varieties tended to produce more biomass at 50% full-seed than the early maturing varieties, which included also the local variety SB21 (Figure 2 A and B). SB5 and SB20 were consistently the most productive in terms of above-ground biomass at both sites. While most varieties showed some degree of response to applied P in Chakol, only SB3 responded substantially to P in Matayos by producing ca. 1800 kg ha^{-1} more biomass than without P. Early maturing varieties showed no, or negative, responses to applied P at both sites. Farmers considered the size and number of pods produced at 50% full-seed stage as predictors of grain productivity at harvest. Only a few late maturing varieties produced more pod biomass than the local SB21 without P in Chakol. SB3, SB5 (intermediate maturation) and SB20 (late) produced substantially more (ca. 1500 kg ha^{-1} more) than the local variety when P was applied (Figure 2 C and D). However, when grain yields were measured and evaluated by farmers at the end of the season, some of the earlier observed trends were not confirmed, e.g. most dual-purpose varieties produced larger grain yields than the local SB21 with or without P at both sites (except the early maturing SB22 in Matayos) (Figure 2 E and F). In general, responses to P in terms of biomass and grain yield were not consistent across sites, save for grain yield of SB21.

Farmers also observed that SB3 and SB19 had filled all pods, and thus grain yields were expected to be higher – which was the case in Matayos (Figure 2 F). In terms of soil fertility management, more biomass represents potentially more organic matter and nutrients to be incorporated in the soil, whereas more grain means more nutrient extraction from the soil. Therefore, harvest indices (HI = grain yield / aboveground biomass) will give greater soil fertility benefits.

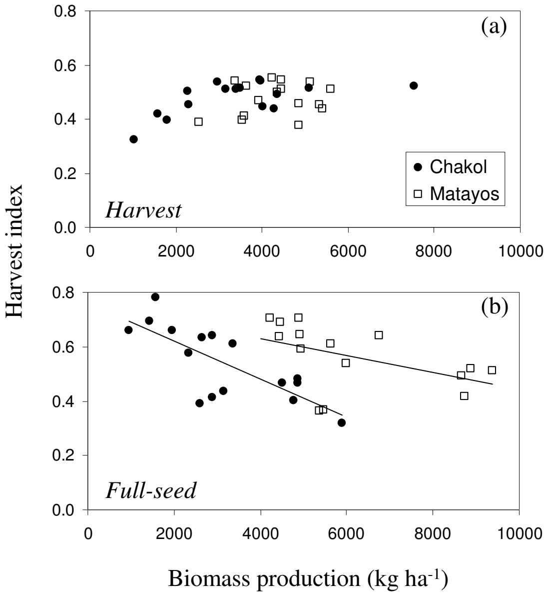

Figure 3: Harvest index (grain / aboveground biomass) of soybean as a function of total aboveground biomass production at Chakol and Matayos, pooling observations from all the varieties tested. (a) Calculated at harvest maturity, (b) calculated at 50% full-seed stage (maximum crop standing biomass). HI calculations done on dry-weight basis.

The HI at harvest maturity increased with biomass production (Figure 3 A), showing a pattern that is normally observed across grain crops (i.e. an asymptotic increase of HI at high biomass – e.g. Sadras and Connor, 1991). However, when the HI is measured at maturity a substantial amount of leaf biomass has already fallen on the ground, adding to soil fertility. When HI was calculated at 50% full-seed stage (i.e. at the peak of standing aboveground biomass), HI tended to decrease for larger biomass production levels (Figure 3 B), indicating a potentially larger contribution to soil fertility by those varieties producing more biomass (and which tend to mature late). At harvest, all seeds were of high quality and there were minimal cases of shrivelled and unusable seeds. However, SB5 and SB20 in Matayos had a significant number of pods that did not form grain (cf. Figures 2 D and F).

Overall, nodulation was better in Matayos, in line with the relatively good soil properties of the host field (cf. Table 2), while nodulation was generally improved by P application in Chakol. The early maturing varieties produced a smaller number of nodules than the intermediate and late maturing ones in Matayos, and did not appear to nodulate in Chakol.

Table 3. Estimation of N-fixation by the screened varieties through the number and colour of present nodules and their yield indicating intensity of nodulation in Chakol and Matayos

Variety		Number. of nodules		Percent of active nodules (pink)		Nodule yield, g m^{-2}	
		Chakol	Matayos	Chakol	Matayos	Chakol	Matayos
SB20	-P	150	835	68	**75**	38	9.8
	+P	276	676	**50**	55	73	7.9
SB17	-P	6	156	100	0	4	6.1
	+P	54	108	0	61	17	6.4
SB15	-P	2	130	100	**74**	3	5.7
	+P	15	115	**60**	78	6	5.1
SB19	-P	160	233	**13**	67	36	3.4
	+P	332	472	0	**57**	63	5.8
SB5	-P	17	690	17	**73**	11	10.8
	+P	192	568	**30**	71	55	8.6
SB3	-P	43	312	26	**50**	8	4.9
	+P	116	172	**21**	0	30	2.5
SB22	-P	0	82	0	21	0	1.2
	+P	0	42	0	0	0	0.8
SB21	-P	0	63	0	0	0	1.1
	+P	0	87	0	0	0	1.5

Participatory Monitoring and Evaluation

In both sites, farmers observed that most of the dual-purpose varieties out-performed the local variety in terms of nodulation (as confirmed in Table 3). There were differences in ranking between sites due to inconsistent performances across sites. Table 4 shows how varieties were ranked, giving only the most critical criteria for each variety identified by farmers at each site.

Table 4: Farmers' assessment and ranking of new soybean varieties in Chakol and Matayos season I, 2004

Soybean	Matayos			Chakol		
Variety	Positive aspects	Negative aspects	**Rank**	Positive aspects	Negative aspects	**Rank**
SB 20	High nodulation ✓ Canopy/biomass ✓ High yield Growth uniformity	× Maturity rate Many empty pods	1	✓ High nodulation Resistance to pests ✓ Canopy/biomass ✓ High yield	High P influence × Maturity rate	1
SB 17	Canopy/biomass Good yield Low P influence	× Maturity rate Growth uniformity	6	Canopy/biomass Resistance to pests High yield	Poor nodulation × Maturity rate	6
SB 15	✓ Canopy/biomass Good nodulation Good yield	× Maturity rate Not so green	3	Canopy/biomass Good nodulation ✓ High yield	× Maturity rate High P influence	4
SB 19	✓ Low P influence Good nodulation Canopy/biomass ✓ High yield	× Growth uniformity	2	Pest resistance High nodulation Canopy/biomass ✓ High yield	× High P influence	2
SB 5	✓ Canopy/biomass High nodulation Huge seed	× Many empty pods	4	✓ Good yield Huge grain Canopy/biomass Pest resistance	× Growth uniformity Incidences of shattering	5
SB 3	Resistance to pests Maturity rate Huge grain	× Incidences of shattering	7	Maturity rate Huge grain Low P influence	× Growth uniformity	8
SB 22	✓ Maturity rate Huge grain	High P influence × Low yield	8	✓ Early maturity Huge grain	High P influence × Low yield Many empty pods	7
SB 21	✓ Maturity rate Resistance to pests	High P influence × Low yield shattering	4	✓ Early maturity Resistance to pests Low P influence	× Low yield Lighter colour Low biomass	3

✓ = most important criterion. × = most negative criterion.
Biomass = no of leaves, size of leaves and ground cover.
P influence = comparison between +p and –P plots

In the highly depleted soils on the Chakol screening plots, P was observed to be vital for the most preferred varieties, SB20 and SB19. Table 4 shows that the most important criterion in the ranking was quantity grain yield. SB19 was also ranked highly due to perceived low P tolerance compared with SB20. Farmers observed that its leaves spread out while SB20 had leaves and pods evenly spread on the whole plant. Importance of biomass was mostly overshadowed by its concurrence with better grain yield of the preferred varieties. Farmers described as "pleasing to the eye" (*hufuraisha macho*, Swahili) the bushy and greener varieties. "Greener" and "bushy" were seen as good for the soil. Important criteria such as pest and disease resistance, drought resistance, good taste, etc (Kitch, 1998; Snapp and Silim, 2002; Nyende and Delve, 2003) were not analysable, given that only one season was given to this exercise. Yield was expected to be the most obviously important criterion, yet this was not so clear cut in the long run. High yield was only an initial criterion. In actual terms farmers wanted quality seed that did not shrivel, that germinated well, that cooked well, and which stayed viable for long. The screening took place over too brief a period adequately to assess all these factors, and resemblances between seeds of different varieties also caused problems Apart from any benefit in terms of soil fertility, farmers favoured high biomass because it: (i) preserved moisture; (ii) suppressed weeds; and (iii) led to reduction of labour (if a plot was well covered it remained soft and minimised tilling and weeding in the next season); and (iv) prevented seed loss in the lower branches. Lower pods that matured fast were covered from the direct sun, which led to shattering. Irregular shattering on one field would mean staggered harvesting is necessary, which would overload the already strained labour supply.

Farmers observed that grain yield cannot necessarily be predicted on the basis of the number of pods. Farmers were thus not impressed by mere number of pods. Many pods that did not seed were "…like planting legumes that have the value of flowers only" (Dis, Chakol).

Nodulation was taken seriously because legumes were known to have a fertiliser value. Given the past research and extension emphasis on N enhancement, farmers were keen to understand whether varieties on trial were good enough to eliminate the need for fertiliser. Varieties that nodulated more, and did not respond significantly to P addition, were similarly attractive (see Table 3).

Varieties with more active nodules in the low fertility soils of Chakol were perceived to be "stable" in terms of yield fluctuation, if planted without P. SB20 was better at nodulation and had a higher yield. SB19 - particularly in Matayos - was, in farmer's language, "reliable" (*yakutegemewa*, Swahili). This meant assured harvest even when no fertiliser was applied (cf. Mango and Hebinck, 2004).

Rate of maturity was the second most important criterion at the beginning of the screening process, followed by low P influence or reliability. Rate of growth was *initially* seen by women as useful because it could allow them to grow quick maturing vegetables in the middle of a season. PM&E discussions show that a variety such as SB21 could allow relay cropping, especially of vegetables by women, who carry out most of the farming activities in western Kenya. This preference for high rate of maturity could be advantageous as competition with other crops and competition for peak labour demand for harvesting is avoided (cf. Ramakrishnan *et al.,* 2000:330).

Why ranking matrixes were not used

A rating scale or *matrix* was abandoned during a previous ranking exercises because of different weightings among the various criteria. Scores on the same criterion given by different participants varied (cf. Almekinders and Elings, 2001:432). Matrixes are useful in comparisons that involve factors that have been well examined, or are directly comparable and of equivalent significance. Attempts to weight[1] characteristics resulted in ranks that were disputed by participants. A variety ought not to be declared "better" solely because of the numerical aggregation of its qualities, many farmers argued.

Screening for only one season was inadequate to enable farmers to make concrete decisions. Concrete decisions could only be made after protracted and rigorous tests, which would, for instance, introduce inter-seasonal predictability of growth and yield as key criteria. Predictability was always an underlying concern to farmers, and is for instance is a central determinant in the perceived superiority of local varieties of maize over hybrids in the short rains (cf. Mango and Hebinck, 2004). Soybean is relatively unknown, and most of the ranking was based on 'good seasons'. During the screening, farmers were interested in the longer term, and often focused on comparing soybean with common bean, groundnut or cowpea. They were more interested in knowing how soybean itself was valuable before choosing among its varieties. Ranking of varieties was, therefore, not an uncontroversial exercise for farmers themselves. Preferences were contested, and attempts to resolve farmer-led matrices resulted in stalemates or dominance by some participants. While the researcher-driven process following participant consultations yielded superficial consensus, many individual farmers doubted the outcomes in private.

Overlap between farmer conclusions and research findings

There were overlaps in the conclusions farmers drew and the researcher documented findings on screening plots, as follows:

(i) Grain sampling by farmers during growth of the varieties showed that the bigger a variety's seed the lower the seed count per plant.
(ii) Many pods without seed was an indicator of high biomass-grain ratio.
(iii) Plants with active nodules improve soil physical characteristics (resulting in e.g. darker soils, "softened soils", improved humus). This appears consistent with scientific criteria such as soil organic C increment and N_2 fixation, and also presence of a strong root system.
(iv) Whenever P influence was high, farmers concluded that a variety would fluctuate significantly under poor management or soils.
(v) "Greener" and "bushy" characteristics are good for soil fertility; varieties with these characteristics had more active nodules, more total biomass, and even more grain yield.
(vi) Farmer predictions of ranks for grain yields before harvesting were surprisingly accurate. Farmers made their preferences well before measuring and extrapolating of results was done. Indeed, extrapolation was not liked as a process among farmers, since they preferred a more "visible" yield that could be confirmed by all.

Nodulation observation skills were mastered by regular participants by the end of the screening process and they continued to apply these skills on their farms. This shows that farmers' system of ideas can be verifiably strengthened through scientific procedures. There is need for further research to look into the relationship between soil properties and nodulation. Tables 3 show that SB3, SB5, SB15 and SB20 nodulated better in good soils on -P than +P plots. These varieties nodulated better on +P than –P plots in poorer soils, however. SB19 was unique in this regard, because it nodulated better on –P than +P plots.

Observed flaws of Participatory Monitoring and Evaluation

Collective assessments were analysed and found to have some inherent shortcomings. The most notable were:

a) Lopsided emphases
There was progressive tendency among participants to be attracted to the bushy varieties. More attention was also put on varieties that flowered first. As the season progressed, less emphasis was put on the middle plots of medium maturing SB3 and SB5. Because SB20 remained on the plots for longer it received protracted attention. The middle plots were ranked without equal scrutiny, since farmers' opinion had already begun taking shape after the first month. During focus group discussions, many farmers wished to re-evaluate SB5 after realising that its yields (Fig. 2) and rate of growth were impressive.
b) Continuity problems
Though this process was participatory, many farmers only participated through visiting the plots only few times. Some of their observations were circumstantial influenced by chance circumstances on the day they visited (e.g. after heavy storms). On individual farms, however, farmers engaged in continuous and rigorous observations specifically against the background of their farm-level circumstances and their specific objectives in planting a variety in a given season. They are also sceptical about absent factors. Mere lack of diseases or pests may only be particular to this season, so varieties need constant observation over a longer period to be sure they meet farmer requirements.
c) Participatory miss-outs
Many local farmers did not participate in collective evaluations, but took keen interest in the varieties and plots nevertheless. These farmers usually visited the plots alone, and noted lessons "in their heads". A researcher under constraints of time may miss out on access to this valuable body of information.
d) Variation in observations between sites
Many individual observations were not integrated in collective analyses. There was much more emphasis on agreement, on "averaging" participants reasoning. If one participant had seen something others missed, or was in general more knowledgeable but could not convince others, her/his views were not incorporated in the rankings. This of course may indeed be a general problem of participatory method, where more often than not, consensus or agreement is more convenient and less socially damaging than critical disagreements or stand-offs. The nature of the screening was to expose as many farmers as possible, and so "test" or "expert" farmers could not be prominently involved to make preferences (e.g. Kitch *et al*., 1998:498; Defoer, 2002:62).
(e) Results were site specific and cannot be used to predict widespread adoption
Ranking results cannot be used across sites for promoting varieties. A criterion was at times positive and negative for one variety in different places - e.g. with SB20, P influence was different in Matayos and in Chakol due to differences in soils. Farmers also observed different results in subsequent seasons, making it necessary to engage in protracted screening on central plots. PM&E ranking is highly specific to context, and is dependent on participants' judgements. It would thus be dubious to depend on PM&E ranks to predict adoption for soil fertility improvement.
(f) The influence of seasonal differences
Selection needed more than one season. Seasons in western Kenya can vary considerably. Farmer groups repeated screening exercises in each site with the view to achieve results that would be as informative as possible, yet different seasonal circumstances resulted in varying results and so key criteria such as yield are hard to evaluate. Many farmers therefore planted varieties which ranked low during the PM&E process, such as SB15

and SB17, with a view to test them further. That is, the screening exercise was not conclusive, and farmers were interested in longer-term evaluation.

(g) Screening and promotion may mean same to participants

Many screening sites were established in other villages, but were not evaluated completely. Seed was secretly taken from the plots mainly by regular participants to test them on their farms. Although this interfered with the screening, it was an early success for researchers promoting soybean before the formal declaration of best varieties (cf. Inaizumi *et al*., 1998; Manyong *et al*., 1998; Sanginga *et al*., 1999). It showed interest among local farmers.

Community studies

In-depth studies among 20 households showed that in subsequent seasons, farmers realised new capacities for different varieties on their individual farms. Many seeds were taken from screening plots secretly by participants and other farmers, which partly explains why agronomic data could not be collected from subsequent screening plots. On the individual farms, the different varieties taken from collective plots could not be completely analysed due to mixing and difficulties in identifying some varieties.

Table 5: Frequencies of farmers' responses for planting soybean in the long rains of 2005

Reasons	Chakol (no=40)	Matayos (no=40)
Easier to process	11	9
Intercrop compatibility	30	13
Research efforts	40	40
Soil fertility	19	16
Used as fodder	0	0
Striga suppression	16	29
Source of food	40	40
Emerging/expected markets	40	40
Failure of the common bean	10	15

Source of data: resource farmer interviews, short rains 2005

Evolution of selection criteria

Evolution of selection criteria resulted from the learn-as-you-use tests. During this process farmers discovered that the time differences between harvesting of an early maturing variety such as SB21, and other intercropped species, made it hard to plant subsequent crops. Planting additional crops would mean interfering especially with the intercropped maize crop. The relayed crop after soybean would be trampled during harvesting of maize. Rainfall patterns also did not favour immediate replacement of harvested early maturing varieties. If it rained early, farmers would have to choose between planting maize in the short rains and harvesting the immature soybean. These kinds of considerations, coupled with generally lower yield, low biomass of early maturing varieties, and limited weed suppression, reshaped farmer perceptions. In 2006, pioneer farmers started resorting especially to SB19, while others increasingly accepted SB15, especially for commercial production. This did not replace SB20. Rather, farmers were searching for insurance in relation to less well known varieties. During the learn-as-you-use try-outs, 15 informants inadvertently mixed up seed of the different varieties. As a result, farmers realised that some varieties shattered too early, and their harvesting affected other yet-to-mature varieties. In spite of this, smallholders continued to mix crop varieties and species. This is the established local pattern. Every home-garden on the 80 farms visited had more than two legumes, mixed with other crops. Farmers knew that the risk of nematodes, pest and disease spread etc reduced when intensively planted farms were inter-cropped rather than mono-cropped.

Preference for the local variety (SB21) was generally low, perhaps because soybean farming was not significant in these sites. SB21 did not occupy a strong niche into which new varieties could be inserted. Varieties preferred in Table 5 were mostly being planted as new crops, i.e. SB20, SB19 and SB15 did not replace SB21. In the 2006 planning meetings, all partner groups decided to bulk these three varieties for seed. While this shows some success for the introduction of soybean itself (as a species), i.e. it was "selected by local farmers as appropriate" (cf. IIRR, 1998), there was need to keep the selection process on-going for longer than one season for success to be assured. In subsequent seasons, preferred varieties were subjected to highly varying farm-level conditions such as (i) different soil types, (ii) low or no input application, (iii) infertile soils, (iv) fertility hotspots, etc, and results were informally shared among farmers. In 2006, more than five (SB5, SB15, SB19, SB20,SB21 and an "unknown" type) out of the eight screened varieties were identified on 80 farms in the study sites. This spontaneous screening resulted in new criteria for selection, as reported in focus group discussions:

(i) The ability to resist strong winds

Strong winds accompanying rains experienced in the long rains of 2005 became a test for the new varieties. Although all varieties were affected, three (especially SB20 and SB15) recovered completely. According to 20 (out of 80) farmers, the bushy nature and stronger roots of SB20 protected it against loss of flowers and being uprooted by run-off.

(ii) Susceptibility to pod shattering

While screening on their farms, 12 farmers observed that many early maturing varieties were prone to shattering. This susceptibility however, was based on observation; there is no measured agronomic data on total number of pods that shattered/ did not shatter.

(iii) New uses for soybean

In 2006, new uses for soybean leaves were observed during participant observation. Nine farmers tried leaves as salad[5], or used it as fodder. In all the 20 households where participant observation was done a correlation between higher biomass and grain yield was consistently noted by farmers. Informants concluded that more leaves protected flowers and pods, and may have other 'hidden' advantages.

(iv) Resistance to rust

Continuous cropping of only one variety SB20 led to rust (*Phakopsora pachyrhizi*) problems and symptoms of K deficiency being noted on 10 farms. These farmers in 2006 planted more SB19 and SB15, observed to be greener and 'cleaner'.

v) Striga suppression

During focus group discussions, farmers specifically observed that SB20 might be better in controlling *Striga* due to its strong root system and bushy nature.

[5] Tender leaves, boiled like cowpea. This was not sustained or widely tried.

vi) Processing

SB20 seed was found to dry slowly, was too hairy and dusty during threshing, and caused cough, according to 9 farmers. It involved repeated drying in the sun, compared to SB19, and would therefore increase labour demands.

Factors underlying spontaneous selection of varieties

Because soybean was relatively new, optimism about it was mainly built on research reassurances, and later on local systems of ideas guiding farmers to assign latent functions to crops. As shown in Table 5, farmers perceived soybean as a *Striga* suppressant. *Striga* is an important constraint on cereal production in the local farming system. Soybean was consumed mainly as grain, but a few farmers were beginning to burn leaves for 'salt', a common traditional use of *Phaseolus vulgaris*. Soybean was more importantly seen to present some promise of income, and it would be considered convenient if it substituted for the common bean that is easy to process and sell on the local produce market.

Emerging constraints

Table 6: varieties grown in two sites during the long rains of 2005 and 2006, and P application *

Selected Site	Farms visited	Average area under soybean (ha)	Common varieties		Source of seed	% who applied P fertiliser
2006 Matayos, Chakol	80	0.13	SB20	57%	a) TSBF 60%	50%
			SB19	20%	b) Group member 14%	
			SB15	19%	c) Other (friends/relatives) 26%	
			Unknown	10%		
			Local	4%		
2005 Matayos, Chakol	80	0.11	SB20	70%	a) TSBF 66%	57% (higher due to fertiliser promotion)
			Unknown	20%	b) Group member 2%	
			Local	7%	c) Other (friends/relatives) 32%	
			SB15	9%		

Source of data: Resource Farmer interviews and researcher

Notes:

i) Farmers with more than two acres of soybean were not included.

ii) The total tally for those with different varieties is not 100% because there were many farmers who had more than one variety.

iii) The number of *unknown* was high mainly because some farmers had bought seed from neighbours or the market, or had harvested before we could verify.

**Mineral fertilisers included Diammonium Phosphate (DAP: N=18%, P=20%) and the commercial blend Mavuno (N=10%, P=11, K=8, S=4, Ca=8, Mg=4)*

Table 6 offers indications of a weak management pattern for soybean among interviewed farmers. Fifty seven percent of farmers applied some source of P in 2005, at the rate of about 9 kg P ha^{-1} or less was far below that (of 50 kg P ha^{-1}) used on the screening plots. In the short rains, fewer farmers used any fertiliser. Fertiliser use in western Kenya correlates with wealth status, and also reflects how a crop is perceived. If seen as promising, and if especially grown with the view to be sold, then more fertiliser use would be used, like other cash crops in the area. Seed or germplasm reliability problems were also beginning to emerge. Many of the seed produced were of low quality and farmers planting the new varieties were getting poorer yields as a result. Most of the

participants in the Folk Ecology Project remembered that soybean was a fertiliser. Indeed there are long-held perceptions of legumes – that they improve soil fertility, and that is how researchers promoted them (cf. Pretty, 1995:114-116). But with no P application in depleted soils, and due to removal of residues, there have been no significant N or C built-up. A majority (70%) of respondents harvested about 500-1200 kg ha^{-1}. Richer farmers (not included in the analyses) got more (up to about 2000 kg $ha^{-1)}$. The farms that most needed P addition were the ones, according to farmers, that had "soul breaking" low yields. Adoption among poorer farmers therefore only led to limited amounts of biomass being incorporated, or was mainly intended to conserve soil moisture or prevent weeds. Most of those who worked on the plots were women who faced severe labour constraints: as a result residue was not returned to the farms, they did not carry out their own protracted screening and they did not consistently participate in the collective evaluations. Participatory experimentation needs to be targeted better on women.
The richer farmers, who planted on average two acres of soybean fertilised their plots well and got better yield. In Matayos for instance, one entrepreneurial farmer harvested 30 (90 kg) bags of soybean in 2006 long rains. He sold his harvest to research projects in the area at KSh.75 kg^{-1} immediately after harvest. No smallholder group of any membership collected an equal amount of soybean during that season, and fetched on average KSh.45 kg^{-1}. In Chakol, three farmers harvested 21 (90 kg) bags and sold it to a UN project at KSh.75 kg^{-1} while a group of thirty smallholders only managed to raise 18 (90 kg) bags.

Summary and conclusions

Promiscuity of the new varieties was not adequate to guarantee N_2 fixation, and screening results show poor nodule count, especially in heavily depleted soils. Because the problem of soil fertility decline is not a farmer priority, establishing soybean as a contribution to soil fertility requires assessment, with farmers, of other manifest and latent benefits. The present study describes an exercise of this sort in which it is shown that in a well-designed participatory experiment farmers can acquire useful knowledge concerning a relatively unfamiliar N_2-fixing crop, soybean. Data analysed suggest that preferred varieties will only be selected for longer term planting if they are strong in manifest roles, and if they offer latent functions, especially because soybean itself has fewer known applications than other grain legume crops among western Kenyan smallholders. One of the key indicators for the new varieties' longer term acceptance is whether women will plant it in their highly valued and crowded gardens. According to farmers, future screening exercises should involve compatibility of soybean when intercropped with other crops such as maize, and be done on relatively larger plots, to aid comparisons. Also, research on *germplasm* development should target low-P-tolerance. Further efforts are also needed to understand other criteria such as taste (e.g. Worede, 1998:21; TSBF, 2004; LRNP, 2004; Republic of Kenya, 2005; Chianu *et al*., 2006:8).

This study illustrates the need for methodological development to strengthen participatory selection of varieties. The evaluation cycle, for farmers, is longer than the period normally available for supervised agronomic and PM&E processes. Although some criteria, especially biomass and nodule activity were prominent, they were mentioned in the main due to research influence. This confirms that soil fertility improvement was neither a prominent goal at the farm-level. Nor, it should be remarked, is it guaranteed even when soybean is adopted. It is possible to embed promiscuous soybean varieties in the local farming systems for soil fertility management. Nevertheless, more co-research efforts are needed to reveal – both to farmers and researchers - the extent to which these dual-purpose soybean varieties actually provide benefits to the soils under smallholder conditions in western Kenya.

CHAPTER 4

Farmers' evaluation of biomass transfer technologies and the concept of organic resource quality: integrating knowledge brands for soil fertility management

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Chapter 4

Farmers' evaluation of biomass transfer technologies and the concept of organic resource quality: integrating knowledge brands for soil fertility management

Abstract

The research concept of organic resource quality (ORQ) for soil fertility improvement, referring to the performance of different locally available resources when used as soil amendments, was shared with farmers through participatory demonstrations in four sites of western Kenya. Local farmers evaluated different treatments of selected organic resource materials, namely *Tithonia diversifolia*, *Calliandra calothyrsus*, maize stover and farmyard manure (a common farmer practice), applied to the soil in plots in which maize (*Zea mays*) was grown. Participant observation, in-depth interviews and focus group discussions indicated that farmer knowledge was influenced in a way that resulted in changes in farm-level practices. These changes consisted of varying rates and styles of application of demonstrated organic resource treatments. Besides labour constraints, availability of organic resources, land and capital, and farmers' experiences and cultural constructs were the basis for interpretation and application of the ORQ concept. For instance, *Tithonia* was perceived as a "hot resource" that could be added to composts to increase the "speed of cooking". *Calliandra* was perceived as fodder, preferably fed to cows, which would in turn provide valuable farmyard manure, instead of applying it directly to the soil as demonstrated through the biomass transfer system. Such "ordinary" usage, long-held perceptions and perceived *inconveniences,* reflecting mainly labour constraints and poor economic returns, resulted in limited application of the ORQ concept for soil fertility improvement among local farmers. It is therefore suggested that relevance of the ORQ concept be enhanced through refocusing research through paying close attention to farmer knowledge and motivations, and makes sense in terms of their own rules for soil fertility management and experimentation.

Keywords: organic resources, local farmers' knowledge, perceptions

Introduction

The quality of organic resources for use in soil fertility amendment is a function of nutrient content and type and proportions of carbon compounds present in the organic material (Palm *et al.*, 2001; Cadisch and Giller, 1997). Organic materials differ significantly in their ability to provide nutrients to the soil and crop, as affected by the relative proportions of lignin, metabolic carbohydrates, cellulose, and the presence of modifiers such as polyphenols, determining the rates of decomposition and nutrient release (Mafongoya *et al.*, 1998). Community-level studies in western Kenya showed that farmers associated fertility of the soil with the presence of some of the materials researchers classified as good quality soil amendments, e.g. *Tithonia diversifolia* (Misiko, 2002). Farmers often used the rate of decay and colour of fresh and decomposed resources as quality indicators, having assessed resource quality in terms of crop performance on spots where certain plants grew previously, or where residues from these plants were left to decompose. In short, farmers and researchers are in agreement about some of the basic materials for soil fertility enhancement.
Previous studies have shown the potential for applying the concept of organic resource quality (ORQ) for soil fertility management to both research station plots and farmers' fields (Wanjau *et al*., undated; ICRAF, 2006; Pali *et al*., 2004; Sanchez, 2002). Since farmers and soil researchers agree about materials we might expect farmers to share the concept of ORQ. This is true to some extent. But it would appear that the farmer concept of ORQ is somewhat wider than the concept understood by scientists, encompassing more than perceived nutrient composition and/or rate of decay of a certain resource. For example, farmers distinguish between the effects of eucalyptus or guava roots (which they hold to be indicators of poor soil fertility) and those of local leguminous cover plants and soil fertility indicators such as *Calliandra callothyrsus*. When cultivating an area where eucalyptus trees had previously been grown, many farmers removed dead roots prior to planting, as they were seen as "bad for soil health", whereas the roots of local leguminous plants were said to "soften" the soil, increase the number of earthworms, improve water retention capacity, and thus to enhance fertility and soil structure. After slashing foot paths, the leaves of indigenous fertility plants were often incorporated into compost, or deposited on the fields. In short, farmers had a definite concept of ORQ, but conceived it to work somewhat differently from accounts published in scientific literature. Clarifying the degree of overlap (or convergence) between farmer and researcher ORQ concepts might be a route to effective use of available materials and farmer knowledge.

Different local strategies for nutrient management practiced by farmers have been observed in western Kenya. For example, some farmers prune leafy hedges once or twice a year to limit competition by hedges and crops over nutrient and sunlight; the prunings are composted, and part left in the fields or put in strips and incorporated at weeding or during ploughing, especially where the material is known to decay fast (Misiko, 2002). Within the study sites of western Kenya there are many different types of organic materials that can be used as soil amendments, especially on hedges, roadsides, or even on few bushy fallows. Prunings from these hedges can potentially be applied as green manures for soil fertility improvement. Shrubs or trees commonly found in hedges or as bushes at these sites include *Senna spectabilis*, *Markhamia lutea*, *Lantana camara*, *Tithonia diversifolia*, *Euphorbia tirucalli*, and *Acanthus pubescens*. However, only few farmers use such prunings as soil amendments (Carter *et al*., 1998).

The use of organic materials applied to the soil, usually freshly cut green leaves of locally available or purposely grown trees and shrubs for mulching or incorporation into the soil before planting, is known as biomass transfer (ICRAF, 2006). Researchers have developed biomass transfer technologies as a way of applying the resource quality concept. This technology has been largely promoted among farmers in western Kenya as an alternative to the use of mineral fertilisers. However, the *in situ* production of high quality resources such as legume trees (e.g. *Calliandra*) or the use of naturally growing shrubs (e.g. *Tithonia*) for application to the soil through cut-and-carry, are not widely practiced by farmers (Misiko 2002), even though the concept of organic resource quality was launched in the region through research in the 1990s (e.g. Cadisch and Giller, 1997; Gachengo *et al*., 1999).

Several studies have shown that labour supply is a major factor limiting the practice of biomass transfer as a soil fertility management technology, while others have pointed to small farm sizes limiting the extent to which niches can be found to produce the green manures, or limited availability of high quality resources due (in part) to poor land quality (Place *et al*., 2005; Palm *et al.*, 2001). Therefore, the application of the ORQ concept should better be perceived as a component of a larger farm-level integrated soil fertility management approach that includes complementary knowledge and technologies (e.g. legumes, mineral fertiliser). Such an approach must try and fit the technology to the user's circumstances. In this regard it is important to consider if and how it might be possible to integrate research knowledge into farmers' understanding, skills and practices.

In 2003, the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT) decided, through the "Folk Ecology" Project (FE) partnering local farmer groups in four sites of western Kenya, to explore farmers' understanding of the resource quality concept through dialogue and participatory experimentation. The concept of ORQ as developed by researchers was demonstrated through several biomass transfer options on farmer identified plots. This involved interactive learning with the goal to enhance the repertoire of local farmers' soil fertility management skills, and to broaden research understanding of local knowledge (Misiko, 2002). This study looks at how that process enhanced farmers' skills, and how the expanded knowledge was subsequently applied at the farm level. The objective was to study how the research concept of organic resource quality was integrated into local farming practices in western Kenya, following an interactive learning process.

Methodology

Overall approach

The present study relied on demonstrations, Participatory Monitoring and Evaluation (PM&E), community studies and simple economic evaluations. Some of the evaluation took place when the activity was still running, or soon after. This may result in misjudgement of adoption, since farmers are still 'supported' by an outside project. This study was not interested in adoption as such, but rather in *how* the sampled farmers were applying knowledge on ORQ for soil fertility management after the participatory knowledge-sharing process.

Study sites

Participating farmers originated from several villages of Chakol Division, Teso District; Butula and Matayos Divisions, Busia District; and Emuhaya Division, Vihiga District, all in western Kenya. The sites were purposively selected to follow up the Folk Ecology (FE) participatory initiative implemented there. The main demographic and biophysical characteristics of these locations are presented in Table 1. Emuhaya has a higher population density than the other sites. The population density of Emuhaya was estimated to be 1500 persons/km^2 in 2001. In 1999 Butula had 389 persons/km^2, Chakol had 393 persons/km^2 and Matayos had 318 persons/km^2 (Republic of Kenya, 2001). Livelihoods in all these communities are generally similar, apart from some cultural and linguistic differences. Chakol is predominantly inhabited by speakers of Ateso (a *Nilotic* language) while the other communities were mainly inhabited by Luyia speakers (a *Bantu* language). Language was an important variable in this study, since it affects understanding of ORQ terminology and the underlying local logic. All sites had active social groups outside the family, mainly clubs and associations operating informally at village level with wide range of goals, including agriculture.

Table 1: Main biophysical characteristics of the study sites

Site	Altitude (m.a.s.l.) (sd)	Rainfall* (mm yr-1)	Coordinates (experimental sites)	Topography	Dominant soil types
Chakol	1155	1270 – 1600	Lat. 00º 57' 99.8" N Long. 034º 19' 00.7" E	Hilly	Dystric and humic Cambisols
Butula	1310	1270 – 1790	Lat. 00º 31' 39.4"N Long. 034º 27' 46.0" E	Gently slopes between 2 and 8%	Chromic and orthic Acrisols and rhodic Ferralsols, partly petroferric phases and dystric phases, with dystric Nitisols
Matayos	1214	1020 – 1270	Lat. 00º 34' 34.3"N Long. 034º 16' 04.3" E	Hilly	Ferralic Cambisols, lithic or petroferric phase and Lithosols (rock outcrops)
Emuhaya	1555	1700 - 2000	Lat. 00º 07' 65.5"N Long. 034º 66' 06.9"E	Slopes between 5 and 16%	Ferralo-orthic Acrisols and Dystro-mollic Ferralsols

*Bimodal distribution (i.e. first and second rain seasons)

Source: FURP (1987); Republic of Kenya (1997); Study data (sd) of experimental farms

Common crops include maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.) cassava (*Manihot esculenta* Crantz), sorghum (*Sorghum bicolor* (L.) Moench), sweet potato (*Ipomoea batatas* (L.) Poir.), cowpea (*Vigna unguiculata* (L.) Walp.), finger millet (*Eleusine coracana* (L.) Gaertn. ssp. *africana*), green gram (*Vigna radiata* L. R. Wilczek), sim sim (*Sesamum indicum* (L.), sugar cane (*Saccharum officinarum* L.), banana (*Musa* spp. L.), coffee (*Coffea* spp.), avocado (*Persea americana*), many species of vegetables, mango (*Mangifera indica* L.), cotton (*Gossypium hirsutum* L.), tobacco (*Nicotiana tabacum* L.) (Busia and Teso Districts), and tea (*Camellia sinensis* (L.) Kuntze) (Vihiga) (Tittonell *et al*., 2005; Republic of Kenya, 1997; Republic of Kenya, 1997; Acland, 1971). Common livestock include poultry, cattle, indigenous goats and sheep (Republic of Kenya, 1997).

ORQ demonstration plots

Demonstrations plots were set up and maintained for one year over two farming seasons (the long and the short rains of 2003) on four farms identified by farmers at each of the study sites (no replications), in which the organic resources *Tithonia*, *Calliandra* and maize stover were used as soil amendments (i.e. biomass transfer technologies) and compared with farm yard manure (FYM) applications. FYM is a common farmer practice, because of its availability and acceptance in the area. These resources were recognised as possessing quality parameters according to the findings and recommendations of Giller (2000) and Palm *et al.,* (2001) (Figure 1).

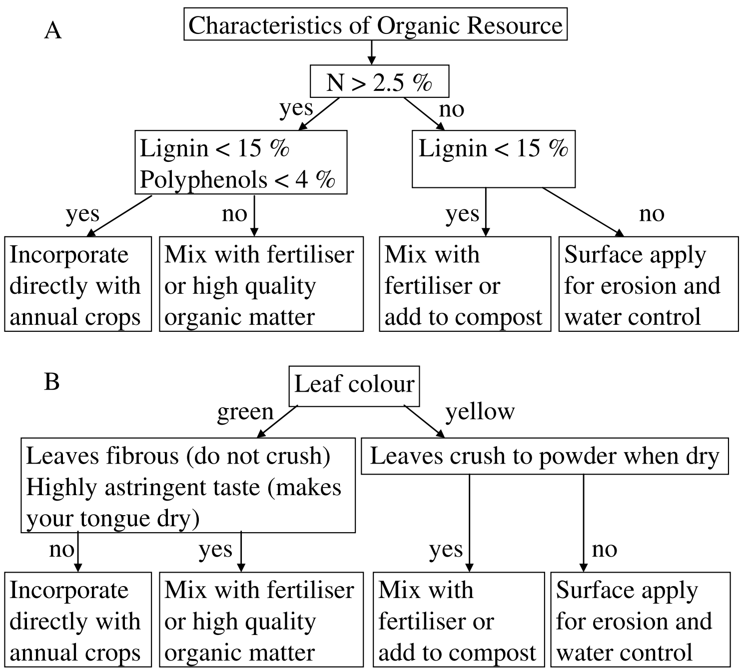

Figure 1. a) A decision tree to assist management of organic resources in agriculture (from Palm *et al*., 2001) and b) A 'farmer-friendly' version of the decision tree (Giller, 2000).

Locally available organic materials were selected by researchers on the basis of their quality (referring to their rate of decay and N release), and corresponding in Figure 1 to three classes of material that must be: (a) incorporated directly with annual crops – i.e. *Tithonia*, (b) mixed with fertiliser or added to compost – i.e. *Calliandra*, and (c) mixed with fertiliser or added to compost – i.e. maize stover. Materials were collected, weighed and incorporated into demonstration plots. The work was done with participating farmer groups. Treatments consisted of:

(i) Control;

(ii) Organic resource;

(iii) Organic resource + P;

(iv) Organic resource + P + N;

(v) P + N.

The organic resources were applied at a rate of 5 t ha^{-1} (fresh weight) on demonstration plots of 6 m × 6 m. The rates of application of mineral fertiliser were 60 kg P ha^{-1} (TSP) and 30 kg N ha^{-1} (Urea). The test crop was maize (HB 512). All sites planted in season I were planted on April 2-5, 2003 and harvested on August 11-14, 2003, i.e. one day per site. Demonstrations were hosted by members of participating farmer groups. Nine willing groups; four farmer field schools and five agricultural groups were selected from lists constructed at the beginning of the 'Folk Ecology' Project (cf. Misiko, 2001). Membership of these groups was diverse (i.e. gender and age), but originated mainly from the study sites. Farm sites were independently selected by farmers on the basis of: proximity to their homes; social acceptability of the host farmer; and representative soils for each site based on participants' local knowledge. Composite samples of each of the plots used for demonstration were taken, air dried, ground and sieved through 2 mm and analysed for soil organic C, total N, extractable P and K, and pH following standard methods for tropical soils (Anderson and Ingram, 1993). Analytical results are given in Table 2 for three of the four sites; reference soil data for Emuhaya were derived from secondary sources and not used in the analysis of the relationship between soil quality and crop response.

Table 2: Average soil properties for the different plots (n = 15) sampled at each demonstration site. Values between brackets indicate standard deviation

Site	Soil organic C (g kg^{-1})		Total soil N (g kg^{-1})		Extractable P (mg kg^{-1})		Exchangeable K (cmol$_{(+)}$ kg^{-1})		pH (water 1:2.5)	
Chakol	6.4	(0.7)	0.56	(0.07)	1.5	(0.6)	0.15	(0.04)	5.1	(0.2)
Butula	7.4	(1.5)	0.69	(0.14)	4.0	(2.3)	0.21	(0.07)	5.6	(0.2)
Matayos	16.5	(2.3)	1.40	(0.12)	32.1	(12.5)	0.84	(0.13)	6.7	(0.1)
Emuhaya*										
Home field	15.0		1.6		19.8		0.54		6.1	
Poor outfield	9.5		1.0		2.1		0.14		5.3	

*Reference data from Tittonell *et al*., (2005)

Participating farmers managed the demonstration plots throughout the process of the experiment, following current local crop husbandry practices in the region. Net plots of 18 m^2 were harvested jointly by researchers and farmers. Harvested plants were weighed at the plot, and grain and stover sub-samples were taken to be sun-dried at Maseno

Research Station and weighed again to determine dry weights. Farmers collected the stover produced in the experimental plots to feed their livestock, and the plots were neither grazed nor put to other uses between the first and second seasons. The residual fertility of the different treatments was assessed via a second maize crop planted on the same plots on September 4-8, 2003 and harvested on January 13-16, 2006, i.e. during the second season).

Interactive learning process

At the beginning of the interactive learning process the research concept of ORQ, as visualised in Figure 1, was discussed with farmers. Partial participatory monitoring and evaluation (PM&E) was carried out. It was partial because researchers selected three of the four materials tested based on research evidence. Farmers independently selected the experimental plots, however. In farmers own words, they picked plots that were known to be "complicated (*tatanishi*, Swahili) so as to test [the] true efficacy of [the] researcher's concept". Farmers evaluated crop *performance* as a means of gauging quality of these materials when used as manures through biomass transfer technology. Farmers also visited other ORQ demonstrations, organised by farmer field schools and agricultural groups. Participation was not however limited to these farmer field schools and agricultural groups' membership; individual farmers also participated. The participating farmer groups were long-established. Dialogue in group meetings was largely unstructured, but followed a general trend to verify whether or why the demonstrated treatments were understood and valued. The overall objective was to encourage farmers to grasp and debate the scientific concept of ORQ, and therefore to strengthen their knowledge, rather than to change or introduce specific practices. Visits were also made regularly by farmers alone to carry out independent PM&E, i.e. to record observations free from researchers' influence. These visits were particularly useful in the early stages of the process, when many participants were reserved in stating important perceptions. This was an aspect of the local idiom of cultural politeness; farmers may praise research activity even though they do not like it. Farmers managed the demonstrations throughout, participated in regular review meetings under their group leaders, and documented observations. At the end of this process, agronomic results (i.e. yields) were presented to participants for further discussion and assessment.

Before the ranking of treatments, farmers identified key criteria commonly used locally to explain good/poor crop performance. Performance assessed on the basis of these criteria (given under results) was used to infer 'quality' of materials and to carry out a comparative ranking (e.g. Werner 2000). This ranking was qualitative, with certain criteria seen as more important, for instance colour of leaves, size of cobs and size of stalks.

Community studies

Community studies were conducted to assess how farmers were integrating research knowledge on ORQ into their farming practices. Participant observation and in-depth interviews (Frankfort-Nachmias and Nachmias 2005) were conducted among 40 households, 10 from each site. These households were selected because members had participated in the FE initiative and they had “try-out” (*kujaribu, Swahili)* plots related to the demonstrations. Participant observation was useful in gauging *emic* perceptions of the research concept of ORQ in farmers own language, especially in regard to demonstrated amendments, and to follow how farmers integrated new knowledge and local understanding. Sixteen focus group discussions (FGD) and in-depth interviews were used concurrently with participant observation to elicit information on farmer practices/decisions, to verify the PM&E results, and to receive farmer suggestions.

Data analysis

Experimental data (i.e. biophysical data from the demonstration plots) comprising maize grain yield were analysed. Beans yield are neither analysed nor presented because of theft and inadvertent mixing of harvests lots from different treatments by farmers. Data from community (in-depth) studies and PM&E (i.e. farmer accounts and field notes) were categorised into broad classes of practices, reasons and methods used. These categories were continuously refined throughout field research, with farmer feedback dialogue, following the *realistic* evaluation approach (Pawson and Tilley, 1997). Economic assessment was based on pooled yields from all four ORQ demonstrations to calculate gross margins for each of the biomass transfer technologies tested. Calculations were based on prices on local produce markets and costs of production. Variable costs (labour and inputs in Table 3) were calculated and deducted from the value of production (= yield x price of output) to calculate gross margins and infer potential profits, on the basis of average prices for inputs from major stockists in the districts and highest prices of outputs on local markets during the period of study.

Table 3: Basic data used for the economic calculations

Activity	No. of persons	Time/ha (Day = 6-7 hrs)	Amount (KSh)	Notes	Totals
Digging	7	5 days/acre × 2.5	@ 100 per person (PP)		8,750
Planting	5	1 day/acre × 2.5	@ 100 pp	With-fertiliser plots	1,250
	3	1 day/acre × 2.5	@ 100 pp	Without-fertiliser plots	750
Weeding	7	3 days/acre × 2.5	@ 100 pp		5,250
Harvesting & transporting	12	1 day/acre × 2.5	@ 100 pp	Total dependent on harvest	
Drying, threshing & packaging	5	4 days	@ 100 pp	Ten 90kg bags of grain. Total Dependent on harvest	
Materials	FYM (5t/ha)		@ 40	Per 20kg (wheelbarrow)	10,000
	Tithonia, *Calliandra* (5t/ha)		@ 2 per kg	Collection & incorporation (planting not included)	10,000
Storage (sacks)	-		@ 20 per 90kg sack, total dependent on harvest		
Fertiliser	Quantity per ha	60 kg N ha-1	@ 1950	Price for 50kg TSP (source of P)	
		30 kg P ha-1	@ 1800	Price for 45kg Urea (source of N)	
Maize seed		30 kg	@ 125/kg	Maize (hybrid 502)	3,750
Maize produce		90 kg bag	@1350	What farmers sold at	

Source: Farmer group discussions in the four sites.

*Kenya Shillings (KSh.100) per person is average payment without offer of meals.
Grain or seed prices based on highest averages for the four sites. Ksh.2 for material collection is TSBF rates for experiments. Material collection for 5t application usually took 10 people a whole day.

Results

Maize yield response to the different organic resources

In general, greater maize yields were harvested in the long rains from the demonstration plots receiving higher quality organic resources, i.e. *Tithonia* and *Calliandra* (Figure 2 a, c, e, g), which correspond to the categories on the left hand side of the decision trees in Figure 1 (with N contents > 2.5%). Plots amended with these organic resources yielded better without mineral fertilisers than those receiving manure in all sites, except Emuhaya, and tended to produce similar yields to plots receiving only mineral fertilisers. *Tithonia* applications led to greater yields than *Calliandra*, when applied alone or in combination with mineral fertilisers. Such differences could be explained by the differences in quality of these resources, since higher lignin contents and the presence of reactive polyphenols in *Calliandra* leaves hamper the immediate availability of mineral N, which is then not synchronised with the demand of the crop for N (Giller, 2000). This is a reason why it is recommended to apply this organic resource in combination with mineral fertilisers (cf. Figure 1).

Sole applications of farm yard manure (FYM) and in combination with mineral fertilisers led to greater yields than the control plots only in Emuhaya, where this (common) farmers' practice also led to greater yields than *Tithonia* and *Calliandra* when no fertilisers were applied (Figure 2 a, c, e, g). Soils in Emuhaya are finer (greater in clay content) and more acidic than in the other sites (Table 1), have a greater capacity to fix P (affecting its availability to crops) and have been cropped more intensively due to higher population densities (Tittonell *et al*., 2005). FYM is known to correct soil pH and provide other nutrients in addition to N and P, and improve the physical properties of the soil (albeit after repeated applications over a number of seasons), which may explain its better performance as a soil amendment in the depleted soils of Emuhaya. However, differences in manure quality used in Emuhaya and other sites may also explain the observed differential responses by maize to this soil amendment. While the manure used in Emuhaya came from a research farm with a zero-grazing dairy scheme using Napier grass and high value concentrates as feeds, FYM in the other sites was poorly managed (stored under rain/sun and sourced from local zebu breeds grazed in open rangelands on poor quality grasses). Livestock breeds and feeding management have an important influence on the quality of FYM (Murwira *et al.*, 1995).

Application of maize stover characterised as poor quality (right hand side of the decision trees – Figure 1) led to poorer yields in general, even poorer than the control plots in some cases. Synergies between all organic amendments and mineral fertilisers were also observed, specially in Emuhaya, and secondarily in Chakol and Butula (Figure 2 a, c, e, g), and the plots that received maize stover produced yields similar to the control plots when mineral fertilisers were also applied. In all sites, the application of *Tithonia* in combination with mineral N and P fertilisers produced the greatest yields.

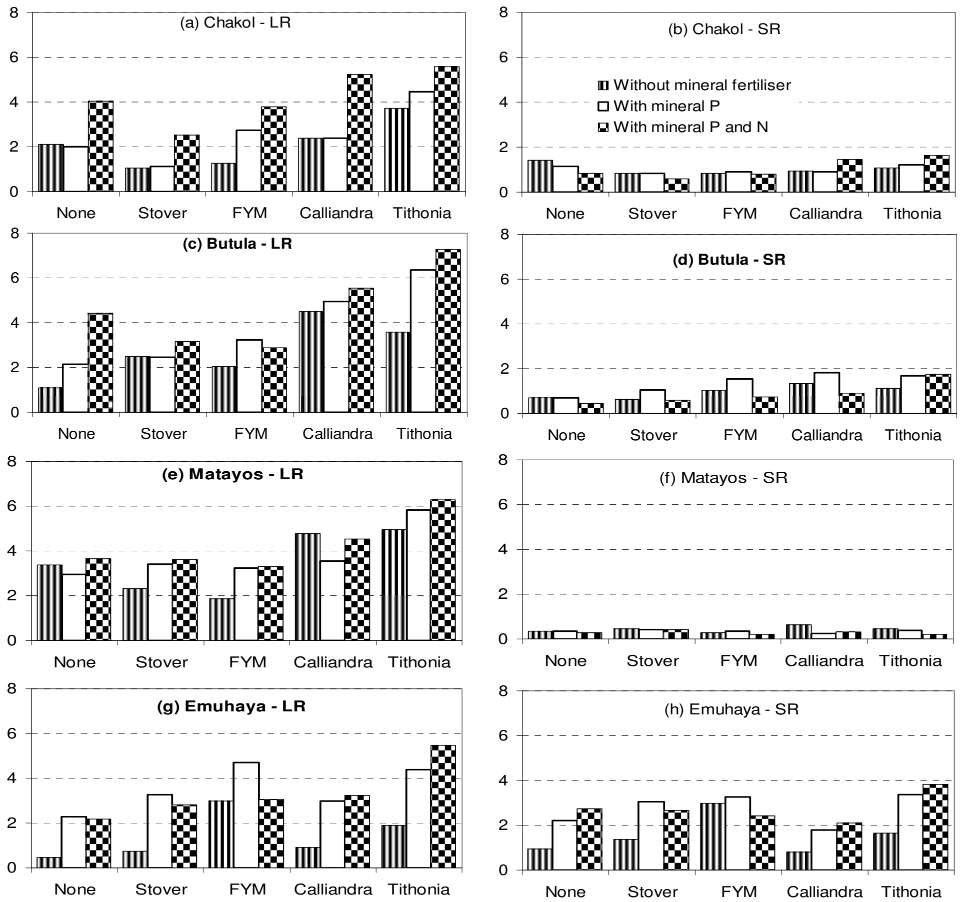

Figure 2. a-h: grain yield of maize (t/ha) as influenced by different treatments of organic resources and mineral N and P.

Maize growing on the residual fertility during the second rains season produced poorer yields in general, although the differences with respect to the long rains were larger in Butula and Matayos, and less in Emuhaya (Figure 2 b, d, f, h). The finer soils of Emuhaya have a larger capacity to store organic C and therefore a greater organic matter content which, together with the higher cation exchange capacity (CEC) provided by the clay particles, contribute to better retention of nutrients (and water) in the soil. There were almost no differences in residual fertility for the short rains between the different organic resources applied in all sites, with only a slightly poorer performance of *Calliandra* in some cases. In Emuhaya, plots receiving mineral N and P fertilisers alone or in combination with different organic resources tended to yield better in the second season. The poor residual fertility observed for the other sites may be the result of their poorer, sandier soils with less capacity to store nutrients (i.e. soil quality directly affects the efficacy of soil fertility amendments).

The effectiveness of the various amendments in relation to soil quality

Soil quality had a strong effect on the performance of the various biomass transfer and fertiliser treatments applied across sites. For instance, regardless of the type and amount of organic and mineral resources applied to maize during the long rains of 2003, yields tended to vary more widely between treatments in soils containing less organic C (Figure 3 a). Soil organic C is used as an overall indicator of soil quality due to its positive influence on soil physico-chemical properties and nutrient availability to crops. Total N and available P were positively correlated with soil C (Figure 3 b and c). This is an expected relationship for C and N, since about 95% of the N in the soil is in the soil organic matter (Giller *et al*., 1997). Previous studies in western Kenya have shown a positive relationship between soil C and available P attributable to different management of different field (Tittonell *et al*., submitted).

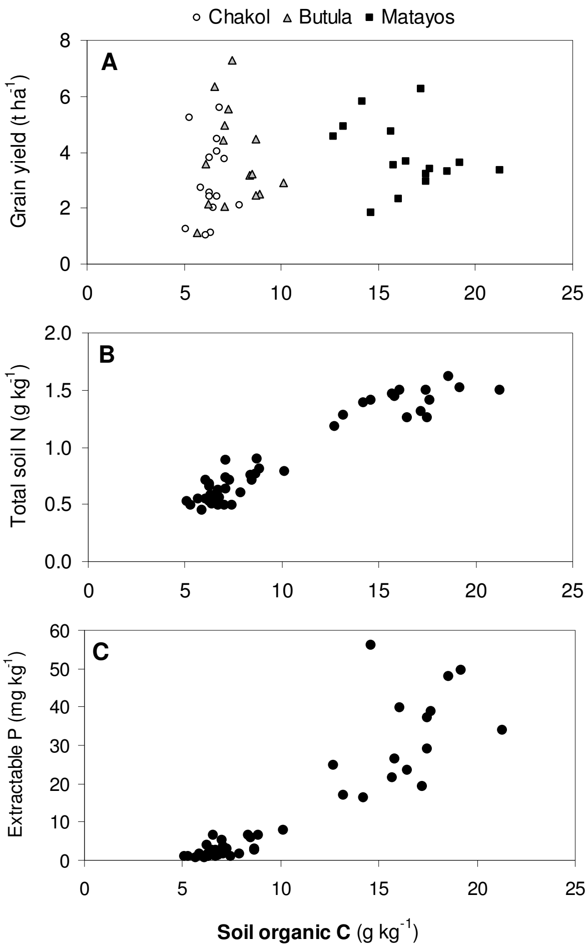

Figure 3. (a) yield (b) total N and (c) available P correlations with soil C

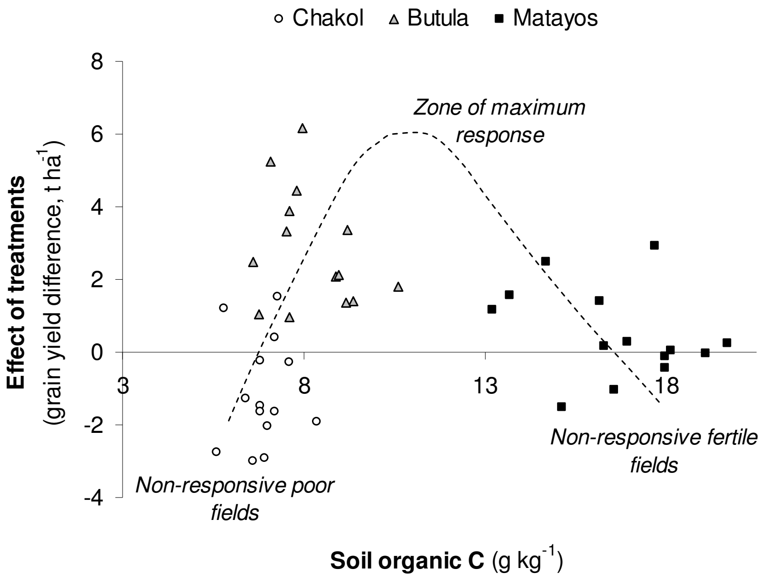

Figure 4. the yield difference between each treatment and the control against soil organic C.

Figure 4 shows the yield difference between each treatment and the control (i.e. no organic matter, no mineral fertiliser) for each site plotted against soil organic C. Both in the poorer soils of Chakol and in the more fertile ones of Matayos a notable number of treatments yielded less than the control. This pattern of response is of course conditioned by the performance of the control plot, and it illustrates the importance of accounting for the background soil fertility when assessing new technologies in the field. The theoretical, hand-drawn dotted line in Figure 4 reflects scientific understanding of how soil quality affects the performance of technological interventions, i.e. as the content of soil organic C (and other surrogate soil properties) increases, the response to nutrient inputs increases up to a maximum beyond which responses to inputs are poor due to good nutrient availability in the soils. This is an idea close to the concept of 'saturated soil fertility' (Janssen and Willigen 2005).

Interactive learning: participatory monitoring & evaluation of treatments

The mid-season assessments in Table 4 were predictions of end results based on (a) *performance* of the crop at knee-height, (b) ditto at flowering, and (c) rate of maturity. Harvest evaluations were mainly based on quantity and quality of maize grain at harvest.

Table 4: Participatory farmer ranks of four organic resource treatments

Treatment	Butula		Chakol		Emuhaya		Matayos	
	Mid-season	Harvest	Mid-season	Harvest	Mid-season	Harvest	Mid-season	Harvest
Tithonia	1	1	1	1	1	1	1	1
Calliandra	2	2	2	2	3	3	2	2
FYM	3	3	3	3	2	2	3	3
Maize stover	5	5	5	4	4	4	5	5
Control	4	4	4	5	5	5	4	4

Key: (a) 1, 2, 3, 4 and 5: are comparative farmer ranks (b) 1 – best; 5 – worst.

Performance reflected the main farmer-generated criteria, and comprised many different dimensions, mainly related to appearance of the maize plant or crop. These criteria were developed over time, reflecting changes at various stages of farmer evaluation. These criteria were contributed by different farmers (not all stressed the same criteria, and no farmer offered all criteria: (a) dark green leaves, (b) big leaves, (c) tall stalks relative to seed type, (d) uniformity of growth in a plot, (e) size of grain (useful in selecting planting seed) and cobs, (f) rate of growth, (g) number of lines of maize on every cob (dependent on variety, (h) number of cobs on every plant, (i) colour of seed, especially in regard to hybrids, where 'pure white' was considered a sign of well fertilised maize, and (j) weight or quantity of maize at harvest. The list of criteria is, in fact, a composite of opinions cited from meeting to meeting, and suggests no fixed or over-riding local cultural scheme for ready assessment of performance. The list itself, and how criteria are seen to be inter-related, is a topic for subsequent investigation and discussion.

The above list of performance criteria indicates that when farmers have an open-ended opportunity to provide assessments a large list of evaluation criteria is quickly elaborated. PM&E (by contrast) was a *deliberate* attempt to make clear-cut inferences, while controlling for common farm-level factors such as undesirable effects of (a) hotspots due to charcoal burning, e.g. on all "none" (control) plots in Matayos, (b) *Striga* on *Calliandra* and *Tithonia* plots in Emuhaya, and (c) termites, especially on stover+P+N in all sites. General trend of PM&E made clear that differences in quality did not clearly convince farmers, given the *inconvenience*[6] of application of the ORQ concept (through biomass transfer). From discussion of the agronomic results, farmers suggested that under 'normal' local circumstances they would get yields commensurate to their effort only when mineral P, and/or N were used and maize planted early.

Common (unanswered) issues or suggestions emerging from PM&E included:

- ✧ A question about the residual effect of different qualities of organic materials, and how this can be determined in "complicated" farms?
- ✧ A suggestion by farmers that ORQ trials be carried out on composts incorporated with equal amounts of *Calliandra*, FYM and *Tithonia,* instead of direct application through biomass transfer.

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[6] Relative low or *uncomplicated* labour demands, low input-based and clear yield increment as a result of use. However, a crop may be labour demanding, but has higher or relatively stable returns

✧ A request that experimentation be repeated with replicates in different soil types for more farmers to learn. There were two exchange visits during this demonstration, and farmers were quick and keen to draw inferences from these visits concerning the influence of soil types and quality on the different treatments.

Analysis of economic returns: an anthropological point of view

Although it is impossible to calculate accurately the actual *future* value of a technology, agronomic data can be used to estimate economic viability under existing smallholder conditions (e.g. Werner 2000). Estimation of economic profitability of different treatments was based on Table 3.

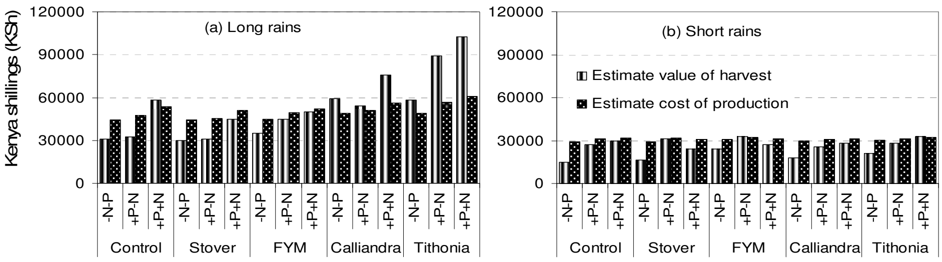

Figure 5. analysis of economic costs and benefits, comparisons of treatments and their residual fertility based on pooled yields from all sites

Values in Figure 5 are based on pooled results from the four locations, which are treated as one recommendation domain.

Assumptions

There are various assumptions made in the estimation process. These assumptions are not always realistic since they assume:

i. Farmers will spend *cash* on labour[7], especially at high markets rates for contract labour (rather than make use of social networks for labour supply).
ii. Recommended rates of inorganic fertiliser, or FYM, will be applied.
iii. Plant on hectares of land or on farms leased hundreds of meters away that requires paid transportation of produce (to be stored at home).
iv. Owners of crops will hoard produce for highest prices. Estimations of economic profitability factored in highest prices of harvests on the local markets during the study period vis-à-vis highest possible costs of all labour and inputs.
v. New sacks will be bought at every harvest, and new seed will be purchased for every planting.
vi. Smallholder farming is driven primarily by pursuit of economic gain.

[7] This estimate does not necessarily represent exchange of cash. The concept of opportunity cost is impossible to accurately apply in such environments where social interdependency is high.

Given these caveats, the estimates show that all *Tithonia* and *Calliandra* plots, and Control+P+N, were profitable in the long rains. In spite of lower costs of production all plots had negative estimates in the short rains. This implies poor residual fertility, which was a disincentive for the various amendments including the high quality resources seen as inconvenient. Although FYM was not profitable, it was seen as *convenient* (see case study). Such perceptions made the ORQ concept less attractive to apply. The application of the ORQ concept did not promise lowered costs of production or increased stability of maize yields. It may not therefore be a sustainable initiative (compare CIMMYT 1988:63).

Community studies

How did farmers' knowledge expand?

Direct observations and focus group discussions showed that farmers were more able to discern which materials to harness for the purpose of immediate or delayed application by use of expanded skills, as shown in Figure 6. These skills guided selection and/or application of resources (i.e. leaves) based on their qualities.

Likely action	**High quality ⇦**	**⇨ Low quality**	**Usual action**
i) Plant crops where it grew e.g. *Tithonia, Vernonia*	Easier to tear ⇦	⇨ Harder to tear	**i)** fodder (maize stover)
ii) Add to cattle manure (*Tithonia*, to increase quantity)	Darker green ⇦	⇨ Light green	ii) Deposit materials on 'traditional' compost (e.g. litter)
iii) use as cattle fodder (*Calliandra*)	Bitter taste ⇦	⇨ Menthol taste	iii) make conservation strips, leave resource in the farm (e.g. prunings, stover)
Expanded practices	**Strengthened local knowledge**		**Derived practices**
iv) Incorporate fresh at planting (selected crops)	Fast decomposition⇦	⇨Slow decomposition	iv) Make cattle "beddings", then (add to) compost
v) Improve compost quality	Soil fertility indicator⇦	⇨low fertility indicator	v) Make mulches, e.g. stover
vi) "heat up" composts (*Tithonia*)	Lesser succulence⇦	⇨Higher succulence	

Figure 6. common cases of integrated ORQ knowledge and application; the new and usual

The concept of ORQ among farmers was intertwined with that of soil fertility indicators. Resources regarded as high quality were also commonly perceived as good indicators and sources of fertility because crops performed better where they once grew. Indicators of low fertility, or plants that naturally grew in infertile soils were regarded as low quality resources. For instance, highly succulent materials such as sisal and euphorbia were known to be unsuitable for composting. Such succulent plants had been observed not to improve soil fertility status. Participating farmers had therefore been applying both research and local knowledge to make 'quality composts'. New knowledge was manipulated on the basis of its "convenience". The "convenience" of applying a technology as seen from an *emic* perspective depends on a set of contextual considerations and perceptions that shape soil fertility management decisions. "Convenience" is a dynamic concept, and has broad influence on how households apply new technologies. It refers to how variably and loosely a concept or technology can be gainfully applied. Convenience relates to such factors as labour, land and capital constraints. For instance, *Tithonia* was picked little by little and incorporated into traditional 'composts[8]' to 'boost' quantity and quality and to speed up decay ('cooking') through increased temperature. A *hot* compost 'cooks' faster. After the FE initiative, participating farmers also knew that hot "composts" comprising resources that easily crush to powder when dry (see Giller, 2000:2) take shorter periods to "cook well". This reduction in time was used to sort materials in traditional composts before application. Additionally, demonstrations aided farmers' understanding of soil nutrient deficiencies and respective symptoms (especially N, P or K).

How was knowledge applied: Case study of Ejakait, Chakol

The household of Ejakait (not the real name) was selected for illustration due to its participation in the learning process and because it seemed representative in terms of organic resource availability and use, i.e. labour and capital constraints that characterise poor households according to wealth ranking studies that preceded this study (cf. Misiko, 2002).

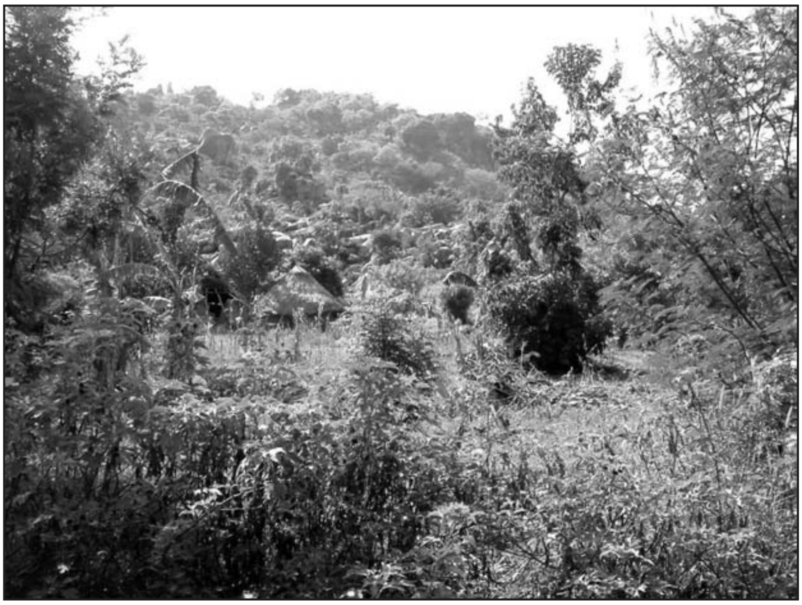

Figure 7. Ejakait, a poor household on the rocky Akites Village farm. Its houses, derelict, represent the most fragile of livelihoods that researchers were striving to improve.
(This farm had all the four resources used on the FE demonstrations: stover, *Calliandra, Tithonia*, and small quantity of FYM [goats + chicken]).

When this farm was photographed on February 20, 2006 it had not yet been ploughed. The household planted late, and neither bought nor applied mineral fertiliser. This household had no cattle, the main source of FYM in western Kenya, and the little

[8] Mostly referred to a collection of decaying materials, swept during cleaning or collected from the homestead. Included in these composts would be highly varied items such as plastic or resources such as sticks that took years to decompose.

available goat and chicken manure was mainly used by Mrs Ejakait on the vegetable garden. Sometimes she could not collect it at all; she did not have adequate labour. Her goats and chicken spent daytime tethered and roaming about, respectively. Like all other informants, members of this household greatly preferred cattle manure.

> "Here, goat manure is used but it is like cattle manure. Goat manure is so little and very hard to collect and fill even a wheelbarrow" (Mrs. Ejakait).

Figure 6 for instance illustrates how farmers created means of increasing the use of cattle manure, which was inadequate. Households with cattle routinely collected manure and "threw" it in the farm or deposited it in one place. This did not involve the *inconvenience* of massive on-one-occasion labour input (Table 3 - e.g. for harvesting, transporting and incorporating) as was the case with *Tithonia* and *Calliandra* on the demonstrations. The latter process required hired labour, which was unaffordable for the Ejakait household. Along with similar households the Ejakaits routinely directed immediate resources to priority problems like re-thatching spoilt roofs. Traditionally, labour groups and family networks are available to assist. But these groups and networks are weakening fast due to formal schooling, immigration, growth of hired labour, disease (notably HIV/AIDS) and abandonment of cultural non-cash payment methods (e.g. for brideservice) and traditional reciprocation such as beer parties.

The Ejakait household maize harvest for both the long and short rains, in 2004 lasted less than eight months. Maize was consumed together with beans, cassava and millet. Locally, cassava, millet and (to some extent) bananas are regarded as fertility-enhancing plants, especially in Chakol, Butula and Matayos. Their peelings were often added to 'compost' or directly deposited in the farm. These were 'practices of convenience'. Besides being adopted as low-input crops, bushy or weedy cassava and banana were still perceived to fertilise the soil.

> "That is how we do it here, …it is straightforward for my people, even my children throw… remains in the farm…. We get better cassava and banana harvests without applying manure and fertiliser, unlike maize" (Mr Ejakaiti).

Given these perceptions and ideas such cases show that there is need for considerable *unlearning* of some widely held, but sometimes spontaneous, categorizations of fertility and infertility enhancing plants. Such local versions of the ORQ concept contributed to practices as summarised in Figure 7; all crops, including the banana plants captured here were not fertilised adequately, notwithstanding availability of *Calliandra* and *Tithonia*.

Local use of Calliandra did not change

The *Calliandra* on the Ejakait's hedge (Figure 7) was planted more than ten years ago during the Kenya Woodfuel and Agroforestry Project (KWAP). KWAP promoted *Calliandra* as fuelwood. Since this plant was given to the Ejakaits, it has been regenerating itself in their hedge. Besides its use as fuelwood, *Calliandra* seeds were intermittently sold in Chakol and Matayos to local seed vendors; 10 informants used it to prevent soil erosion or to mark boundaries and farming units; 5 informants used it for bee keeping; and 10 farmers used it as fodder for dairy cows (mainly richer farmers). In spite of awareness of soil fertility value and close proximity to the demonstration, the Ejakaits had capital, labour, and land constraints. This household did not harvest *Calliandra* for soil fertility, did not have cattle to use it as fodder, and mainly perceived it as a fuel[9] resource and hedging material to "cover the homestead" etc.

Local relevance of Tithonia for soil fertility management

Tithonia has been growing in western Kenya for almost a century. It was not deliberately (re)planted for soil fertility by local farmers. Focus group discussions showed that it was widely perceived as a: (i) weed; (ii) hedge plant; (iii) medicinal herb; (iv) fuel resource; (v) fuel for tobacco curing (in Chakol). Even after its soil fertility value was made clear through participatory ORQ demonstrations, *Tithonia* as a material for biomass transfer had not carved itself a convincing niche in Emuhaya, Chakol, Butula and Matayos three years later. The Ejakait case for instance shows that *in situ* production of such resources as *Tithonia* specifically for soil fertility would be complicated, given the fragility of local livelihoods in the study sites. Even on the 17/40 farms where fresh *Tithonia* was directly used (i.e. through cut and carry) in 2005, its application was initially on a try-out basis, and later was mostly limited to sporadic application on small plots of 'high-value' crops (Jama *et al.*, 2000:216; ICRAF, 2006; Place *et al.*, 2005). Initial application looked promising due to collective labour and researchers' presence. When the ORQ learning cycle ended in the short rains of 2003 , farmers gave up, or applied it in varying (lower) quantities and ways. The adapted nature of application changed or even reduced the basic relevance of the researchers' ORQ concept, which was partly fashioned for N preservation before application, and also was designed to be synchronous with plant nutrient requirements, i.e. applied materials release nutrients to coincide with crop requirements. Research over a number of years has established the value of nutrient release in amounts similar to and in synchrony with crop nutrient demand (Cadisch and Giller, 1997: 393–399; Gachengo *et al.*, 1999).

Traditional use of maize stover was strengthened

The Ejakait household, was not typical, however, in its failure to use stover. This was regularly used by: (i) 30 informants as fodder, ii) 40 informants as fuel, (iii) 20 informants as cover on terrace tops, or in soil conservation lines or as mulches, (iv) 10 informants as cattle "bedding" later moved to compost, and (v) 10 informants as an item for cash (i.e. they sold it, especially to wealthier farmers). The Ejakait household did use stover, but as a fuel for cooking. Mr. Ejakait's rich local knowledge, for instance on the role of termites and earthworms in improving soil texture and humus, did not influence him to use stover for these widely practiced purposes listed above. When interviewed, he proposed: "give me a cow, I will feed it and use its manure to do soil fertility management…". The low yield on stover plots on the demonstration served to strengthen local farmers' perceptions of stover as an animal fodder or fuel material.

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[9] Had been cut down for fuel few times. It mainly served as "a homestead cover". Ejakaiti was "part of" the KWAP process. Planting a new variety may as well be symbolic allegiance to a project, which is common in the study sites.

Discussion

Expanding farmer knowledge and skills in the application of the integrated knowledge was not straightforward. Because synergies were seen in the response of crop yields to organic manures and mineral N and P in combination, application of the ORQ concept appeared complicated and thus potentially expensive. This resulted in farmers' perceived *inconvenience.* The perception of *inconvenience* was further complicated by low residual fertility as observed from low harvest (Figure 2). In spite of the link created between farmer and researcher notions of ORQ, the context of application for the farmer and researcher were far apart.

Integrating knowledge: only the beginning

Integrating new ORQ knowledge and farmers' ideas does not readily lead to hybrid knowledge adequate to sustain applications. The problem of soil fertility and productivity is evidently broader and more complex than either party appears ready to entertain. For instance, Table 2 shows how soils were contrastingly different in terms of inherent fertility. Some farms, such as the one hosting the demonstration in Matayos, had unrepresentatively higher soil fertility on main maize plots than the general standard for western Kenya. Yet farmers offered this plot for the demonstration, knowing from previous harvest that there were hidden 'complications' in the plot, in spite of manure and fertiliser use. They were "testing" the experiment, to see if researchers would uncover hidden difficulties (in this case mainly micro-variation in fertility) and to test the reliability of the new technology under these local contexts. As yield results in Fig. 2 indicate, farmers face a number of such "hidden" challenges, such as acid soils, in their quest to improve farm productivity. When their crops fail on such plots, they tend to draw conclusions that involve bad seed, disease and witchcraft, etc., rather than blaming soils as such. Knowing some of these local difficulties, they may choose not to cultivate a certain area, and then inform a researcher they did not cultivate this part because they are "lazy". They prefer to offer an explanation the researcher might believe, rather than enter into open-ended discussions about detailed complications they fear the researcher might not understand or believe. But it is a mistake to assume, too quickly, from lack of explanation that farmers do not know where the problem is. Unlike most other farmers, the farmer hosting the demonstration in Matayos actually normally plants early, applies organic fertilisers and even uses some mineral fertiliser, etc. But he may also prefer to appear not to be "enlightened" more than other farmers to avoid socially awkward conversations he cannot readily control with superiors (including agricultural experts). High variability in local soils makes it impossible to make blanket recommendations of certain amounts of any organic material. It also contributes to negative perceptions on new technologies. Variability is as challenging to the farmer as delayed rains and labour constraints that result in delayed weeding, theft, weeds, pests and poor seed. But even science lacks a language to talk about uncertainty (as opposed to risk). Farmers fear to delve too deeply into open-ended speculations in case they appear presumptuous in the eyes of assumed social superiors.

An anthropology of knowledge application

Bringing together the knowledge of farmers and scientists requires a specific anthropology of knowledge application. One aspect is to close the gap between two styles of experimental thinking. Exact measurement is the basis of this difference. Farmers knew that some processes or plants such as eucalyptus interfered with soil properties and reduced productivity. Nevertheless, farmers do not possess the tools to analyse soils for their nutrient content, so as to see how the nutrients correlate with soil C (e.g. Fig. 3 b and c). There is a gap between the way farmers experiment and draw conclusions, relying mainly upon signs and indicators, and the way scientists incorporate exact measurement into experiments. Farmer experimentation is a useful resource (Richards, 1989), and needs to be understood and strengthened so as to appreciate what motivates the rules of soil fertility management, but perhaps even more to the point farmers need opportunities to understand scientists' experiments, and their strengths and limitations. It is perhaps only when there is mutual appreciation of the two styles that integration in regard to ORQ could be contemplated.

The way in which practical constraints bear down on farmers, but not on researchers, also needs to be fully grasped. The application of the scientific research-based ORQ concept through biomass transfer had an accompanying level of *inconvenience*. Farmers are so focused on inconvenience (in conditions of labour scarcity) that it affects their entire reading of an experimental design. Researchers looked at *Tithonia* as a treatment, measured against a control. But farmers looked at both control and *Tithonia* treatment in terms of convenience. In farmer's terms (Figure 2) the experimental control was more practical than *Tithonia* due to comparative *inconvenience* of cut-and-carry, notwithstanding the differences in economic gains. In other words, a means to enhance soil fertility should not overshadow the main goal among smallholder farmers, which in this case might be summarised as efficient production within their total resource constraints. The meaning of a technology to farmers therefore is rooted in social and practical considerations which affect experimental variables. As observed during participant observation, social aspects of farmer science are often more important than the measured outcome of the experiment. By offering "complicated farms" for demonstrations, farmers are testing the trustworthiness of research itself to grasp and engage with the total situation in which farmers find themselves. Their expectation was that answers would be forthcoming in regard to that total situation, and not in regard only to a narrow subset of problems (such as whether *Tithonia* is an effective biomass enhancement treatment). This is not to imply that the ORQ concept should be abandoned, but that further thought is needed as to how to embed it within the total socio-economic world smallholders encounter in western Kenya.

Application of ORQ concept through cut-and-carry was demanding, and holistic cost-benefit considerations were not positive when compared with technologies that doubled as food, or as fodder and weed suppressants such as grain legumes. Although farmer desire to make economic profits is evident (see also CIMMYT, 1988:4; Cramb, 2000) their perception[10] of losses and gains was not based on economic or agronomic considerations alone. *Tithonia* gave greater yield returns in the long rains (season I), but costs were higher, and the residual fertility in the short rains (season II) did not offer much incentive for ORQ knowledge application and intensive work, including longer hours of labour supervision by richer farmers. Given the anomalies in yield responses resulting from 'hidden' factors, farmers were not prepared to "predict" gains from an approach solely emphasising soil fertility management. Application of the ORQ concept via biomass transfer was also knowledge intensive (cf. Misiko *et al*., 2004). While the ORQ knowledge was seen to have some relevance and application, it simply failed to spread spontaneously (especially among the very fragile livelihoods encountered by households such as the Ejakaitis) Seemingly lacking dynamic linkage, or salience, to other pressing concerns (or making those concerns worse!) the knowledge was noted, but not embraced enthusiastically to the point where it spread of its own volition (Misiko, 2001). In reformulating the ORQ concept for application more attention must now be paid to the key point that farmers' understanding of causality between improved soil fertility management and better yield does not exclude intervening factors. The ORQ was formulated specifically for soil fertility enhancement; yet benefits from its application were subject to many intervening variables such as those suggested by farmers under the PM&E results. Although it enhanced yield, its application also needed alignment of old practices that were perceived as convenient.

> "…burning of stover improves yield. There is indirect quality in all organic materials. You researchers are always trying new ways, and we are always left behind to use old convenient ones…". (Omwami, Matayos)

The meaning of ORQ like any other technology was therefore not merely determined by soil fertility outcome. Rather, it was also based on ways in which concepts of farmer science link ORQ and other pressing concerns such as food needs or labour supply. Although all the 40 informants said burning is bad, 20 of them still burnt matter, not as a direct fertility management strategy, but as a manageable and empirically proven means of improving crop output. That is, the qualitative aspects of ORQ did not present themselves in clear-cut 'usable terms', and as a result farmers' resorted to conservative interpretations. Further, the economic gains estimated during the PM&E were based on extrapolation of demonstration results on a per hectare basis (see also Meinzen-Dick *et al.*, 2004:4-5). Poor households, such as the Ejakait, pay more attention to the gap between what they harvest and what rich households harvest in total more than relative yield increments per unit of land. Where they consider a standardised measure it might make more sense to convey it in terms of productivity per unit of human effort. Figure 2 shows that the synergy of locally-available soil amendments, such as *Tithonia* combined with mineral fertiliser, can be gainful, especially in the shorter term. The challenge is how to make this clearer to poor households, and to provide an enabling environment within which a group like the Ejakait household can invest in soil. The case for soil improvement may seem compelling to the poor only when technologies such as ORQ are linked to poverty alleviation more broadly (Sacred Africa, 2000:6; Pali *et al*., 2004:379; Bationo, 2004).

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[10] Social and cultural meanings of farming are important, besides economic gains.

Conclusions and suggestion

We show that the integration of researcher and farmer versions of the ORQ concept needs methodological improvements to be fully achieved. For instance, there were reality distortions associated with participatory demonstrations, especially availability of pooled labour not easily accessible to poor farmers. The application of this concept at the farm-level faced complications stemming from (i) 'hidden' soil qualities, (ii) poverty, (iii) entrenched local soil fertility dichotomies and perceptions, (iv) marginal returns after application due to limited management, (v) prohibitively large (research recommendation) biomass transfer quantities. These complications resulted in the perceived *inconvenience* of an involved and relatively complicated process, of which knowledge access issues and labour constraints were an important part. End results appeared considerably less meaningful and exciting to farmers than to researchers. Those who depend on fragile agrarian livelihoods in western Kenya, have, in practical terms, short planning horizons with regards to soil fertility management, and any benefits from new ORQ knowledge must not take too long to show real effects. But at the same time ORQ knowledge needs to be coupled to other aspects of poverty alleviation, so that it becomes part of a wider livelihood enhancement package. At present ORQ is seen (by farmers) to be too specialised and limited a concern. There are other (and perhaps more pressing) concerns. If the ORQ concept is to be seen as less marginal and abstract by a majority of poor farmers then it is probably best to begin with knowledge that is clearly shared and practised. In western Kenya this would mean seeking to enhance farmer capacity to experiment upon and improve compost and FYM quality, since these are seen locally as ordinary and accessible resources. Currently biomass transfer using shrubby materials such as *Calliandra* and *Tithonia* is a stretch too far for many of the poorest and labour-stressed farmers of the region.

CHAPTER 5

Strengthening understanding of mineral fertiliser among smallholder farmers in western Kenya

This chapter has been submitted for publication as:

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Chapter 5

Strengthening understanding of mineral fertiliser among smallholder farmers in western Kenya

Abstract

It is widely recognised that mineral fertiliser will need to play an important part in improving agricultural production in western Kenyan farming systems. However, use and disuse of mineral fertilisers is influenced by farmers' understandings, among other factors. We show that farmers' notions were broadly generated by poor or unsteady yield responses when fertilisers are used, association with high cost (especially if recommended rates were to be applied), awareness of alternative technologies, association of certain crops and seasons with fertiliser use, technologies associated with its use such as hybrid maize, problems with accessing available but inappropriately packaged information (or lack of it), long-held beliefs, and historical factors. This study assessed these factors by analysing results from farmer-researcher fertiliser-response demonstrations, farmer notes taken during a participatory monitoring and evaluation process, participant observation and in-depth interviews among 40 households. We identified that fertiliser promotion must be tailored to be a component of existing, albeit imperfect, systems of crop husbandry. In these systems, complex relationships affect fertiliser use response, and hence farmer attitudes. These attitudes cannot be changed by promoting more fertiliser use alone, but require a more basic approach that, for instance, also encourages farmer experimentation and practices to enhance soil properties such as carbon build-up in impoverished local soils. It is concluded that such an approach would improve chances of better yield after fertiliser use and therefore contribute to more sustained use by smallholder farmers.

Key words: Fertiliser response, demonstrations, farmer knowledge

Introduction

For mineral fertilisers to be used effectively there is need to improve the somewhat negative perceptions farmers have of their effectiveness, resulting from a number of factors, including disparate crop responses under smallholder conditions. Disparate responses can be targeted through research focused on recognizing within-farm soil variability, with the aim to guide better potential management options involving mineral fertiliser (Vanlauwe *et al*., 2006). Scenario analysis, using a long-term, farm-scale modeling framework, has been proposed to assist design an efficient nutrient use and soil fertility management (Giller *et al*., 2006). In addition to variability in farm-level response, mineral fertilisers often have little effect on smallholder farming due to poor agronomic practices, e.g. poor seedbed preparation, narrow spacing, limited use of improved genotypes, delay in planting and incorrect fertiliser placement, or weed and pest problems (Tittonell *et al*., 2006). Whilst some of these problems may result from lack of knowledge, constraints of time and labour play an important role. These often lead to poor information on the use of fertilisers; and from several constraints that farmers face. Such constraints include poor distribution infrastructure, leading to limited availability and high costs in rural areas, and a discouraging policy environment (e.g. abandonment of fertiliser subsidies since the 1990s). Infrastructure and accessibility problems have been identified by several institutions and are being tackled through participatory approaches to enhance innovative partnerships (e.g. CABI, 2003; Mubiru *et al.*, 2004). Poverty, or cost of fertiliser as a major deterrent to increased fertiliser application is widely cited (e.g. Grandin, 1988; Crowley and Appendini, 1999; Place *et al.*, 2003). Low investment in fertilisers often results from lack of cash at planting due to competing demands for other household needs such as food or school fees. This means that even if the fertiliser price is lowered, there may still be a problem with access to cash when needed (Vanlauwe and Giller, 2006). Boosting plant nutrient sources does not necessarily require heavy application of inorganic fertiliser (Buresh and Giller, 1998) and some degree of farmer scepticism concerning rates of recommended application may indeed be well founded. Application of fertiliser is also a question of under what circumstances any amount is efficient. Fertiliser use needs to be efficient, which is not same as application of massive amounts, and scientists may therefore need to recognise farmer constraints beyond those discussed above.

Several constraints determine crop responses when mineral fertilisers are applied, and therefore influence farmer understanding which in turn results in low fertiliser use. This realization has brought soil scientists to the paradigm of Integrated Soil Fertility Management (ISFM) to address the management of tropical soils (Vanlauwe and Giller, 2006). ISFM refers to socially acceptable, sustainable soil management practices that integrate the biological, chemical, physical, social, cultural and economic processes regulating soil fertility (CIAT, 2006). ISFM calls for use of locally available resources, and the use of organic resources and fertilisers in combination, to enhance the efficiency of use of both types of inputs (Vanlauwe *et al*., 2002).

Why is there focus on mineral fertilisers?

ISFM recognises that mineral fertilisers are necessary for regulating soil fertility in depleted soils when organic resources are limited in quality. Fertiliser use in depleted soils is therefore part of the broad objective of integrating soil fertility management practices and resources at the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT), targeting judicious use of organic and mineral fertilisers. To facilitate this, TSBF launched the Strengthening "Folk Ecology" (FE) project in western Kenya, to improve and sustain agricultural productivity through generation of a common understanding between scientists, farmers and other partners about how agro-ecosystems function and can best be managed. This initiative employed interactive learning tools (e.g. demonstrations, focus dialogues, etc) to facilitate the exchange of knowledge and skills between farmers and scientists. One of its specific themes has been to disseminate generic scientific principles rather than empirical prescriptions or technology packages, while aiming to extend farmers' knowledge rather than to change specific farmer practices.

One of the specific expectations was that extending farmers' knowledge would strengthen their understanding of mineral fertilisers, shaped (negatively) through years of limited information and experience with their use. The objective of the present study, therefore, was to document, describe and interpret smallholder ideas about mineral fertilisers by examining results from a participatory learning initiative and community study in western Kenya.

Materials and methods

Study sites

Participating farmers originated from several villages of Emuhaya Division, Vihiga District; Chakol Division, Teso District and Butula and Matayos Divisions, Busia District (all in western Kenya). The sites were purposively selected to follow up TSBF-CIAT research done under the Folk Ecology (FE) participatory learning initiative. However, fertiliser demonstrations were situated only in Emuhaya and Chakol, because farmers in these two sites requested them. The percentage of small-scale households using fertiliser in these sites was about 8% in 2004 (Tegemeo Institute, 2006). However, that percent may correspond to wealth classes in the villages, and does not mean recommendations are followed when applying fertilisers.

The soils of the study villages in Emuhaya are ferralo-orthic Acrisols, on slopes between 5 and 16%, receiving an annual rainfall of between 1800 – 2000 mm, bimodal in distribution (Jaetzold and Schmidt, 1982). The experimental farm was located 1556 m above sea level. In Chakol Division, soils can be generally characterised as dystric and humic Cambisols, with a fairly flat landscape (slopes << 5%), and receiving between 1270-1500 mm of rain annually (*ibid.*). The experimental farm was located 1225 m above sea level. Commonly grown crops in the study sites are maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.) and cassava (*Manihot esculenta* Crantz), sorghum (*Sorghum* *bicolor* (L.) Moench), sweet potato (*Ipomoea batatas* (L.) Poir.), cowpea (*Vigna unguiculata* (L.) Walp.), finger millet (*Eleusine coracana* (L.) Gaertn. ssp. *africana*), sugar cane (*Saccharum officinarum* L.) and bananas (*Musa* spp. L.) (Tittonell *et al*., 2005; Acland, 1971).

Fertiliser response demonstrations

At Chakol and Emuhaya, demonstrations were set up to guide smallholder farmers on the use of mineral N and P fertilisers. The experiments served to analyse crop responses to incremental applications of these nutrients alone or in combination. Previous nutrient allocation research (e.g. Vanlauwe *et al*., 2006) and participatory assessments involving farmers (…, 2001) pointed to P being the most limiting nutrient for crop production in Emuhaya, and to N being the most limiting in Chakol. Considering this, and to avoid a complex and potentially confusing experimental design, the demonstrations consisted of maize plots receiving increasing rates of P in Emuhaya and of N in Chakol. This was then backed up with exchange visits between the sites. Farmers identified host fields on the basis of proximity to their homesteads, the popularity of the host farmer, and the need to ensure that fields selected for the experiments had soils representative for each locality. Composite samples taken from the fields on adjacent demonstration plots were air-dried, ground and sieved through 2 mm and analysed for soil organic C, total N, extractable P and K, and pH following standard methods for tropical soils (Anderson and Ingram, 1993). Soils in Emuhaya had on average: organic C, 12.3 g kg^{-1}; total N, 1.3 g kg^{-1}; extractable P, 5.6 mg kg^{-1}; exchangeable K, 0.34 $cmol_{(+)}$ kg^{-1}; pH, 5.7; whereas soils in Chakol were poorer than those of Emuhaya, having on average: organic C, 4.8 g kg^{-1}; total N, 0.5 g kg^{-1}; extractable P, 2.6 mg kg^{-1}; exchangeable K, 0.18 $cmol_{(+)}$ kg^{-1}; pH, 5.9 (… *et al*., 2007 [unpublished]).

Maize was the test crop planted on 6 m × 6 m plots, spaced at 0.75 × 0.25 m within the plots, during the first and second rainy seasons of 2003.

(a)

0 kg N ha^{-1} (-P)	45 kg N ha^{-1} (-P)	90 kg N ha^{-1} (-P)	135 kg N ha^{-1} (-P)	180 kg N ha^{-1} (-P)
		↕ 1m		
0 kg N ha^{-1} (+P)	45 kg N ha^{-1} (+P)	90 kg N ha^{-1} (+P)	135 kg N ha^{-1} (+P)	180 kg N ha^{-1} (+P)

(b)

0 kg P ha^{-1} (-N)	30 kg P ha^{-1} (-N)	60 kg P ha^{-1} (-N)	90 kg P ha^{-1} (-N)	120 kg P ha^{-1} (-N)
		1m		
0 kg P ha^{-1} (+N)	30 kg P ha^{-1} (+N)	60 kg P ha^{-1} (+N)	90 kg P ha^{-1} (+N)	120 kg P ha^{-1} (+N)

Figure 1: Layout of the demonstration plots in Emuhaya and Chakol Divisions, western Kenya: (a) response to incremental N application rates with and without P (at 60 kg ha^{-1}); (b) response to incremental P application rates, with and without N (at 60 kg ha^{-1})

Fertilisers were broadcast on the experimental plots during the long rainy season, using the following rates and combinations:

> Chakol: N was applied at rates of 0, 45, 90, 135, and 180 kg N ha^{-1}, with and without simultaneous application of 60 kg P ha^{-1}, totalling 10 experimental units (Figure 1a).
>
> Emuhaya: P was applied at rates of 0, 30, 60, 90 and 120 kg P ha^{-1}, with and without simultaneous application of 60 kg N ha^{-1}, totalling 10 experimental units (Figure 1b).

There was a 1 m space between rows with and without fertilisers, and 0.5. m separating plots that received different N or P rates.

There was only a single replicate of each treatment combination, because having many replicate plots per site had proved confusing during a previous participatory monitoring and evaluation (PM&E) exercise conducted in 2002, and because these were not the only trials present on the experimental farms (… *et al.*, 2003 [unpublished]). It was not easy to get sufficiently large areas of adequate land protected from theft or grazing and easily accessible to all farmers. Maize was planted on the two demonstrations on April 3, 2003, and harvested on August 13, 2003. Yields for harvested plots were weighed with farmers present at the plots, and then taken to the TSBF laboratories for oven-drying and weighing. Maize grain yields were assessed jointly with farmers, as part of the participatory monitoring and evaluation process. Possible causes of fertiliser responses were identified and analysed together with farmers.

The residual fertility on plots where response to N and P had been tested was evaluated on maize without fertilisers in the second season (planted September 10, 2003 and harvested on January 14, 2004). Unfortunately, although the participating farmers had the opportunity to follow the progress of the complete trial from planting to physiological maturity of the maize, biophysical data (i.e. final dry matter yields) could not be collected from the residual fertility plots at Chakol due to premature harvesting by unknown persons.

Participatory Monitoring and Evaluation (PM&E)

Participatory monitoring and evaluation (PM&E) is used here to refer to the participation by willing farmers associated with the FE initiative in activity as follows:

(i) recognising fertiliser as an important issue, to select jointly with researchers a hands-on tool for interactive learning;
(ii) to be wholly responsible for deciding on the location of demonstrations – including (inter alia) selection of heavily depleted sites, infested with *Striga.* Farmers described the status of these heavily depleted farms as "complicated" (*tatanishi*, Swahili);
(iii) to participate in design and set up of, and to wholly manage (including harvest), demonstration plots;
(iv) to decide, independently, which criteria should be used to assess demonstrations; and
(v) to take part in collection and analysis of information and generate suggestions.

Researchers from TSBF and the Kenyan Ministry of Agriculture interacted with farmers over the different treatments demonstrated during the 2003 cropping seasons. This dialogue was largely unstructured, but aimed to verify whether the crop responses to different rates of mineral fertiliser were "as expected". Visits to experimental sites were also paid regularly by farmers on their own initiative to carry out independent monitoring and evaluation, and (in farmer language) to record observations free from researcher influence. Notes from these meetings were usually shared and analysed by farmers with the researcher in open forum, or in focus group discussions. There were two exchange visits, arranged by farmers and facilitated by TSBF to aid exchange of knowledge and experiences between farmers in Emuhaya and Chakol, and farmers from Butula and Matayos also participating in the Folk Ecology Project. These exchanges were usually recorded on audio tapes, and the content analysed for trends or patterns.

Community Studies

Forty households, ten from each site were purposively sampled because they had 'try-outs' related to the fertiliser demonstrations, and members had also participated in exchange visits. Participant observation was used in these cases to learn more about farmer expertise as applied to try-outs and everyday practice. The research was here interested in *emic* perspectives (i.e. culturally shaped understandings) on mineral fertiliser. As a tool, participant observation works best in long-term enquiries, and is best suited to in-depth understanding of processes on a few farms. Focus group discussions and in-depth interviews were focused on four main themes: (a) what the farmer learnt from the demonstration; (b) how fertiliser is defined; (c) selection of fertilisers; and (d) fertiliser use. Narratives and actual practices were documented as part of the in-depth data collection on fertiliser beliefs and practices. Analyses of data from focus group discussions were done with farmers. Interview guides were used to generate in-depth data according to categories that were content-analysed with reference to participant observation data sets. Frequency counts and comparisons were carried out on all data from informants.

Data from a survey that sought to understand management of soil among various wealth classes in Vihiga has also been drawn into the analysis to illustrate fertiliser usage further. This survey relied on stratified sampling to ensure a proportionately representative sample of 99 farmers. Sample strata were obtained from household lists ranked according to 3 local wealth classes.

Results and discussions

The demonstration plots at Emuhaya revealed that the application of N or P alone was insufficient to enhance yield of maize during the long rains.

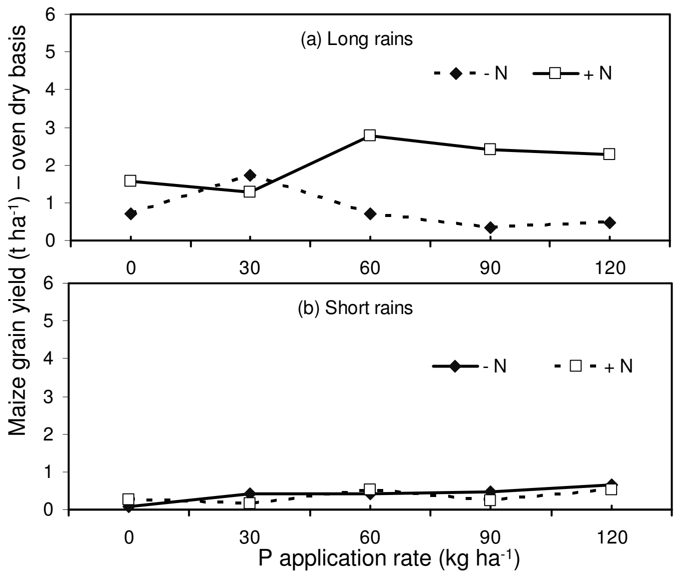

Figure 2. Maize grain yield response to increasing rates of P applied as triple super phosphate with, or without N added at the rate of 60 kg ha^{-1}: (a) in the season of application (long rains) and (b) in the subsequent season (short rains) when no additional N fertiliser was added i.e. residual effect of N and P combined, in Emuhaya.

Plots receiving 30 kg P ha^{-1} without N and 60 kg N ha^{-1} without P produced more than double grain yields when compared with control plots without P and N, yet grain yields remained below 2 t ha^{-1} in all fertilized plots. Higher rates of P application without N led to poorer yields than the control without fertilisers. When 60 kg N ha^{-1} was applied together with P, yields increased up to application rates of 60 kg P ha^{-1} (up to ca. 3 t ha^{-1}), and no further yield increase was recorded at higher P rates. The response to P on the demonstration plots was highly influenced by the incidence of the parasitic *Striga* weed and by spatial variability in the background soil fertility of the experimental plots. There was no residual effect of P fertilisers on maize yields in the short rains (Figure 2b). This subsequent crop helped illustrate the interaction between N and P; although crops often benefit from the residual fertility of applied P in a previous season, the grain yield of maize was very low at all rates of P because of lack of N (clear N deficiency symptoms were observed in the field). N is more mobile in the soil and prone to losses by leaching between seasons.

The interaction of P and N was clearer in the demonstration plots for incremental response to N in Chakol, where the maximum yields achieved were notably much larger than those normally obtained by farmers.

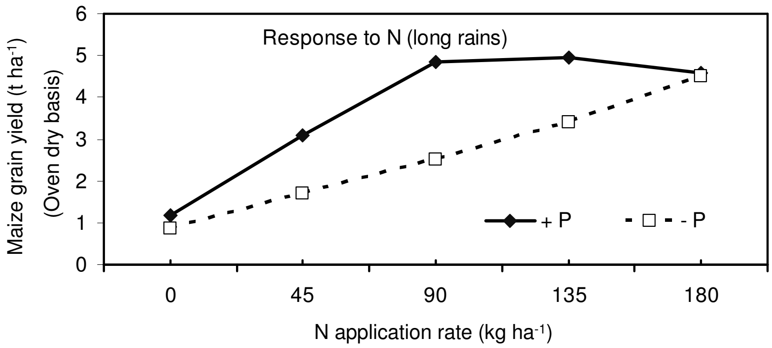

Fig. 3. Maize grain yield response to increasing rates of N applied as urea with, or without P added at the rate of 60 kg ha^{-1} (as P_2O_5), in Chakol. Residual experiment was destroyed.

The application of N at increasing rates without P led to an almost linear yield response, resulting in grain yields of >4 t ha^{-1} (i.e. 4 times more than in the control plots) when 180 kg N ha^{-1} was applied. The incremental application of N together with 60 kg P ha^{-1} led to a steeper yield response up to application rates of 90 kg N ha^{-1}, and no further yield increase at higher N rates. The application of 60 kg P ha^{-1} when no N was applied did not improve yields with respect to the control plots without N and P.

Participatory Monitoring and Evaluation: analysing 'ambiguity' of crop response to fertiliser application

Farmer notes and analyses

The following were the major observations and conclusions made independently by participating farmers during the monitoring and evaluation process. These observations have been classified as:

a) Management specific factors:
   i) spacing of crops goes hand in hand with fertiliser application. Many farmers had opted for higher plant densities especially when using mineral fertilisers "to optimise use of the gained fertility". Farmers said that, after all, residual fertility of these fertilisers was limited and could not be relied upon.

b) Climatic factors:
   i) Crops fed with mineral fertiliser need adequate water; low rainfall resulted in seed germination problems. Participants observed that the short rains were not ideal for fertiliser use or planting of slow-maturing varieties and hybrids.

ii) At the point of application, mineral fertiliser can lead to seed scorching in low moisture circumstances, e.g. when there is a dry spell after application. Broadcasting of fertiliser, as done on the demonstration, was seen to increase labour demands. After application, several participants incorporated fertiliser into the highly moist soil to avoid prolonged contact, of N especially, with the sun. Although broadcasting was seen by researchers as a way to save on labour demands, incorporating fertiliser due to fear of rainfall failure or run off would complicate farmers work.

c) Site specific factors:

i) The mineral fertiliser responses witnessed on demonstrations were small due to farmers' selection of heavily depleted host fields. Suggestions for optimum application cannot readily be derived in these conditions

ii) Lack of incremental yield increases with increasing rates of fertiliser input were explained by TSBF as possibly resulting from "other" causes, especially soil chemical properties. Studies in these sites have found high variability between different fields within farms. This variability has been "observed to have different soil fertility status and this may affect the response of a maize crop to applied N, P, and K fertiliser" (Vanlauwe *et al*., 2006:34). Farmers therefore suggested that it may be necessary for scientists to develop simple and accessible gadgets or procedures for in situ soil chemical analysis (e.g. pH, mineral N availability) so that poor farmers "could …target applications appropriately".

iii) Field hotspots (e.g. hedges, termite mounds, charcoal making sites, sites of former cooking fires, etc) positively affected response of maize to mineral fertiliser. Hotspots, and other sources of within-farm variability, are therefore perceived by farmers to be highly conducive to farm productivity.

iv) Imidazolinone Resistant (IR) maize was used in the experiment, and touted by researchers as resistant to *Striga*. Farmers observed that these IR varieties did not in fact perform better than 'normal' hybrids or even local varieties (believed by scientists to be less responsive to fertiliser use). The seed coating meant to kill germinating *Striga* plants, may in fact have been washed off due to heavy rains at the time of planting. Farmers observed that "maize performance on demonstrations compared unfavourably with adjacent farms". Farmers suggested that it would therefore be helpful to do an experiment on effective *Striga* control and fertiliser response with different maize varieties.

Farmer analyses showed that these fertiliser demonstrations were useful for learning about other related issues such as appropriate plant densities, the role of soil physical qualities and weeds, and the effects of soil erosion on fertiliser response. These factors affected farmers' understandings both directly and indirectly, and thus constrained their decision-making on fertiliser use.

Farmer-researcher joint analyses

Fertilisers were seen as exogenous elements, with a history of introduction and promotion under the colonial government and later by extension agents and researchers associated with the Kenyan ministry of agriculture. They were introduced to solve the problem of poor harvests (e.g. Newbould, 1989:306) in highly variable physical and social environments. Demonstrations thus make sense as a useful starting point for further dialogue and action specific to any site. On-farm demonstrations gave variable responses that highlighted the interactions of crop response to nutrients with weed flora and aspects of agronomic management. Thus demonstrations increased awareness among farmers about challenges of soil fertility experimentation, especially in a highly variable site. They also showed how research does not bring "the solution" but can serve as rather a basis for farmer decision making. This perspective is valuable, but also challenging for participatory processes. It is valuable because farmers were encouraged to experiment and to learn more about how fertilisers can work better under the local conditions. But experimentation, of its nature, also produces failures and negative results, not all of which can be easily explained. This leads to negative perceptions of fertiliser use for some farmers if very high rates are applied as done on the experiment, or if labour demands are seen to increase. Seemingly, trials confirm a warning. They are not seen as tools for "digging deeper" into complex, systemic relationships.

Community studies

Farmer try-outs showed that all informants had done some basic fertiliser experiments in the long rains of 2004 and 2005. Farmers planted maize (and soybean in some cases), and compared *performance* with and without fertiliser, and between types of fertilisers, or responses on different soils. The general objective was to evaluate response through performance and to increase yield. Many of these try-outs were also learn-as-you-use experiments. Comparisons between different responses were made over more than one season in many cases, and so farmers relied on memory to draw conclusions. In spite of this lack of 'standardised' learning, some trends became apparent. The majority (30/40) of the learn-as-you-use processes included combinations or comparisons with the commonly used farm yard manure. Nonetheless, procedures used and amounts applied by farmers did not allow much scope for broad learning or new knowledge on fertilisers to form. Some of the evidence is examined in the sections below.

Common farmer analogies: what is mineral fertiliser?

Results of all eight farmer focus group discussions showed that "soil is like the human". Farmers suggested that the same way humans get used to fried foods, soil gets addicted to mineral fertiliser; "once used, always to be used". If one stops, maize yield plummets badly compared to those who do not regularly use it. Using fertiliser is like frying food. Although fried food tastes good, it can 'pollute' the body. During dialogue meetings, some participants advocated a pollution-free practice, i.e. 'organic farming'. This must be seen against the backdrop of many non-governmental organisations working in the areas. Promotion of what farmers quoted as "clean farming" seems to be playing well with some of the poor smallholders who cannot afford enough fertiliser, yet do not have adequate organic inputs.

Fertility of the soil was closely associated with its colour and with decomposition. Fertility meant richness of soil, and not mere nutrients. Analysis of local terminology for fertility in focus group discussions made the point clear. For instance, among Luyia-speakers (Butula, Emuhaya and Matayos), fertility was referred to as *obunulu*, meaning "fatty" or "sated". When soil was "sated", it had *mabole* i.e. decomposed resources. The Ateso (of Chakol) referred to this as *Abosetait*. *Mabole* or *abosetait* were generic terms, comprising dark colour, richness of resource etc, and did not refer only to soil nutrients.

Fertilisers were instead commonly referred to in Swahili (not the indigenous vernacular), as *mbolea ya duka* (fertiliser from the shop) or *mbolea ya kizungu* ("white man's fertiliser"). Mineral fertiliser is therefore associated with buying from shops and viewed as a "special" or even 'formal' commodity. Since it was not *abosetait* or *obunulu* in the broad sense, five elderly informants believed fertiliser can "bleach" or "spoil" the soil and reduce earthworms (*ekaeret,* Chakol; *emiambo/milambo,* elsewhere). These informants insisted that repeated use or over-use of fertilisers would limit abundance of soil fauna. Mineral fertiliser was therefore narrowly defined as "sifted food for plants".

The most common analogy presented after the demonstration was on residual value. Mineral fertiliser is like sugar. It "is a quick-fix addition" which "replenishes lost energy almost instantly, but does not remain in the body for long". One must then use it with other foods (*chakula cha nguvu* meaning "strong traditional") digested slowly. 'Traditional foods' are organic inputs, which decay and/or release nutrients slowly and add carbon to the soil. Analogies were also applied in other ways. For instance, as knowledge on fertilisers increases so does knowledge on soil nutrients. Participants coined farmer-friendly names for nitrogen and phosphorus. N became Jeni, and P was referred to as Fosi. Potassium (K) was referred to in Swahili as Kali. These were easier to remember, and even their roles became clearer to perceive. *Jeni* was likened to protein, and *fosi* to carbohydrates in a meal. Besides being highly needed, they both are complementary, as Figure 3 shows. Local soils lacked both *fosi* and *jeni*, and so the soils were "unhealthy". But farmers also knew that carbohydrates and protein can be sourced from 'traditional' foods. The body does not differentiate between protein from meat and groundnuts. Similarly, soil nutrients from mineral fertiliser and organic fertiliser are the same to the plants. Because both may be accessible only to a limited extent, combining them is better. One also needs to know the respective "symptoms" of an 'unhealthy' soil due to lack of *fosi* and *jeni* etc, so as to "identify the right treatment".

The foregoing account shows something of the way mineral fertilisers were viewed as embedded in history, farmers' experiences and local knowledge. These continue to shape the nature of fertiliser use. All 40 informants experienced or considered the following as important in affecting the way they viewed fertiliser: (i) marginal or unsteady yield gains on many plots, (ii) difficulty of access, iii) awareness of other technologies, iv) type of crop; v) associated technologies; vi) fertiliser information.

Marginal yield gains

Thirty informants said that over the last ten years they had experienced performance ambiguity, i.e. yield increase uncertainty when they used mineral fertiliser on "infertile" sections where it was most needed. They commonly described yields as "soul-breaking" (i.e. *mavuno ilivunja roho*). These farmers said that they had on some plots experienced drop in yield, lack of clear yield improvement or "ambiguous responses". Although the demonstration was meant to improve understanding on such issues, farmers expected researchers to solve ambiguity. Usually ambiguity was blamed on "fertilisers of nowadays" (*mbolea za siku hizi*, i.e. fake or adulterated fertilisers), bad seed, rain failure, or 'diseases' in the soil. Fertiliser was therefore targeted to plots where "results would either be clear or assured" (focus group discussion, Emuhaya, March, 2005). Omitting to apply fertiliser during the second maize crop was consistent among 20 informants. This resulted in no or low residual build-up of P.

Access to fertilisers

In all focus group discussions, farmers ranked cost as an important deterrent to use of mineral fertilisers. All forty informants said they experienced difficulty buying fertilisers. Only five of the forty interviewed farmers bought a 50 kg bag of fertiliser in 2004. In particular, 10 informants said that a worsening fertiliser-maize price ratio had resulted in reduction of application rates (see also Carloni, 2001:15). Falling or negative net gains for existing cash crops, which received more mineral fertiliser than maize, had a negative effect on purchase of fertilisers. The problem of returns, however, is not merely a matter of the relative price of fertiliser and maize. It has more to do with sudden drops in produce prices after abundant harvests. Since farmers have immediate needs such as school fees and medicine they sell maize immediately after harvest, or even when the crop is still green for roasting. This meant that on average maize received declining amounts of inorganic fertiliser over consecutive seasons due to farmer cash flow problems and poor marketing strategies for the produce. Also, although the concern with cost doubtless reflects genuine concern, it should be noted that this study was carried out by researchers associated with TSBF. The expectation of assistance in acquiring subsidised fertiliser may have influenced farmers' responses.

Access to fertilisers can be enhanced through appropriate packaging and reducing distance to the nearest retail shops. This is being tried in FE sites, through an initiative of researchers and a private agency to promote a new fertiliser called *Mavuno* (harvest, in Swahili). *Mavuno* was sold to farmers in small packages at KSh.40 kg^{-1} (US$60 cents) through outlets within the study locations. Accessibility, nonetheless, is a more complex issue than availability of outlets alone. In settlements where more than 50% of the farming population lives on less than 1 US$ a day few small-holders prioritised buying fertiliser during the second season of 2004. Fifteen informants who had used fertiliser during the long rains would not contemplate to get it during the short rains, whether the outlet was near or far. On the other hand, all informants used manures in the short rains of 2004. The general perception was that FYM is cheaper, local, a known quantity, and it does not tie up any significant amount of money at once. However, amounts of manure available are limited.

Awareness of other technologies

The Folk Ecology Project was a broader initiative encouraging use of other technologies as well as mineral fertiliser. These included cereal-legume rotations, legume screening for varietal choice, and FYM and biomass transfer demonstrations. These other initiatives were invaluable in showing that mineral fertiliser, especially P, was of critical significance (… *et al*., 2007 [unpublished]). This thesis shows that these other demonstrations played an important role in training farmers about the value of mineral fertiliser. A majority (30/40) of the farmers whose practices were studied preferred to intercrop maize and soybeans during the first season of 2005. Try-outs revealed that fertiliser applications were more often targeted on maize and beans (or soybeans) than any other crop. When quantities of fertilisers available were inadequate, plots considered more fertile and likely to produce better harvests received high priority. Whenever informants used di-ammonium phosphate (DAP) they also applied FYM or compost when planting maize.

Table 1: Frequency of application of mineral and organic fertilisers in smallholder farms of Emuhaya surveyed during the short rains of 2004

Type of fertiliser applied	Number of farmers
No fertiliser	3
Mineral fertilisers alone	0
Organic manures alone	84
Manure and fertiliser combined	12
Total respondents	99

Source: Survey done in 2004. Emuhaya is one of the sites where Folk Ecology project is implemented.

By contrast, only DAP was used when planting soybeans. Nine informants said they specifically targeted DAP to soybeans to give P. Most (30) farmers who planted soybeans also understood that soybeans could biologically fix N_2 in soil. By encouraging soybeans (a grain legume with many uses) as an alternative soil fertility management technology, research helped make use of mineral P more effective. Furthermore, as shown in Table 1, use of mineral fertiliser did not replace FYM, and it thus makes sense to promote both as complementary.

Type of crop

During all focus group discussions, participants pointed out that it was not worth using fertiliser on certain crops. Although there were clearer cases of when P should be used, (e.g. the obvious differences between +P and -P rows), groundnut plots in the cereal-legume demonstrations did not clearly reveal such differences. This lent credence to a farmer view that mineral fertiliser was less necessary when planting groundnuts, and also to some extent on cassava, millet and indigenous vegetables. These crops were also believed to add fertility to the soil. It is a widespread belief of farmers in Africa, with some support from research, that cassava can sometimes improve soil fertility (cf. Saidou 2006).

It seems, therefore, that judicious intercropping or rotating of such 'fertiliser-free' crops with legumes showing fertiliser responses might 'unobtrusively' encourage P application that may benefit all crops in the rotation (cf. Giller, 2002).

Associated technologies

The history of fertiliser promotion in the area played an important role in farmer perceptions. Since colonial times, maize hybrids have usually been promoted concurrently with mineral fertilisers. As a result, not only did farmers closely associate maize hybrids with mineral fertiliser, but also inevitably with the expenses associated with this technology. If one has to buy fertiliser, then one has to also purchase hybrid seed. The package generally included recommendations on a per hectare basis, while use conditions were still widely unknown to poor farmers. The package and information supplied with it are mainly suitable for large scale farmers. The hybrid maize seed - fertiliser was part of a long-held perception that this was rich farmer's technology, and came under the scrutiny of poor farmers during the PM&E. According to informants, some hybrid maize, promoted as *Striga* resistant and planted with inorganic fertilisers performed worse than local varieties planted with less/no doses of mineral fertiliser. Focus group discussion suggestions show need for sensitivity over information targets, as follows: (i) application per smaller areas, e.g. 10 kg per given square paces rather than many kg bags ha^{-1}; (ii) application on different varieties of maize; (iii) use of simpler language; (iv) specifying conditions of application that minimise seed burning and N leaching.

Fertiliser knowledge and information

Fifteen informants said they had used *mavuno* or more DAP (on soybeans) due to research influence and new knowledge. However, a majority of informants (35/40) did not have clear knowledge on the various nutrient contents of the different fertilisers available on local markets, even after participating in the FE initiative. Common fertiliser distinctions included: (i) the "dark one" used by researchers; (ii) "the one given to tea farmers"; (iii) the "salty one" that scorches easily; (iv) the "whitish one" for top dressing, or (v) the "grey one" for planting. All informants differentiated DAP as "for planting", and therefore different from calcium ammonium nitrate and urea for top dressing maize, but no informant had ever used triple super-phosphate (TSP) commonly used by researchers. Fertilisers were not therefore known in terms of their nutrient values, which hindered farmer experimentation. In any case, soil nutrient deficiencies were assigned different interpretations, e.g. the "dangerous disease" for purple colouration often symptomatic of P deficiency. Farmers therefore needed information on how to diagnose deficiencies, e.g. through soil nutrient test strips, and to know the role of key limiting soil nutrients (e.g. whether N or P) to be able to experiment and make useful conclusions.

Research and extension on fertiliser must not give the impression that mineral fertiliser will be the sole or overriding determinant of yield increase. In reality achieving yield potentials is an interaction between improved cultivar use, improved soil physical and chemical conditions, adequate rainfall, and good agronomic management practices (timely planting and weeding), including *Striga* control. Understanding timing of top-dressing of N fertilisers can also enhance fertilisation without loss to leaching etc. It is thus more useful to promote fertiliser use when farmers adequately understand basic channels of soil nutrient loss (cf. Smaling *et al*., 1997).

Information and knowledge must be clear and based on research evidence to avoid common myths such as "clean farming" (cf. Vanlauwe and Giller, 2006). Misinterpreted messages about organic farming sometimes result in the idea that mineral fertiliser reduces incidence of earthworms or organic matter in the soil, key indicators of soil fertility for farmers. Since some of these myths circulate locally farmers need to take part in experiments designed to "test" any such fears. Research data suggest that indeed the contrary is true (Vanlauwe and Giller, 2006).

Suggestions

Farmers had the advantage of engaging in protracted fertiliser response observations on their farms. We need to tap into their experimentation better to understand how their notions are formed. Farmers did not have the capacity to study mineral inter-dependencies, and therefore to strengthen their understanding of the various intervening factors affecting crop response to fertiliser use. Besides interdependencies in crop mineral uptake, farm level variability and land use histories are difficult to unravel but together contribute to the cause-effect relations between fertilisers and yield. It is more meaningful to promote mineral fertilisers as part of the existing, albeit imperfect, systems of crop and animal husbandry.

There is need to focus attention on mode and consistency of current fertiliser use by farmers, even if the amounts are limited. Steps to encourage consistency of use were being undertaken in these sites. Supporting the establishment of input credit schemes with farmer groups is activity supported by TSBF partners. Registered and active group members receive fertiliser and seed, and were usually expected to repay within a period of six months. This form of credit inadvertently promoted fertiliser application on vegetables and legumes that were sometimes sold through group networks to enhance repayments. The Sustainable Community-Based Input Credit Scheme (SCOBICS) initiative funded by the Department for International Development (DfID) through TSBF's partner institutions was an example of support introduced through credit that is accessible to poor cultivators organised in groups. It encouraged farmer institutions actively to access fertiliser information and to negotiate with suppliers of inputs, critical when researchers leave. A similar initiative by Farm Inputs Promotions (FIPS) Africa together with TSBF-CIAT is encouraging access to the *Mavuno* compound fertiliser through packaging it in 1 kg packages, and retailing it within the study sites. Such small packages are ideal for micro-dosing on mainly-for-subsistence vegetables and legumes grown on selected plots by a majority of poor farmers, especially women.

Yet despite these promising developments, this study shows that more research is needed on the contexts of actual fertiliser use, and especially on the intricate labour management decisions of farmers. Smallholders preferred point application because of long history of its promotion as more efficient. Point application may not be significantly better in terms of crop response, and there is need to clarify fertiliser broadcasting which was inadvertently interpreted as labour intensive due to reworking of the fields during incorporation at planting on the trials. Such intricacies may mean increased access to fertilisers (and markets) alone will neither improve fertiliser knowledge among Kenyan smallholders nor guarantee its sustainable use. Use modes have to be 'convenient', and farmers need better farm gate prices. Access to information, especially by women, who may be the main appliers of fertilisers, is critical. Researchers and governments will need to think more broadly about use of participatory techniques in information sharing, including making available information to women farmers – key actors but often lacking time to take part in experiments. The new response by the Folk Ecology Project has been to test-implement a scaling up initiative involving local resource-person farmers as trainers. These resource-person farmers are working on behalf of their umbrella groups, with some minimal support from TSBF-CIAT, in order actively to involve less visible groups in accessing valuable knowledge.

Conclusions

There was poor crop response to incremental increases in fertiliser application on demonstration plots. The treatments, however, showed clear positive interactions between P and N. For their part, farmers did not perceive fertiliser in terms of N, P or other nutrients, but rather in terms of crop performance and yield. Their assessment of the demonstrations focused on performance, and revealed that they had identified management and fertiliser response to be related. Mineral fertiliser perceptions were embedded in history, farmers' experiences and local knowledge. Fertilisers were seen as 'special food', i.e. 'factory-refined' for 'selected applications'. Poor yield or low response was for instance blamed on adulteration. Low and inappropriate information also played a role. Information that farmers accessed was not always clear, nor always based on research evidence. Some development agencies, perhaps unwittingly, "feed" ideas about soil "pollution", via advocacy for "organic farming".

Co-research with farmers did not address all underlying causes of poor information or dubious concepts. Strengthening of fertiliser knowledge among smallholder farmers also requires tackling a variety of wider factors, including historical, bio-physical and social trends. It is concluded that fertiliser applications do result in higher and more predictable yields, but that a more targeted approach will benefit from taking cognisance of the heterogeneous context of smallholder farming in western Kenya.

CHAPTER 6

Getting real about soil fertility: context-mechanism-outcome gaps

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Chapter 6

Getting real about soil fertility: context-mechanism-outcome gaps

Abstract

The difference between scientists' and African smallholders' notions of soil fertility centres mainly on the attention paid to mechanisms. Smallholder understanding emphasises contexts and outcomes. Scientists operate with context-mechanism-outcome configurations, with emphasis placed on mechanism. We demonstrate this claimed difference through both literature review and interviews with African farmers and scientists. Small-holder contexts shape local rules for "doing" soil fertility, and also influence local notions of expertise. It is therefore necessary to avoid polarised over-generalisation about "science" and "farmer knowledge". Farmers may well modify their knowledge sets once they have been engaged in well-designed and sustained experimentation targeted on making transparent mechanisms of soil capacity to meet plant nutrition needs. Experimentation is seen as the best way to explain 'nutrients' and make them more visible, so that farmers can engage in soil fertility improvement activity that is both effective and meaningful.

Key words: soil fertility definition, realism, local knowledge, soil fertility improvement, smallholder farming systems

Introduction

In scientific research, soil fertility is broadly recognised. Many authors describe low soil fertility as a fundamental bottleneck for food security in smallholder farms in Africa (Scoones, 1997; Sanchez and Jama, 2002; Murwira *et al.*, 2002; Bationo, 2004). The emphasis on soil fertility is rooted in a long history of agricultural research linked to deeply-held beliefs about rural development, food security and agricultural modernisation as keys to transformation in Africa. For instance, the Soil Science Society of America (2001), in a special issue of the society's journal (no. 58), introduces soil fertility as necessary to sustain agriculture on a continent threatened with high population growth. This Malthusian orientation is espoused by many scientists determined to develop technologies they view as essential to alleviate problems stemming from poor soil fertility (e.g. Ker: 1995; Gigou and Bredoumy, 2002; Mokwunye and Bationo, 2004). Such framing is attractive because of the widely shared perception of Africa as a continent significantly dependent on agriculture for basic survival, and faced by looming doomsday scenarios through rampant population growth. Even where the gloomy predictions of Malthus about famine and population growth are rejected others still treat such increase in numbers as an essential "motor" of technological transformation (i.e. the so-called Boserupian[11] view).

Convergence between the two viewpoints (Mathusian and Boserupian) on agro-technology places soil fertility on a pedestal as a target for intervention. (Keeley and Scoones, 2003). Thus it is frustrating to find that African farmers are often harder to convince concerning the strategic centrality of soil fertility amelioration. This is sometimes too quickly dismissed as ignorance based on extreme poverty. We will here argue against this notion of educational deficit, attempting to show (instead) that farmers face a genuine epistemological difficulty. Specifically, lacking the resources or support for a probing, experimental approach, they tend to reject realist perspectives based on concepts of mechanism, and build explanatory paradigms of crop performance based on correlating contexts and outcomes (a position we will label "African farmer positivism"). In the absence of clear mechanisms, African smallholder positivism tends to adapt explanatory constructs normally used to regulate relations between persons to relations between persons and things (for example, bad luck or witchcraft beliefs may be used to explain crop failure). Farmers are often quite experimental about their approach (i.e. they seek evidence to guide decisions, e.g. through divination). But these experiments often basically yield signs to guide action, rather than serving to test between alternative candidate mechanisms. Scientists' explanations, by contrast, tend to espouse the idea of mechanisms of soil fertility enhancement or degradation (cf. Cardoso and Kuyper, 2006; Woomer and Swift, 1994). This is not to say any mechanism is better than none at all, and many explanations seemingly conceal the realities of soil fertility (cf. Patzel *et al.*, 1999). Tropical soil science – like any science – has its share of failures, and these failures often centre around dogmatically maintained adherence to the *wrong* mechanism (Patzel *et al.*, 1999). Soil scientists have their share of fantasies (Giller 2002). A realist view of science is committed only to the view that in the end it makes a difference to test between candidate mechanisms and reject those for which evidence cannot be found.

[11] See Boserup, E. (1965) *The Conditions of Agricultural Growth*. London: Aldine.

Realism is an epistemological position in which it is held that science (including social science) is more than simply "interpretation" (telling of satisfactory stories to quieten human anxiety). Realism deals in explanations under the assumption that the world contains real and enduring entities. Pawson & Tilley (1997) explain the realist stance by invoking three key terms – context, mechanism and outcome. Putting matters in admittedly over-simple terms, positivists seek correlations between context and outcomes, "interpretative" accounts of social and cultural worlds deal mainly with contexts, while realism, by contrast, seeks real entities (mechanisms) as the explanation of regularities linking context and outcome. A satisfactory realist explanation requires to be established in terms of what Pawson & Tilley (1997) refer to as the context-mechanism-outcome configuration (henceforth CMO). The choice between CMO and other approaches is not necessarily that between "right" and "wrong", more what is appropriate in the context at hand. Here, we advocate for both approaches, and suggest that farmer positivism e.g. interpreting contexts through indicator plants (Mowo *et al*., 2006), be bolstered though scientific validation (cf. Richards, 1994). Consider doctors, epidemiologists and virologists facing an influenza epidemic. General practitioners might be content to address context alone (assess the patient's symptoms, offer encouraging words and wait for recovery). An epidemiologist might need to assess both context and outcome, in order to build a model of the spread of an epidemic. But of the three the virologist will certainly not be content without locating the mechanism – the mutant virus causing the disease. Most soil scientists, we will argue, are realists (they seek mechanisms of soil fertility). Many African farmers, by contrast, either assume the position of the doctor (they are aware the field is in poor health, but assume it will recover with rest) or the epidemiologist (they "model" the spread of soil infertility as a product of human agency, and attempt to find solutions by limiting the anti-social actions of others, much as a government might attempt to stem an epidemic by advocating people stay at home when sick) but by-and-large have few if any means to sort out true and false mechanisms (any more than they would have the analytic capacity to identify a new disease pathotype). The nub of the problem of African soil fertility, however, is that farmer agency is needed as part of the solution. Farmers need to work for soil fertility solutions. How can they be persuaded to offer up such work if they have no real insight into soil fertility mechanisms? The paper concludes that accurately evidencing CMOs and making (validated) mechanisms transparent and convincing to a majority of poor African farmers is a key challenge for soil fertility studies in Africa today.

Methods and sites

This paper analyses concepts of soil fertility, their description and meaning, through scientific literature review and interaction with farmers and scientists. Indigenous definitions were acquired through focus group discussions with knowledgeable farmers. These farmers were selected purposively, based on (i) age – more than 50 years, (ii) local farmer recommendations, (iii) demonstrated skills in previous focus discussions, (iv) farming activities. Scientific definitions were acquired from professionally recognised scientists and researchers and through literature review. Twelve interviews were held as follows (i) four scientists from Wageningen University (ii) four international researchers and (iii) four Kenyan national researchers at an MSc level. Their operational definitions of soil fertility are analysed for trends, and compared with smallholder' conceptions of soil fertility. Analyses make reference to preceding studies done in western Kenya and West Africa.

Smallholders are defined as "rural cultivators practising intensive, permanent, diversified agriculture on relatively small land in areas of dense population" (Netting, 1993:2). "Western Kenya" here refers to Chakol Division, Teso District; Butula and Matayos Divisions, Busia District; and Emuhaya Division, Vihiga District. Farming populations in these areas are predominantly smallholders studied by Michael Misiko for his Ph.D. They have serious soil fertility problems (Ojiem *et al*., 2004; Ayuke *et al*., 2004). Notwithstanding a long history of project work (Misiko, 2001), they have low adoption of new practices (TSBF, 2001; Republic of Kenya, 2005). Chakol is predominantly inhabited by Ateso (*Nilotic*) speakers while the remaining farmers are mainly Luyia (*Bantu*) speakers. This linguistic distinction has some importance when interpreting soil fertility terminology.

Review of literature: definitions of soil fertility

What kind of concept is "soil fertility"? Seemingly, it is a totalising notion equivalent (in the language of Pawson and Tilley [1997]) to an entire context-mechanism-outcome (CMO) configuration. Literature review shows that only some soil scientists bother to define it.

"Soil fertility is concerned with the ability of soil to supply enough nutrients and water to allow the crop to make the most of the site. Soil productivity integrates both the climatic potential of the site, and the fertility of the soil" (Cooke, 1967:351). Janssen and de Willigen (2006a:132) refer to saturated soil fertility, as "the fertility at which the soil by itself does exactly satisfy the nutrient demand of a crop producing the target yield, provided no nutrients get lost". They also define ideal soil fertility, as "the fertility at which the soil in combination with 'replacement input' exactly satisfies that nutrient demand". According to SSSA (1997:3), soil fertility is "the relative ability of a soil to supply the nutrients essential to plant growth". "Although it [i.e. definition] omits the importance of soil physical and biological conditions for crop productivity, it is a useful simplification" (SSSA, 2001:3). "Soil fertility' describes the soil's ability to supply plant nutrients. It is also used in a wider sense to cover any soil property that influences plant growth" (DfID, 2002:1). "The term soil fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and suitable proportions" (Brady, 1974:10). "[P]roductivity is a broader term since fertility is only one of a number of factors that determine the magnitude of crop yield" (Brady, 1974:10).

Table 1: Trends in definitions of soil fertility from selected sources

Source	Description	What	Proportions	For
Hartemink, 2003	Quality that *enables…*	Provision of *nutrients*	Adequate/proper	Specified plants
DfID, 2002	Describes *ability*	Supply of plant *nutrients*	-	Plant growth
Brady, 1974	Refers to *capacity*	Supply *nutrients*	Adequate/suitable	Plants
Cooke, 1967	Concerned with *ability*	*Nutrients*	Enough. plus water	Crop
SSSA, 1997	*Ability*	supply *nutrients*	Relative	Plant growth

A sample of more than 50 text books with titles including the phrase "soil fertility" or devoted to the topic had no definitions. Their focus from the start is on mechanisms. So important and central is a mechanism to the scientific approach to soil fertility that it becomes a metonym for the entire CMO. Typically, these books homed in on mechanism by discussing at length leaching, fixation, immobilisation, mineralisation, plant nutrition or growth, soil fertility improvement or analyses, etc (e.g. White, 1987; Glass, 1989; Miller and Donahue, 1990; Brady and Weil, 1996; White, 1997; Scoones, 2001; Rattan, 2002; Vanlauwe *et al*., 2002). Singer and Munns (1996) avoid fertility as such but instead describe soil potential as the usefulness of a specific site for a specific purpose. Many authors prefer to focus on defining soil quality instead (e.g. Miller and Gardiner, 1998:54-55; White, 1997:324). Harris and Romig, 2002:643 describe soil quality as the "degree of fitness of soil for a specific use" or "the capacity of soil to function". According to Hartemink (2003:3) "soil fertility is defined as the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops. There are many references to soil health, which denotes soil as a living system (Harris and Romig, 2002; Uehara, 2002), or to the meaning of soil fertility decline (Bationo, 2004:1).
In sum, then, we can say that formal definitions, aimed at training soil scientists, tend either to focus exclusively on mechanisms known to be associated with soil fertility, or to make a connection to outcomes through some notion of (mechanism-grounded) "soil quality". Totalising (contextual) definitions are notable by their absence. In the view of soil text book writers context (apparently) is presumed to have been absorbed with mother's milk.

Scientist operational definitions

Given the metonymic character of the above definitions, and the apparent silence of certain key text books and internet pages about soil fertility "as such" (e.g. CGIAR and major Universities' websites), it is useful to ask if and how the notion surfaces in everyday research. What is the working definition of soil fertility for scientists?

"Soil fertility is the capacity of a soil to support plant or crop growth (Ellis Hoffland, email personal communication). According to Oene Oenema (personal communication), it is the "capacity of soil to supply nutrients to plants". Bert Janssen (pc) concurs. However he quantifies it as the capacity to supply 12 basic nutrients. Andre Bationo (pc), Oenema and Janssen agree that the supply of nutrients is needed in appropriate proportions. Bationo and Janssen distinguish soil productivity as a holistic concept, inclusive of water, sunshine and other factors necessary for nutrients uptake or crop life. Peter Leffelaar (pc), like Oenema, Jeremy Okeyo (pc) and Boaz Waswa (pc) also say “there is no one single agreed upon definition”. Leffelaar and Waswa specify three types of soil fertility: (i) physical soil fertility – which includes water, drainage capacity, penetrability by crop roots; (ii) chemical soil fertility – a soil’s ability to retain certain amounts of nutrients, or cation exchange capacity – dependent on clay and soil organic matter; (iii) biological soil fertility – i.e. soil life and life forms, including turnover of organic matter and micro-fauna. According to Leffelaar, soil is fertile when these three requirements for fertility are fulfilled. He offers no single definition, however.

Table 2: Trends in operationalisation of soil fertility among selected scientists

Source	Description	What	Proportions	For
Hoffland (em)	Capacity	–	–	Plant/crop
Janssen (pc)	Capacity	Supply nutrients	Appropriate (12 basic nutrients)	Plants
Oenema (pc)	Capacity	Supply nutrients	Appropriate (14 basic nutrients)	Plants
Bationo (pc)	Capacity	Productivity	Relative (16 basic nutrients)	Plants
Okeyo (pc)	Ability	Supply nutrients	Required	Plants
Waswa (pc)	Ability	–	–	Desired yield

These “practical” definitions (the kind that might be offered informally to an enquiring student) are interesting in restoring the contextual and “outcome” elements missing from the “mechanism”-weighted text-book discussions. The reason the full CMO reappears seems to be that an informal definition can be readily elaborated with caveats and qualifications. Text-books formalise essentials, whereas as a more “relaxed” definition finds more room for context and outcome. Thus the differences between the two sets of definitions owe more to presentational logics than to any fundamental difference. Comparing Tables 1 & 2 shows a connecting thread – capacity for plant growth is key to both sets of definitions. This is a way of emphasising the extent to which soil scientists are realists. Students are being reminded of the central significance of the mechanism. Without a mechanism a soil science explanation of soil fertility is nothing. So central is this point that in some text books context and outcome are shaded into obscurity. This (we will argue) is perhaps a strategic mistake of some importance in talking to farmers who emphasise context, or context and outcome, to exclusion of mechanism, since it suggests opposing conceptions of soil fertility, rather than common ground.

Farmer concepts of soil fertility

Selected (i.e. knowledgeable) farmers had ‘interacted’ with soil fertility closely and for some time, via a project on indigenous knowledge and soil improvement. They represented different villages in the study areas, had wide knowledge of their soils and fertility (e.g. indicator plants), and had participated in earlier projects also. It may be that their concepts were, therefore, already somewhat hybridised with scientists’ conceptions. But the fact that differences of conception can still be clearly identified suggests that other African farmers, not so exposed, may find the gap between scientific (mechanism-based) conceptions and African farmers’ largely contextual and outcome weighted notions even wider than here described.

Smallholder’s idea of soil fertility is perceived as part of the land and land holding, and is usually expounded in terms of analogies. An example of a widely held analogy in all four sites in western Kenya is the idea that “soil is mother” (*udongo ni mama*, Swahili). Like a mother, soil can be barren. Fertility levels were described in terms such as health, energy, tiredness, etc. A common definition of fertility was "richness of the soil". Analyses of the local terminology in preceding focus group discussions showed that among the Luyia (Butula, Emuhaya and Matayos), soil fertility was referred to as *ovunulu*, meaning "fatty" or "sated". When soil is "sated" (*elinulu*), it is rich with *vuvole/mabole* i.e. decomposed resources, water, and life. The Ateso (of Chakol) referred to this as *abosetait*. *Mabole* and *abosetait* were generic terms, alluding to dark colour, balance, resourcefulness etc. According to these informants, soil on virgin land is usually healthy, i.e. full of *mabole* or *abosetait*. "The more soil is used, the more tired it becomes" (Sylvestre, Chakol). Soil fertility is therefore not in need of explanation, since it is the normal condition, when plant growth is satisfactory. As would be the case with humans, good health is the normal, expected condition, and not something requiring explanation or even comment (other than thanks to God for maintaining it). Ill-health, often blamed on the supernatural or human factors, then becomes the focus. Terms like tired, low in energy or old, when applied to soil, continue the smallholder focus on infertility (i.e. deficiency and ill-health). A soil that is "unhealthy or low on energy [i.e. tired, as seen in crop performance], is weak and possibly old" (Clement, Matayos). When a soil is "low on energy then it is hungry and in need of rest or food" (Wilfred, Matayos). According to Jacob (Emuhaya, and also Professor, Butula), "like women, some soils are naturally barren. That is how God created this world; we have strong soils and naturally tired and fruitless ones".

The language is general in the population and comparable across ethnic groups. It brings out very clearly that soil fertility in the local conception is something deplorable (like ill health or bodily fatigue) but not necessarily something about which much can be done. A "hungry" soil probably needs to "eat" (perhaps a mechanism?) but soils that are "tired" and "sick" are perhaps best left to rest. Apparently, these days, there is a lot of such sickness about, but it may be more a product of a disordered social context (greed, wickedness, etc) than the work of any specific "organism" (or lack of such) in the soil. Where soils are "old" re-fertilization might seem decidedly risky. The elderly are to be respected but not necessarily rejuvenated. Men and women who once enjoyed great power and influence sometimes resort to witchcraft or other esoteric means to revive their powers. Witchcraft is universally regarded as problematic. By extension, there is perhaps a frisson of alchemy associated with the idea of tampering with mechanisms of aging in the soil. The general point is clear. Farmers in western Kenya have a clear understanding of the context and outcomes of soil infertility, but attempts to explain why certain soils (belonging to some farmers) "fail" are likely to favour moral rather than the technical mechanisms (as indeed would be the case in any local account of why X rather than Y succumbs to a particular human disease). Given that scientific accounts are predicated (almost exclusively) on technical mechanisms the scope for misunderstanding is indeed great.

Epistemology: how soil fertility is known

In this section we look briefly at what scientists and farmers know about soil fertility, and how they know it. Scientists engage in complex studies and tests, and record and share findings widely, unlike local farmers. According to Oenema (pc), it is about 75% possible to know the capacity of soils through: (i) observing colour; (ii) feeling the texture; and (iii) testing friability. You can increase accuracy of knowing through laboratory analyses, especially of about 14 key soil nutrients that are fundamental for appropriate plant growth. According to Leffelaar (pc) however, "most soils in the lab are analysed while dead". These soils are dried, they no longer have microbes, etc. "such soils can never be fertile". Brady (1996) categorises diagnostic tools and methods into three: (i) field observation; (ii) plant tissue analyses; (iii) soil analysis, and advises that "all three approaches should be integrated" (p551).

The vocabulary of farmers was rich on observable matters widely known or shared between participants. Common parameters were especially based on appearance, feeling, colour, earthly smelling humus, friable, crumb structure, soil tilth, erosion, drainage, softness and soil depth (cf. Harris and Romig, 2002). Figure 1 shows qualitative scoring results done in the four sites with twenty knowledgeable farmers. But 'hidden capacities' were beyond smallholder's ability to know, e.g. organic C %, C:N ratio, extractable Ca (and Mg, Na, K, CEC and pH). Some of these 'hidden' elements were described indirectly.

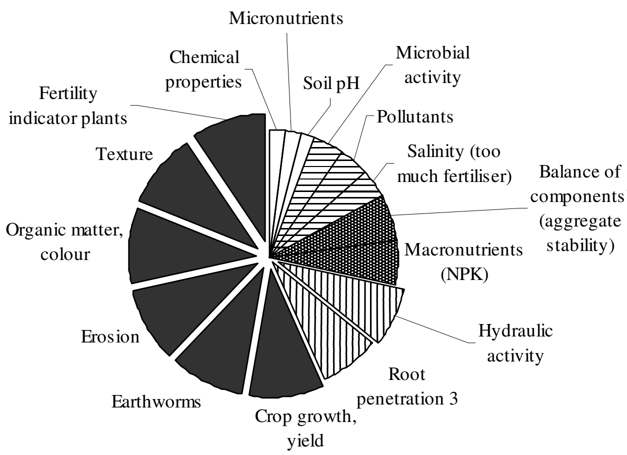

Figure. 1. 'Soil fertility as a complete circle': parameters plotted according to farmers' qualitative scores based on Table 1. Sizes are based on a qualitative scoring mechanism, that allocated importance or values based on a scale of 1-5 as explained in Table 1.

Table 3: qualitative scoring criteria and respective values based on data from western Kenya

Farmer qualitative criteria	Qualitative score	Colour in figure 1
Preferred	5	Black
Comprehend well	4	Vertical lines
Heard about it	3	Dotted
Suspect it	2	Horizontal lines
Cannot determine or not aware	1	Blank (no pattern)

Farmers perceive their expertise as normal (cf. Scoones and Thompson, 1994), but they do not talk about knowledge of soil fertility in terms of mechanisms. They dwell (as seen) more on signs of deficiency (i.e. infertility described in terms of tiredness or low energy). The focus on deficient output leads to diagnostics. Why is this thing so poor? Is it ill-health or disease? Is it witchcraft or bad luck, i.e. are these soils "cursed"? Farmers hunt for "signs" and "signatures" pointing to the agency or entity responsible for this kind of ill fortune. This might then be talked about in terms of a range of circumstantial (i.e. contextual) factors - e.g. poverty, enemies, etc. The focus on diagnostics, leading to identification of esoteric causes such as witchcraft, intensifies when faced by problem soils (*udongo tatanishi*, Swahili), in which there might be little predictability of crop response. One such example was a farm hosting the organic resource quality experiment in Matayos. Initial analysis suggested ideal observable parameters, and laboratory analysis confirmed good nutrient levels, but it had a reputation among farmers for inexplicable responses. Analysis would need to unravel pollutants, microbial activity, chemical properties, etc (as indicated in Figure 1). Because of its problematic reputation this plot was not, in fact, well suited to learning experimental design. But that was not farmers' concern. Since it was so intractable to their own diagnostic way of thinking the farmers gave it to the scientists in order to find out what kind of forensic skills scientists possessed. In other words they were looking at a tool intended to adjudicate between hypothesised mechanisms as a divinatory device. It was only afterwards that they confessed to one of the present authors (MM) that they had deliberately offered up this plot for experimentation to see what the scientists would do with it, and whether they would recognise its well-deserved reputation. Here we have an example of farmers experimenting on an experiment, but from a different starting point than that of the soil scientists.

Ontology: scientist vs. smallholder configurations

By and large, researchers and smallholders begin from different places, the former with the mechanisms of fertility and the latter with signs that the soil is not all it should be. In terms of the analysis mapped out in the introduction scientists are realists working with a context-mechanism-outcome (CMO) configuration, and farmers are positivists, looking especially at context and outcome (Pawson & Tilley 1997, cf. Saidou, 2006). As already noted operational definitions of soil fertility tend to emphasise mechanism (i.e. issues of 'what' and 'proportions' – cf. Table 1 and 2) which support plant growth. 'Capacity' of a soil to provide nutrients, or to support plant growth dominates in the scientific literature, but this is often a difficult notion to convey to the smallholder within a single project. Capacity of the soil can be hampered differently under different conditions. For instance, low pH may be good for some crops and not others. Or indeed some crops perform badly in certain soils but not in others. In 2004, it was debatable among farmers whether lime applied on TSBF experiments was a fertiliser. If it was meant to improve yield, why should it not qualify as a fertiliser. Farmers, introduced to the notion of pH, wondered why it is seen as a parameter of soil fertility, just like N or P, yet it has no fertiliser. In other words, is pH management a mechanism like adding N or P, or not? A similar scepticism applies to burning. Some literature shows that during burning "most of the nitrogen is lost as volatile N_2 and NO_2" (Ruben *et al.*, 2006:173). However, the smallholder observes better performance as a result of burning. In some cases, burning reduces N and C but makes P more readily available. Informants in effect observed that burning 'shocks the soil back to life' and saves labour, yet like lime application it is not promoted as a soil fertility management practice by researchers. This suggests to smallholders that scientists are crucially departing from manifest reality and focusing on hidden complexity, but they have no real means to envisage what the hidden "something" might be. Thus smallholders are not in a position to understand why scientists seemingly overlook what is manifest before their eye, e.g. better performance after burning. Scientific explanations such as N volatility and P immobilisation after application of mineral fertiliser simply 'puzzled' smallholders, since they had no conception of a CMO configuration.

Another troubling difference, reflecting the divergence between realist and Farmer positivist approaches, stemmed from how benchmarks of soil fertility were established. Scientists determine benchmarks through estimating potential production of a specific site by comparing it with actual harvest; this is determined by such factors as radiation, rainfall, slope, etc (Leffelaar, pc). When all conditions are appropriate, an optimum production is calculated as a site-specific benchmark. Janssen and de Willigen (2006a) refer to saturated soil fertility and ideal soil fertility as constituting the reference-points for sustainable *nutrient* management. Saturated soil fertility is calculated as a function of target nutrient uptake, and ideal soil fertility as a function of target nutrient uptake and recovery fractions of input nutrients. There is also consideration given under a CMO configuration to what indicators and parameters should be used to evaluate suitable nutrient management protocols in practice, and about benchmarks for assessing what is good and what is poor (Oenema and Pietrzak, 2002). Soil fertility decline can be estimated using chemical data (pH, organic C, total N, available P, cation exchange capacity (CEC), and exchangeable cations), as routinely collected in soil sampling. Or decline can be assessed in terms of a set of properties from different periods at the same site or from different land use systems with the same soils (Hartemink, 2006). Recommendations on nutrient inputs can then be based on these assessments, and tailored to target yields: "at soil fertility levels lower or higher than ideal soil fertility, nutrient input must be higher or lower than replacement input" (Janssen and de Willigen, 2006b:154). Again, all these various indicators or assessment standards are (implicitly) linked to knowledge of soil process mechanisms.

The smallholder, by contrast, is unaware of, saturated, optimum, ideal or potential, nutrients; all s/he knows of benchmarking is the highest yield ever achieved on a specific field, or what a richer neighbour harvests. Decline and increase in actual harvests (i.e.

outcomes) are determined through comparisons with the best-ever performance or yield. The scientific conception of soil fertility in terms of potential and differential performance of mechanisms is hard to perceive and even harder to relay to the small-holder. In the real world of small-holding, soil fertility is measured in relative terms, against more (or less) successful neighbours (or seasons). A section on a resource-deprived smallholder's farm may actually only produce half what an 'infertile' plot on a wealthier neighbour's farm produces (cf. Vanlauwe *et al*., 2006) but still be regarded by the poorer farmer as "fertile". Or farmers at times count an unexpectedly good outcome (perhaps the product of favourable rainfall) to be an increase in "fertility", whether or not the causes are related to the soil (or even understood at all). Fertility is in other words a label for a satisfactory outcome and not a process. Soil performance is inseparable, in fact, from many larger and at times mysterious forces determining wealth and poverty, blessing and misfortune. A farmer warned by a soil scientists about fertility decline, may (in fact) choose to pray for blessing, and be rewarded when factors hitherto unconsidered in any model (such as a fortunate configuration of weather events) result in a satisfactory harvest.

Scientists need not retreat in the face of obscurantism at this point. Crop performance goes beyond usability of nutrients. It further depends on the ability of a plant to exploit a given soil, which varies from plant to plant. Some plants may grow well where others fail due to deeper roots that can access leached minerals. Other crops have more developed coexistence of mycorrhizas in roots that help nutrients to be taken up. African farmers are not insensitive to possible candidate mechanisms at this point. For example, African smallholders often see cassava as either tolerant of low fertility or 'acquiring' its own fertiliser and even improving the soil. This suggested to one African soil scientist (Saidou 2006) that there are candidate mechanisms for science still to consider. Saidou's subsequent work (based on negotiating experiments with farmers) actually allowed some of these mechanisms to be tested to the provisional satisfaction of both scientists and farmers. While the scientist is interested in the biological and chemical functionality i.e. mechanism (cf. Cardoso and Kuyper, 2006, Woomer and Swift, 1994), the farmer makes a direct link to the state of the crop (Sikana, 1994), but both observational frames can be deployed in a single experiment, as Saidou demonstrated. The point at issue, therefore, is that farmers are not dogmatically fixated upon African positivism. Given encouragement to join in the right experiment they, too, start to think in terms of candidate mechanisms, and thus may find themselves better equipped to participate in mechanism-based soil fertility interventions.

Context matters: soil fertility decline is more than soil mechanism alone

Dense population can lead to cultivation of fragile areas. But population growth alone does not account for soil fertility decline; rather it is the lack of resources that accompanies these changes, alongside other factors such as inappropriate gender policy. Smallholders have limited access to technical information and also characteristically occupy the most marginal soils, Many (especially women) have land tenure setbacks. They also have labour problems regardless of many household members, and suffer from low off-farm income. As a consequence the populations most likely to suffer from poor soils are also those with the least resources to predict or deal with the problem (Brown, 2004). There is no evidence that soils in Emuhaya, with a population density of 1500 pers./km^2 (Tittonell *et al*., 2005a) are more infertile than in Chakol with a population density of 393 pers./km2. Parent material is often important with regard to inherent fertility (Sillitoe, 1996), but soils in Emuhaya (i) have longer history of intensive cultivation than in Chakol, (ii) are cropped with maize more often than Chakol, and (iii) are on steeper slopes on average than in Chakol (Republic of Kenya, 1997). Research shows that sites closer to living quarters (on farms) are more fertile than the furthest fields (see Figure 1, see also Crowley and Carter, 2000). Soil fertility decline is emphatically (as farmers insist) a contextual issue linked to larger regional and historical processes of poverty causation and maintenance. Leach and Fairhead (1996:4) provide systematic evidence of "attention to specific land management techniques, grounded in farmers ecological knowledge, and to the social and economic relations…" in Kissidougou, Guinea. They show how local communities, seen as destructive, had a close religious, economic and broader cultural relationship with the forest. With findings similar to Tittonell *et al*., (2005b) in the Emuhaya study, Leach and Fairhead (1996) (cf. similar but much earlier evidence reviewed in Ruthenberg, 1980) show that the more intense the daily and domestic activities of many people living in a village the more they fertilise and enrich the soils. Kitchen gardens, often maintained by women, are developed over land behind the compound where household wastes are deposited, where people have defecated, where animals have dropped dung. The more intense the human settlement, the more such activities cause islands of fertility and, when villages relocate forest regenerates quickly. In short, the larger context matters. But talking about context alone at this point is too limiting. These larger processes also need analysis according to a realist framework using a CMO configuration. The mechanisms on which soil scientists focus are matched, at the larger scales examined by such authors as Leach Fairhead (1996) by institutional mechanisms and social processes determining wealth and poverty and the extent to which management of soil fertility enhancing mechanisms can be triggered and deployed. The issue is not alone to align farmers with CMO configurations as addressed by soil scientists but to ensure that soil science is itself aligned with larger poverty alleviation processes and emancipatory mechanisms.

Soil fertility dynamics and the institutional contexts in western Kenya

In order to align farmers to science, and science to the needs of smallholders, it is necessary to understand the genesis of the smallholder contexts which so dominate the paradigm of African positivism. Western Kenya is affected both by the types of crops grown (e.g. Carter, 1997), and the larger historical factors shaping the agrarian landscape (cf. Scoones, 1997). The landscape is rooted in cultures, and has developed in response to markets and other important service resources such as watering holes and availability of grazing lands across subdivided lands. It is a world also shaped by migration (Carter, 1997), and a colonial legacy of imposition of infrastructural resources alienating many inhabitants from development plans and markets, with a lingering legacy of high-handed administration that still fosters exploitation in the independence era (Basil, 1992; Basil, 1995).

Land tenure, which is a crucial factor for long term investment in soil fertility (Adjei-Nsiah, 2006; Saidou, 2006) has problematic aspects for many local farmers and would-be farmers (especially women and youth). Colonialism established a short-term, extraction ethic, and farming is still largely based on extraction of resources. The fact that most of the cash crops are of exotic origin – introduced by colonial farmers – helped ensure a long-lasting externally-oriented control over production knowledge, helping ensure that local labour remained available to white farmers. This created a dependency relationship in which locals saw themselves as forced to buy, produce, and sell resources they could not control locally or self-sustainably (cf. Netting, 1993:282-288). This worked with an infrastructure of preferred routes following watersheds that disregarded local settlements or kinship order. Road systems re-oriented local settlement and land-use patterns. Previously, local livelihood styles promoted nucleation of household living quarters on top of slopes for security reasons, to allow householders to observe crops from vantage points, to keep livestock from harm, and leaving valleys, rivers and forests for wild animals, circumcision ceremonies, religious affairs, and gathering fuelwood or wild food resources.

With years of population growth, farming eventually spread to the slopes and former nutrient-rich valleys which are now heavily depleted. Their recovery is dependent on outside forces beyond farmer control (Republic of Kenya, 2005). The alternative requires resources that smallholders do not possess, in order to maintain the landscape balance. In Emuhaya, for instance, dense population and poverty have contributed to migration (cf. Carter 1997) because farming is ever more failing to provide survival basics of many locals now increasingly reliant on off-farm income (Tittonell *et al*., 2005b). The unfavourable local context (i.e. low soil fertility) is linked to the interplay between poverty and unfavourable inputs-produce price ratios, market failure, poor policies and ill-conceived legislation. It is also shaped by the knowledge and health of members of the household and environmental factors such as climatic change (Hedlund *et al.*, 2004).

Even so, within this generally unpropitious context, soil fertility is in some cases (notably closer to homesteads) not just preserved but improved due to intensive activity adding more soil organic carbon, around which other fertility parameters can be extended.

Giller *et al*., (2006) and Tittonell, *et al*., (2005b) identify different field types within smallholder farms in this western Kenyan landscape, varying in production activities, resource allocation and management practices. They show that home gardens are typically small fields around the homestead, intensively cropped with a high variety of crops. As farms get smaller, this pattern intensifies, which explains (for instance) some of the differences between Emuhaya and Chakol. In Emuhaya, slopes are likely to be cultivated all the way from top to bottom, but the diversity and intensity of crop types decrease with increasing distance from the homestead (see also Ruthenberg, 1980). The various activities on the soil catena are not undertaken independently of each other but belong to a logical management sequence smoothing labour and other input requirements (Richards 1986; Ruthenberg, 1980).

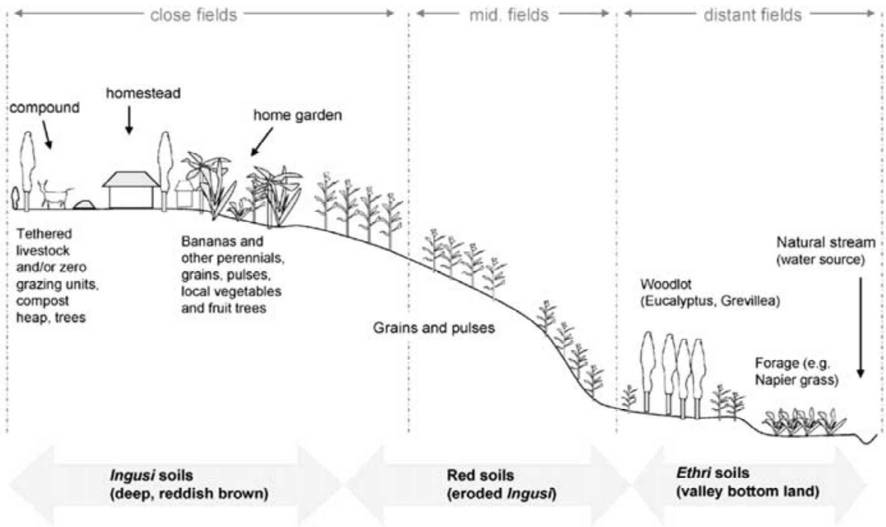

Figure. 2. Schematic representation of a generic farm in Emuhaya based on the farm transects. Grains and pulses are normally intercropped. In some cases, the cattle manure is collected in compost pits instead of heaped. In the flatter landscape of Chakol, however, there was no clear association between farm layout and topography. (Tittonell *et al*., 2005b:171)

"All this, however, is usually no static situation" (Ruthenberg, 1980:76). Land use and catena management strategies vary from one context to another. When the slope is not steep, or the middle or lower part is stony, the farm arrangement tends to alter especially in terms of location of houses, but also other uses such as grazing fields (Tittonell, *et al*., 2005b). But catenary management is not a complete solution. On the whole, poorer households in western Kenya have been unable to manage soil fertility on slopes and the original soil types have changed, (in Emuhaya from *Ingusi,* dark red, to *Esiyeyie,* i.e. light red, inherently infertile).

Leach and Fairhead (1996:88) observe that while certain activities are deliberately targeted to promote forest growth, "many of the individual activities which contribute to forest establishment are nevertheless undertaken without this outcome in mind" (see also Scoones and Thompson, 1994). The developments depend on the diverse activities of villagers, rather than on deliberate management (i.e. manipulation). This process shapes the rules that underlie soil fertility management among the smallholders, which becomes an institution embedded within a way of life (cf. Scoones and Thompson, 1994; Netting, 1993). Similarly, in the ordinary processes of crop production in western Kenya, fertility is seen as entangled within local institutions, and perhaps better 'made' as a part of institutional reform and good governance, rather than established as an explicit and separate goal. If farmers need to grasp mechanism-based thinking, while soil scientists open up to a broader conception of contexts, both need to discover ways of linking institutional mechanisms regulating land to technological mechanisms of soil improvement. Routine restoration of poor and degraded soil by means of manuring and other soil management practices are seen by the smallholder in western Kenya as imperative, but the ameliorative mechanisms overlap in complex ways, rooted in specific

household and communal characteristics, experiences, ecosystem configurations, and social and biophysical contexts.
The means by which nature manages fertility has been interfered with. Soil fertility decline occurs amid farmers' long term interaction with nature within a limited but diverse ecosystem that has bestowed them with rich ethnoecological expertise (Moran, 2000). Natural or low input methods served well the past generations under open land tenure, there was therefore no emergency demanding the adding of phosphate, potash or Nitrate fertilisers. When plants like tea, coffee, maize, and bananas became common, they were raised without quality manure for long periods in natural fallows. But these crops eventually squandered soil fertility reserves, forcing smallholders to follow over-generalised designed interventions. Sophisticated local ethnoecological expertise remains an important asset, but on its own is inadequate to cope with the rapid soil fertility lose. Over centuries of experience soil fertility has been embedded in livelihood practices and contexts, and has not been seen as a major or separate activity to be treated as an end in itself. African positivism in regard to soils makes historical sense. But now these experiences have had to be expanded and supported with knowledge, capital and tools if soil fertility is to be improved by farmer agency. Time is important (Sillitoe, 1996). But conceptual orientation is also needed, both by farmers and scientists. Farmers need to acquire a working appreciation of soil fertility mechanisms. But scientists need to step back from too close a focus on soil fertility mechanisms, and recognise that context matters, and that there are other (often social) mechanisms at play in determining complex mutual interactions between mechanisms of poverty and soil infertility. One path to pursue seems to be convergent research (i.e. co-operative investigation between both scientists and farmers, and between social and technical scientists). As demonstrated in Benin, co-research activities not only evidently improved farmer knowledge, but also strengthened their capacity to innovate, practice and share better cropping practices as well as soil fertility management. Saidou (2006) shows how joint experimentation systematically improved farmers understanding of soil fertility mechanisms; N, P, K nutrients and mycorrhizal fungi. An experimental framework was used to make soil fertility management a learn-as-you-do process. Saidou also succeeded to raise and link the issue of integration of fertility issues with institutional reforms around land tenure. The present paper has argued that there no inherent reason why the same kind of approach could not be adopted in western Kenya. But to achieve this end, soil scientists will have to contemplate an expanded (socially-informed) variant of the realism currently driving their research, while farmers will have to abandon the African positivism that has guided their soil management strategies for several centuries.

Conclusion

"Indigenous agricultural revolution" has long been advocated as a means to improve African small-holder agriculture. But as this paper has argued in relation to the specific case of soil fertility management, smallholders tend to see soil problems in terms of African positivism (an undue focus on context and outcomes to the exclusion of detailed examination of mechanisms). This is because the typical farmer lacks the tools or epistemological orientation to engage in 'mechanism'-based soil science unaided. Scientists hence need to devise interventions in such ways as to help farmers see the problem of soil fertility in terms of mechanisms. But scientists can become too narrowly focused on mechanisms, to the exclusion of wider contexts and outcomes. Both parties need to develop shared understandings in relation to locally and regionally important context-mechanism-outcome configurations. This should then be the background to engage the smallholder especially through longer-term well-designed participatory experimentation, essential for application of research technologies. This way, novel technologies and tools can then be developed for, or, amended into the existing contexts without loss of their underlying conceptual validity. Any application has to preserve the workability of the underlying concepts. Active co-production of agro-technological knowledge in a context of institutional reform aimed at poverty alleviation is the approach here advocated to ensure an end to the stand-off between soil science and local agency.

CHAPTER 7

General discussions

To the smallholder, soil fertility is an elephant. It is a big issue. The smallholder knows the trunk (i.e. daily functionality of fertility) and does not move close enough to know more about the eyes (i.e. soil nutrients) that are all too important, etc. The big issue is powerful but dynamic. To deal with it the smallholder needs to know the ways of the elephant. The scientist needs first to perceive soil fertility as the elephant in the smallholder's world.

Fertile Ground?

Soil fertility management and the African smallholder

Soil fertility has many definitions, and viewpoints vary widely with regard to its meaning (Patzel *et al.*, 2000). But if the meaning of the term is hazy its importance is clear (Misiko *et al.*, 2007, unpublished). Poor soils and human poverty go hand-in-hand, especially in the tropics. Many studies have therefore been devoted to unravelling major factors constraining tropical soil fertility in order to achieve sustainable agriculture (Cardoso and Kuyper, 2006). These efforts have yielded many useful findings, concepts and technologies (cf. Vanlauwe *et al.*, 2002; Bationo, 2004). Nonetheless, stagnation of agricultural development in many sub-Saharan African regions is commonly attributed to the limited adoption of new and improved technologies (Ruben *et al.*, 2006). It is now widely accepted that the transformation of soil fertility requires a complex interaction of factors, mediated by a variety of social, economic and political institutions over time (Izac, 2000; Carter, 1996). This has directed attention towards a holistic paradigm for soil fertility research often termed "integrated soil fertility management" (ISFM), embracing the full range of driving factors and consequences of soil degradation (Bationo *et al.*, 2006). This holistic paradigm calls for a more embedded, context specific, adaptive and learning-based approach to intervention. Such an approach must neither entail simplistic nor aggregated assessments of people-resource relationships, but rather embrace uncertainty, complexity and the potential for non-linear change (Scoones, 1997). The present study has proposed that for such a tricky task to be handled with notable success, it is critical for the smallholder to gain generic knowledge, in addition to pre-adapted or ready-for use technologies that function only so long as the 'correct' research concepts and rules are applied. For a generic approach to work, smallholders have to be placed at the centre of technological and conceptual configurations, and "own" the necessary knowledge in a way that permits development and adaptation, rather than simply following a prescription. This thesis has explored the issue of whether this degree of intellectual ownership of the problem seems feasible, in African conditions.

Core findings of the thesis

Amendments to cereal-legume rotation were geared to solving shorter term and priority objectives. Findings in chapter two show that soil fertility was enmeshed; and was not perceived as *the problem.* Amendments to the research rotation scheme targeted related problems of *Striga*, fodder and land constraints, etc. The latent functions and benefits of legumes were thus given priority by smallholders. However, when increases in yield of a cereal in rotation with legumes were easy to see, the soil fertility management value was strengthened among smallholder farmers. Chapter three shows that promiscuity of the new varieties or N_2-fixation was not adequate to guarantee selection of soybean or its new varieties among smallholder farmers. Although participatory evaluations showed positive preferences of the new varieties introduced, conclusive selection happened only after farm-level testing and identification of latent benefits and the strengthening of manifest roles. Soybean's compatibility when intercropped with other crops such as maize, and other related roles such as *Striga* control played a direct role in integrating it within smallholder systems.

Chapter four shows that integration of the organic resource quality concept into local farming practices was achieved indirectly through amended practices such as 'quality composts'. The original concept faced complications stemming from: poverty; traditional uses associated with the materials used; and labour constraints, etc. Biomass transfer was *inconvenient*; due to the complicated process *vis-à-vis* end results and smallholder perceptions about some of the resources used, specifically *Tithonia*. Similarly, perceptions about mineral fertilisers were deeply rooted. Chapter five shows that smallholder perceptions about mineral fertiliser were embedded in history, unpredictability of crop response after application (due to poor soil properties) and past experiences. Fertilisers were seen as 'special food'. Poor yield or low response was, for instance, blamed on adulteration of this food, and this study found that low and inappropriate information had also played a negative role. The Folk Ecology Initiative (FEI) collective trials showed positive interactions between P and N, and contributed to improved understanding of mineral fertiliser in terms of the mechanisms of nutrients and crop response. This, and findings in chapter 2-4 are analysed in chapter six which shows that the smallholder needs to appreciate the concepts behind research technologies to be able to successfully apply them in varied local contexts i.e. within the context-mechanism-outcome paradigm.

Soil fertility: head or tail?

The preceding core findings show that soil fertility can better be pursued as a means, and not as *the goal* in improving local livelihoods in western Kenya. Targeting soil fertility will be achieved more effectively by developing technologies that fit within local livelihoods, which retain validity when applied loosely and concurrently address more manifest priorities. Similar to these findings, other studies have shown that soil fertility is cloaked in wider concerns of livelihoods.

Smallholders have adapted their livelihoods to their environments (Altieri and Andres, 1995; den Biggelaar, 1991). Relationships between livelihoods and natural resource management strategies have been described and analysed (cf. Crowley and Carter, 2000). For instance, the choice of crops and management practices are deliberately varied by farmers in accordance with small-scale variations in soil conditions (*Ibid.*). Studies also show why local knowledge and skills should be part of the means to improve natural resource management (Agarwal, 1995; den Biggelaar 1991). Such studies explain the scientific basis of indigenous smallholder farming (Innis, 1997). Crowley and Carter (2000:410) found that "farmers view soil management as a means to an end, not an end in itself. Ease in application, cost, short-term increases in yields, and benefits to particular crops are the major considerations in their choices of soil management practices". Studies also show that labour is a key factor in soil conservation (Berry, 1993), which is also found in the current research.

Smallholder approaches to soil fertility management should therefore be studied as elements within broader social and livelihood systems (Misiko, 2002). The way researchers study and present the practices of smallholder "soil fertility management", such as indigenous (or indicator) plants and composts, may not always reveal the full significance of the alternative meanings attributable to them (meanings sometimes associated with emergent properties resulting from the combining of social and pedological facts). Soil fertility may be reported to the researcher as a priority, and such practices as composting, fallowing and indigenous fertility plants, as widespread. In 2002, baseline studies for the FEI showed that more than 90% (n=201) of farmers relied both on composting and fallows to manipulate soil fertility (Misiko, 2002). Follow-up studies (participant observation) confirmed these results, but at the same time uncovered new layers of meaning. (The practices in question were, in fact, rooted in other systems of explanation than soil fertility.

Case 1. Fallows (Misiko, 2002)

The traditional role of bushy or weedy fallows was to 'rest the soil'. There were other underlying non-agricultural reasons influencing the existence of natural fallows and the 'practice' of agro-forestry. For instance, many participants in the study believed that *Sesbania sesban* 'guarded' their farms against moles, and there were cases where *Tephrosia vogelii* was used to 'drug' fish in small streams (the use of this plant as a fish poison is in fact widespread across Africa). Out of 201 farms visited in 2003, more than 157 had at least one of these shrubs or other species[12] formally introduced by researchers growing on their farm as weeds e.g. *Leucaena* and *Sesbania* but tolerated on many farms due to their new assigned roles. Giller (2001:220) shows *Leucaena* is widely used for shade in Ethiopia. In Western Kenya, *Sesbania* served this role on some farms. These species were introduced to be grown systematically as fallows, but after the end of research projects these species began to regenerate naturally as weeds in cropped fields; on terraces; hedges; and in fallow fields. Newly-assigned uses were geared towards

[12] *Calliandra calothyrsus, Sesbania sesban, Crotolaria grahamiana, Mucuna pruriens, Tephrosia vogelii, Tephrosia candida, Canavallia insiformis, Leucaena leucocephala, etc.*

finding socially and economically viable alternative uses to land. Leaves of these species would be moved to a 'compost' pit or fed to cattle and were rarely directly incorporated into the soil while still green.

Figure. 1. *Mucuna* plot was ranked as the best in terms of contributing to crop 'performance' on the cereal-legume rotation co-research plots compared to groundnut and soybean in all sites. *Mucuna* was found to be very pervasive as a 'weed' (season the middle path, germinated from abandoned seed after harvesting the legume phase). Groundnut and soybean seed were all taken, in spite of their lower ranking during participatory evaluations between 2003 and 2005.

(Misiko, 2002)

Traditional fallowing was fundamentally different from that of improved fallows. The former occurred naturally, e.g. as grazing fields, shrubs or woodlots, none of which was weeded or systematically maintained for agricultural reasons. Many were established as 'safe' areas for herbs, calls of nature, etc. There were also a few woodlots of *Calliandra* in the study sites. These were mainly useful as firewood, fodder, fences, and also for bee-keeping. They were not rotated or mixed with crops, and three were burned down in 2003. They had been 'adopted' for other purposes than soil fertility management and were not devastated by, or did not harbour serious pests.

Case 2. Compost (Misiko, 2002)
Compost materials varied significantly from farm to farm. The quality of composts was determined by type of plant *residues available* on a given farm, and the type of knowledge applied, e.g. research or extension advice. Materials that decomposed fast (such as *Tithonia* leaves) and those that took longer, such as Eucalyptus leaves and twigs would normally be mixed in the same 'compost'.

Figure. 2. A 'compost' pit on Paulia's farm, Emuhaya, visited on March 28, 2003. Note the black and green polythene sacking, sticks and mixture of: soil, green leaves, maize stover and other dry matter (which included eucalyptus leaves). Farmers were forced to sort through such manures before applying. Also note the walking pathway (which allowed water into the pit), and *Tephrosia* (top right).

Misiko, 2002

Tephrosia (growing next to the pit) was cut and incorporated into this 'compost' one week later. Paulia was attempting to convert recently acquired knowledge of legume shrubs into regular routines. This and other observations showed that knowledge of leguminous shrubs did not necessarily replace, but rather modified old practices.
When households were cleaned, especially in the case of the fronts of houses where visitors were received, women routinely heaped litter at convenient places, and commonly in pits dug by their husbands. With time, these pits were filled, sometimes with cuttings or leaves of leguminous shrubs introduced as cover plants through research. They were established for convenience in cleaning, and not to make compost, even though that is practically what some provided. Other materials such as ashes (not from beans), material from collapsed houses, left-over food, e.g. after ceremonies, were deposited there. Women, however, deposited kitchen waste, chicken droppings and even other livestock manures directly into their home (i.e. vegetable) gardens every morning after cleaning their houses. Again, these were practices of convenience by local women, constrained by the need also to perform many other tasks; new pits were not dug every season, neither would the women sort the different types of litter or transport them to remote sites on their farms. Such 'composts' were exposed to sunshine and runoff. The application of the resultant compost manure varied depending on the quantity more than its quality. In these cases compost resulted from the application of a domestic theory of cleanliness rather than a theory of soil fertility.

Delicate options for fragile livelihoods

Findings in chapters 2-5 show that the technologies demonstrated under FEI were dependent on knowledge of basic concepts of their functionality and were labour demanding. They were mostly perceived as *inconvenient* (Misiko, 2002). For instance, applying organic resource quality concept through biomass transfer is complicated. As a means of enhancing soil fertility biomass transfer tends to overshadow the greater goal of better yield. But to the smallholder any technology is a means to make farming easier within a framework defined by a range of social and environmental requirements. Biomass transfer, unlike promiscuous soybean varieties, lacked alternative and/or latent functions. Soybean was planted more as an economic enterprise or as food crop. The main research goal for the new promiscuous soybean varieties was to improve N in local soils through atmospheric N_2-fixation and biomass incorporation. These two processes were often compromised during application within smallholder systems. For instance, host soils did not have adequate P for N_2-fixation to occur, while legume residue management was poor. When promiscuous soybean was rotated or intercropped with maize, yield increases were not maintained, as observed on co-research plots.

Unlike other technologies studied, fertiliser application can be seen as crosscutting. However, the use of fertiliser on smallholder farms was hampered by false perceptions, poor crop response to P and N due to low organic carbon and poor agronomic practices, etc. Given that smallholders farmed within difficult contexts, research technologies tended to increase the complexity of 'doing' soil fertility. Simpler practices like mulching, weeding, relying on both modern and traditional coping mechanisms, and using the farm as a laboratory to ensure better targeting of P and N on plots highly variable in terms of the distribution of these factors, need to precede any recommendation or scaling out of grand plans. Similarly, illustrating fertiliser use efficiency should precede efforts at packaging it in small quantities at affordable pricing, etc.

Outcomes, however promising on co-managed or purely research-managed experiments, were not comparable with farm-level results. Recent research evidence, for instance Tittonell *et al*., (in preparation), (Table 1) seemingly illustrates significant yield gaps between farmer fields and researcher-managed maize crops on-farm and on-station. The gaps between farmer management on their farms and researcher managed on-station trials are shown in Table 1.

Table 1: Average and range of variation of maize grain yields (t ha^{-1}) measured on farmers' fields, average yields and yield ranges for selected treatments from the on-farm experiments and reference yield levels under controlled, on-station trials (FURP, 1994). *Extracted from*: Tittonell *et al*., (in preparation)

Site and position within the farms	Farmers' fields (farmer management)	Control plots (on-farm experiment)	Full N-P-K plots (on-farm experiment)	FURP-reference* (on-station experiment)	
Chakol				Control	Fertilised**
Homefields	1.7(1.2-2.3)	3.6(2.1-7.3)	4.7(2.5-7.4)		
Midfields	1.0(0.8-1.3)	2.0(1.0-2.8)	4.1(3.2-5.0)	1.6	5.2
Outfields	0.7(0.3-1.1)	1.8(1.1-2.4)	3.9(2.1-5.0)		
Emuhaya					
Homefields	2.4(1.1-3.8)	2.9(0.9-5.5)	4.2(3.3-6.2)		
Midfields	2.2(0.9-3.6)	2.6(1.2-3.7)	4.0(2.9-4.8)	2.3	6.0
Outfields	1.4(0.7-2.9)	1.8(0.3-3.0)	3.8(2.7-5.5)		
Shinyalu					
Homefields	2.6(1.7-4.0)	2.3(1.3-3.3)	2.9(1.4-5.4)		
Midfields	1.7(0.7-2.1)	1.6(1.1-1.9)	2.8(2.0-3.5)	2.3	7.1
Outfields	1.4(0.8-2.3)	1.0(0.2-2.3)	2.5(1.2-3.7)		
SED	0.26	0.39	0.38		
CV	0.46	0.54	0.31		

*The position within the farm does not matter in this case; FURP: Fertiliser Use and Recommendation Program, Kenya National Agricultural Research Laboratory.
**The figures correspond to fertiliser combinations and rates leading to the highest yields (excluding those that also received animal manure) at each site. Maize grown during the long rains season.
SED: Standard error of the differences; *CV*: coefficient of variation (= standard deviation/ grand mean across sites and fields)

Doing participatory research within target areas does not necessarily address smallholder contexts. Participatory research relies on pooled labour, research input, consultations etc. Resources are combined in time, and planting follows recommended spacing, etc. Maize yields under individual farmer management (as in Table 1) differed significantly across sites (P = 0.002; with averages of 1.1, 2.0 and 1.9 t ha-1 for Chakol, Emuhaya and Shinyalu[13], respectively) and decreased significantly from the home to the outfields (P < 0.001) in all sites (interaction site x position within farm non significant). Yields on the same field plots but under researchers' management did not vary significantly across sites (P = 0.058) on the control subplots (without nutrient inputs); however, they differed significantly (P < 0.001) when full fertiliser nutrients were applied.

Community studies showed that the suitability of the tested technologies in fragile livelihoods primarily depended on social and economic issues not apparent when agronomic benefits are assessed or participatory monitoring and evaluation outcomes evaluated. For example, smallholders face labour constraints, while capital barriers inhibit take-off towards sustainable agricultural intensification (de Costa and Sangakkara, 2005; Mowo, 2006; Zingore, 2006). In western Kenya, there were further complications of low land productivity even when tested technologies are applied, strong variability in rainfall conditions, significant erosion problems, and ecological difficulties (weeds, pests

[13] Found in Kakamega, adjacent to Vihiga District in which Emuhaya lies.

etc). In these settings, it was too expensive to produce for market, and/or local produce markets were not sufficiently functional to absorb the extra produce. In short, additional gains were not certain or valuable enough to guarantee continued fertiliser use, use of hired labour etc. Smallholder systems were, as a result, highly diversified; they combined different cropping, livestock, and non-farm activities in a search for endurance. As opposed to soil fertility management being a specialised enterprise (cf. Oenema and Pietrzak, 2002), the smallholder undertook crop residue recycling, animal manure collection/deposition, and 'compost creation', as an extension of a more general round of daily activities. Farmer managed fertility systems were characterised by much heterogeneity, as also observed by, for example, Ruben and Pender (2004) and Tittonell *et al*., (2005). Heterogeneity at the field level was created constantly through such practices as residue deposition, burning, and concentration of activities at certain spots (Leach and Fairhead, 1996). Many of these activities were not aimed directly at soil fertility targets.

Implications for further work on soil improvement

A technology toolbox, not a basket of options

'Toolbox' comprises different devices for 'fixing' a system. The different devices perform different but related functions. Various soil fertility technologies are interrelated, and do not necessarily play substitutable roles. The application of one enables the other to function efficiently. Conversely, a basket of options implies 'devices' that can be used as alternatives without the necessity for combination. For instance, this assumes that all FYM can do is increase N in the soil, just like mineral fertiliser. In smallholder systems, FYM is available in small quantities and is low in quality. Its use does not eliminate the need for mineral N. In reality, successful application of legume technology may necessitate the use of mineral P fertiliser. The application of mineral fertiliser in fields with low soil organic carbon can result in negative perceptions caused by poor crop response. Soil organic C can be enhanced through legume residue incorporation or application of the resource quality concept. The application of the resource quality concept and N addition through legume cropping without mineral fertiliser will not adequately improve P status in such depleted soils.

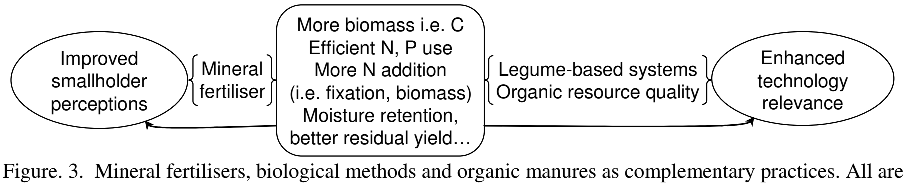

Figure. 3. Mineral fertilisers, biological methods and organic manures as complementary practices. All are crucial for improved relevance of concepts and strengthened farmer perceptions.

Fig. 4. Cereal-legume rotation experiment, Yehonia Okwiri, Butula. Participants appreciated the value of P in legume cropping and rotations, and observed low crop response to fertiliser use where less biomass was produced and incorporated.

Between 2003 and 2005, plots with mineral P on co-research plots had better crop performance: there was better N utilisation, more active legume nodules (soybean screening), more biomass to incorporate, higher yield and better residual yield than plots without P. Smallholders may better benefit by identifying complementarity of different technologies. One technology, if adopted as an "alternative" to others, may not serve the end purpose sustainably, even though it seems attractive to promote the message of "options" to resource-poor smallholders. Soil fertility is a complex phenomenon, and its enhancement requires efficient complementary 'tools'. Smallholders need accessible soil fertility management toolboxes. i.e. sets of technologies to be used in combination, because they are not substitutes. Presenting technologies as baskets of options may pass invalid messages, since many of the available technologies are not strictly alternative considering how smallholders apply them. Chapter 2 shows that low use of P compromised the chances to improve and sustain the gains in harvests due to poor legume growth. Chapter 3 further shows that low nodulation in some promiscuous soybean varieties was attributable to low P. Promiscuity of the new varieties was not adequate to guarantee N_2-fixation, screening results show poor nodule count especially in much depleted soils. Residue was not well managed, and so the full anticipated benefits were not realisable. Chapter 4 shows that biomass transfer quantities demonstrated under the FEI were prohibitive, and the technology was perceived as *inconvenient*.

Soil fertility, cloaked in wider concerns

Findings in chapter 2-5 on farmers' amendments to the demonstrated technologies show that soil fertility was enmeshed; not *the problem*, rather an avenue to solve the urgent (albeit related) priorities and problems such as hunger and *Striga*. The latent functions of the new soybean varieties (chapter 3) or of groundnuts and *Mucuna* (chapter 2) were more important in addressing more visible problems emanating from low incomes or food insecurity. All learn-as-you-use try-outs were geared towards getting around urgent problems such as labour constraints, and/or land shortage. For instance, the application of organic resource quality through 'hot' composting or the preference of intercropping rather than rotating legumes and cereals, respectively.

Soil fertility was therefore tangled beneath a dense web of more pressing problems and objectives, when the perspective of smallholder farmers is addressed. Even so, many of these more pressing problems, such as poor harvests, are actual consequences of low fertility, so there is need to engage with farmers to develop some kind of step-wise and longer term approach, working towards better soil fertility management through addressing these more visible and pressing issues.

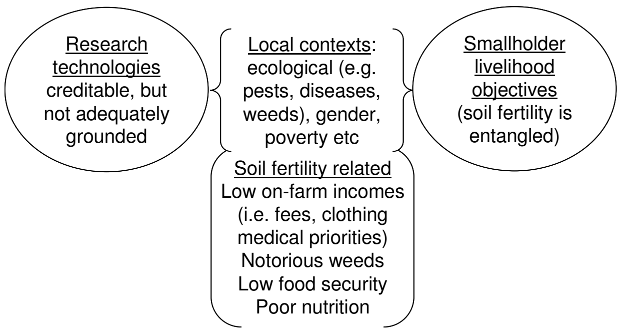

Figure. 5. The position of soil fertility. The farm and household are meshed, and so livelihood objectives are not distinct. Yet concerns at this level eclipse soil fertility management issues.

Put another way, technologies need to be more closely geared to farmer concerns and address the most pressing problems if they are to strike deep roots in farmer practice. Given that smallholders face a complex of burdensome challenges, knowledge intensive or concept-laden technologies tend to be applied only loosely or are adapted in ways that risk watering down their conceptual relevance. The best way perhaps to channel soil fertility messages and techniques is through attaching them to activities that farmers are likely to undertake for other reasons. The compound cleaning case (Misiko, 2002) mentioned above, the 'hot' composting and legume latent functions provide such instances, but efforts are needed to uncover and strengthen other such routes.

Implication of research

There are two options to be followed. 'Take' smallholder farmers up to the level of concept-laden technologies or modulate tools and methods for doing soil fertility to suit their status. A critical look at these options shows that both must be pursued concurrently. The first option is long term. Researching on suitable options and development oriented initiatives must be synchronised with actual interventions. In fact, (monitored) intervention must become the research methodology, and the present thesis has shown there is considerable scope for such activity, provided researchers know how to interact with farmers and to "read beneath the lines" of "with farmer" experiments. Further, it seems essential to embed research components within actual smallholder development initiatives (including those sponsored by government).

Integration of research methods

Community studies and outcomes of participatory monitoring and evaluation (PM&E) exercises sometimes gave rise to different sets of findings. Participatory processes of evaluating technologies are good for getting initial impressions, and exposing more farmers to a technology or practice. But by themselves they do not give the whole picture. Experimentation was an invaluable tool not only for gathering more specific data on interventions but also for training farmers in longer term soil-management skills, and assisting them to draw reliable and valid conclusions about research technologies and concepts. However, responses in collective discussions need always to be corroborated through more detailed anthropological follow-up investigations, including following individuals to their homesteads and farms. Depending on the context, it can be dubious to rely only on research-led PM&E ranks to predict likely adoption of soil fertility improvements.

Different contexts need mutual experimentation to build smallholder expertise. Knowledgeable farmers can apply generic knowledge in different settings, and can interpret and share results more ably, as shown in the FEI.

Implications of research

It is important to rely on several methods to evaluate technologies for suitability. Outcomes of participatory experimentation and evaluations (as shown in chapter 2-6) are not automatically predictive of future application. Participatory experimentation especially under 'farmer-management' and within local environments was neither necessarily reflective of the farm-level social conditions nor future smallholder application. Collective experimentation under the FEI happened within smallholder ecological circumstances, but sources of atypicality included labour pooling, reliance on group and project guidance, and availability of input resources. These were common constraints on individual farms. One useful set of indicators of technology preferences were the parallel farmer learn-as-you-use try-outs, only known by observation and assessed via in-depth studies. By qualitatively assessing try-outs, viability of a technology was estimated in terms of soil fertility worth and priority benefits accruing to the smallholder. On one hand, the smallholder priority benefits were a clear indication of whether a practice would be sustained. On the other hand, the nature of application of any concept within smallholder contexts determined its value in terms of soil fertility improvement. The challenge therefore is to close gaps between soil fertility conceptualisation and smallholder contexts.

Closing concept-context gaps

There is limited use by and experimentation with research technologies by smallholders (Giller *et al.*, 2006). This study has observed that this is partly to be explained by a misalignment between research technologies and concepts and smallholder contexts (Misiko *et al.,* 2007). Research should therefore treat smallholder contexts, such as tenure insecurity, labour and capital constraints, dysfunctional markets, etc) as part of the general problem. Where possible, soil management issues should be addressed in relation to, for example, tenurial problems, as advocated by Saidou (2006). It is well understood that smallholders possess in-depth knowledge about their ecosystems (Moran, 2000; Leach and Fairhead, 1996; Netting, 1993; Richards, 1985). This knowledge can be utilised in research and development initiatives (cf. Walker *et al*., 2006). This study shows that farmers' attention to research technologies is focused on outcome within their contexts. But possession by farmers of local knowledge does not bestow on them an ability to examine the complex causal mechanism involved in soil fertility maintenance or improvement, especially via experimentation.

Closing this gap requires an institutionalisation of links between farmer participation and mainstream experiments. A major requirement is the need for the scientist to understand the rules of smallholder soil fertility management, and what shapes farmer perceptions, so that institutional experimentation "speaks" more directly to farmer contexts. Perhaps more importantly still, farmers should be encouraged to improve their skills in drawing conclusions from these institutional experiments. This study shows that, at times, farmers drew conclusions based on memory, i.e. comparisons of performance across different seasons, or through reference to treatments in one type of soils. Conclusions about many try-outs were sometimes based on circumstantial outcomes, and it is perhaps important to realise that memory may be quite a fallible guide.

Since the gap between scientific work and smallholder contexts is quite wide (according to the present study), inept practitioners fill it by disseminating often flawed expertise. It is necessary that the core institutional research be bolstered, to avoid general misinterpretation of existing knowledge (cf. Vanlauwe and Giller, 2006). In spite of years of embracing participatory approaches, mainstream trials remain at the centre of soil fertility research, but also (in a way) are quite isolated, socially speaking. Mainstream trials in particular remain domains in which scientists rule without subjects. Need was found to open them up to scrutiny by and input from smallholders, in terms of perceptions, priorities and even knowledge (e.g. ideas about treatments).

Farmers perceived institutional research as being remote from their daily lives. Visits to on-station research plots during this study confirmed farmers viewed institutional research as a strange kind of 'performance'. They were surprised at the effort invested in scientific activities, e.g. the care that went into orchestrating trials, yet were puzzled these experiments did not result in quick successes trickling down to village level. At the same time, on-station soil fertility research largely treats social components as unimportant, and the smallholder is regarded as an end beneficiary not required to understand the processes studied by scientists. However, there is great potential for scientists to do soil fertility management research in which typical or likely smallholder interventions (whether as interference or enhancement) are treated as part of the process (whether through simulation or by involving farmers directly in the experimentation). Introducing social factors as "externalities" in experimental design might help achieve an integration of natural and social science concerns in soil fertility management research and feedback techniques. Fig. 6 offers one way, conceptually, to envisage the interlinkage involved. Among an agenda of items for this kind of "convergent" research it is possible to list:

- social science approaches (e.g. technography, cf. Richards 2001) as a means to grasp and distil farmer input based on actual soil management practices
- identifying possible uses or interpretations by the smallholder for ISFM concepts and technologies
- assessing farmer decision-making criteria once technologies are released
- making anthropological (i.e. technographic) enquires to study seed selection decisions or what knowledge is implemented before official release (cf. soybean screening experience)

- strengthening and regularising communication between scientists and the smallholder through feedback seminars.

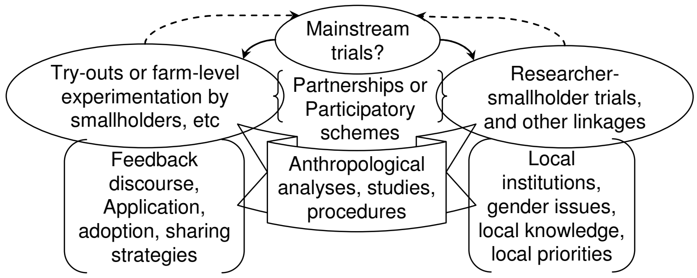

Figure. 6. Strengthening and institutionalising smallholder dynamic expertise: towards an embedded social science approach.

Within this scheme (Fig. 6), partnerships based on the FEI (chapter 1) can be built among scientists, and between them and farmers. Local institutions, such as farmer groups and farmer field schools representing women and men had under the FEI been leading efforts of adaptive experimentation, sharing new knowledge and providing effective forum for feedback. The FEI can be expanded or modified to incorporate smallholder feedback on mainstream experiments.

Potential new initiatives

1. Studies are needed to: (i) map the spread of generic research knowledge; (ii) to understand gender dynamics with regards to the use of different technologies; (iii) to comprehend the utilisation of different 'chains' of incentives and linkages between local farmers and 'outsiders'; (iv) to scrutinise the suitability of partnerships for scaling out; and (v) to document enterprises at farm level or group level resulting from the FEI initiative.

2. Some cautious scaling up of interactive learning processes based on the Folk Ecology scientist-farmer initiative as a development approach, based on institutional partnerships, should now be attempted.

3. Smallholder resilience in fragile rural contexts needs to be strengthened if soil fertility management is to be improved. Adoption of soil fertility management in western Kenya is clearly hindered by poverty. At the root of poverty lies vulnerability to risk. Soil fertility management schemes should therefore be coupled to interventions designed to reduce the riskiness of cultivation to the poor. A variety of approaches can be applied to risk mitigation, ranging from breeding and dissemination of hardy (e.g. drought-tolerant) crop types to institutional mechanisms such as risk spreading through agricultural insurance and re-insurance schemes.

General conclusions

This study shows that research technologies and concepts improved soil fertility. Yield on co-research plots generally improved after their application. Nonetheless, research technologies were found to be knowledge intensive and demanding. Their application was generally bolstered when they fulfilled indirect benefits (i.e. not soil fertility management, but rather uses such as food and fodder e.g. soybean and *Calliandra* respectively). Such technologies can therefore be described as credible but 'delicate', given that their relevance (and therefore advantage) of soil fertility enhancement was reduced due to loose application on smallholder farms aimed at priority benefits. Smallholder livelihoods were fragile, riddled with: unstable ecological conditions; poverty; and heterogeneous social contexts. It is therefore concluded that to increase the utility of research requires a shift from component research to research at subsystem or whole farm system level to address broader household objectives. The FEI shows that chances of sustainable application of scientific innovations by smallholders will be greatly enhanced if field research embraces and embeds social science methods of engaging the farmer sustainably as a partner in experimentation and not simply as a client. Research technologies should be introduced progressively, and not disseminated in a quick "package" fashion, since this may undermine their relevance in the long run. This means that partnering with fewer smallholder community groups at a time should precede wholesale scaling out. This negates ambitions for faster outreach, but serves well to first verify the quality of research technologies when applied by smallholders. It is perhaps better for fewer farmers to gain deeper appreciation, then to build on their qualitative comprehension, and to facilitate rapid feedback schemes that involve many farmer groups.

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Summary

Many technologies and concepts have been developed by researchers to combat low soil fertility. However, the stagnation of agricultural development in many sub-Saharan African regions is still commonly attributed to declining soil fertility. One of the reasons for this is the gap between smallholder social and ecological contexts and the technologies that are developed by researchers.

The objective of this thesis was to study and examine application of agro-ecological knowledge for soil fertility management by smallholder farmers, with the view to enhancing the utility of research among resource deprived farmers of western Kenya.

Between 2003 and 2005, participatory trials, monitoring and evaluation of technologies and concepts were explored. Those experiments involved: (i) cereal-legume rotations; (ii) screening new soyabean varieties for selection among smallholders; (iii) organic resource quality concept and biomass transfer; and (iv) mineral fertiliser response. Farmers' practices following these experiments were investigated mainly through in-depth interviews and participant observation, with particular focus on their underlying justifications and livelihood objectives. Participating farmers selected experimental plots to ensure that the soils were representative in terms of type, fertility levels and history of cultivation. Farmers deliberately selected infertile plots infested with *Striga* to "see if the new technologies worked", and as part of their wider experimentation objective. These experimental plots were research-designed.

Amendments to concepts and technologies were geared to solving shorter term and priority objectives. Findings show that soil fertility was cloaked in wider concerns; and was not perceived as *the problem.* Farmers concerns were prominently geared to solving, for instance, problems of *Striga*, fodder, labour and land constraints, etc. The latent functions and benefits of technologies were thus given priority by smallholders. For instance, when soyabean "smothered" *Striga*, it was likely to be preferred than if it only increased soil fertility. However, when increases in yield of a crop when a concept or technology was applied were significant and easy to see, the soil fertility management value was strengthened among smallholder farmers. The application of a preferred concept, however, depended primarily on social and economic issues not apparent when agronomic benefits are assessed or when participatory monitoring and evaluations are done. The successful application of technologies studied in this thesis was dependent on knowledge of basic concepts of their functionality and were labour demanding. As a means of enhancing soil fertility, they mostly tended to overshadow the greater goal of better yield. But to the smallholder any technology is a means to make farming easier within a framework defined by a range of social and environmental requirements.

Targeting soil fertility will be achieved more effectively by developing technologies that fit within local livelihoods, which retain validity when applied loosely and concurrently address more manifest priorities such as food and income. Smallholder approaches to soil fertility management should be studied as elements within broader social and livelihood systems. Research must also embrace more holistic approaches that combine different "devices" to manage soil fertility. Various soil fertility technologies are interrelated, and do not necessarily play substitutable roles. The application of one enables the other to function efficiently.

There is great potential for scientists to do soil fertility management research in which typical or likely smallholder interventions (whether as interference or enhancement) are treated as part of the process (whether through simulation or by involving farmers directly in the experimentation). The introduction of social factors as “externalities” in experimental design along side uncertainties (e.g. rain failure, ecological problems) might help to integrate farmer priorities with natural and social science concerns in soil fertility management research.

Samenvatting

Vele technologieën en concepten zijn ontwikkeld door onderszoekers om lage bodemvruchtbaarheid te lijf te gaan. Echter, de stagnering van landbouwkundige ontwikkeling de Afrikaanse regios wordt nog steeds toegewezen aan teruglopende odemvruchtbaarheid. Een van de redenen is de kloof tussen de sociale en ecologische omstandigheden van de kleine boer en de technologieën die door onderzoekers worden ontwikkeld.

De doelstelling van dit proefschrift was het bestuderen en onderzoeken van de toepassing van agro-ecologische kennis van beheer van bodemvruchtbaarheid door kleine boeren, met oog op het vergroten van de bruikbaarheid van onderzoek voor boeren in West Kenya die geen of nauwelijks toegang hebben tot hulpbronnen.

Tussen 2003 en 2005 werden participatief experimenteren, het monitoren en evalueren van technologieën en concepten explorerend onderzocht. De experimenten betroffen: (i) rotaties van graan – leguminosen; (ii) screening van nieuwe varieteiten van soyabonen voor selectie door kleine boeren; (iii) concepten van kwaliteit van organisch materiaal en 'biomass transfer'; en (iv) respons op minerale meststoffen. Boerenpraktijken die volgden op deze experimenten werden hoofdzakelijk onderzocht door diepte interviews en participant observation, met daarin speciale aandacht voor hun onderliggende argumenten en 'livelihood' doelstellingen. Participerende boeren selecteerden de velden om te verzekeren dat de bodems representatief waren in termen van type, status van bodemvruchtbaarheid en gewashistorie. Boeren selecteerden met opzet onvruchtbare stukken land die geinfesteerd waren met *Striga* om "te zien of de technologieën werkten", en als onderdeel van hun bredere doelstelling van de proeven. Deze proefveldontwerpen werden gegenereerd door onderzoekers.

Aanpassing van de concepten en technologieën gingen in de richting van korte termijn oplossingen en prioriteiten. De bevindingen laten zien dat bodemvruchtbaarheid overvleugeld was door bredere zorgelijkheden, en niet beschouwd werd als *het probleem.* De bezorgdheden van de boeren waren vooral gericht op het oplossen van bijvoorbeeld *Striga* problemen, en beperkingen ten aanzien van veevoeder, arbeid, land etc. De latente functies and voordelen van technologieën kregen dus voorrang bij de kleine boeren. Bijvoorbeeld, als soyabonen *Striga* verstikten, dan werd hieraan waarschijnlijk de voorkeur aan gegeven dan wanneer enkel bodemvruchtbaarheid verhoogd werd. Maar, als het toepassen van een concept of technologie gewasopbrengsten verhoogde op een significante en gemakkelijk zichtbare manier, dan versterkte dit de waarde voor het beheer van bodemvruchtbaarheid voor kleine boeren. Het toepassen van een geprefereerd concept hing echter in de eerste plaats af van sociale en economische kwesties die niet duidelijk naar voren komen bij het bepalen van agronomische voordelen of als op participatieve wijze het verloop en uitkomst worden nagegaan.

Het met succes toepassen van technologieën die in dit proefschrift zijn bestudeerd was afhankelijk van de kennis van het basis concept van hun functionaliteit en waren arbeidsintensief. Als middelen om bodemvruchtbaarheid te verbeteren overschaduwden zij tot op zekere hoogte de grotere doelstelling van opbrengstverbetering. Maar voor de kleine boeren is elke technologie een middel om het boeren te vergemakkelijken binnen het kader dat gedefinieerd word door een serie van sociale en omgevingscondities.

Het nastreven van verbeteren van bodemvruchtbaarheid zal meer effectief gebeuren door het ontwikkelen van technologieën die passen binnen de lokale ‘livelihoods’, welke hun validiteit behouden als ze ‘losjes’ worden toegepast en gelijktijdig beantwoorden aan meerdere duidelijkere prioriteiten zoals voedsel en inkomen. Kleine boeren benaderingen van beheer van bodemvruchtbaarheid zouden als elementen bestudeerd moeten worden in een breder sociale en ‘livelihood’ systemen. Onderzoek moet ook meer holistische benaderingen omarmen die verschillende middelen en instrumenten (‘devices’) combineren om bodemvruchtbaarheid te beheren. Verschillende bodemvruchtbaarheids-technologieën zijn gerelateerd en spelen niet noodzakelijk elkaar vervangende rollen. Door toepassing van de ene wordt het efficiënt functioneren van de ander mogelijk gemaakt.

Er bestaat een grote potentieel voor wetenschappers om onderzoek te doen naar beheer van bodemvruchtbaarheid waarin typisch en waarschijnlijke interventies van kleine boeren (interfererend of stumilerend) worden behandeld als deel van het proces (door simulatie of door boeren direct in de proeven te betrekken. De introductie van sociale factoren als “externalities” in het ontwerp van de proef, samen met onzekerheden (zoals het uitblijven van regen, ecologische problemen), kunnen mogelijk helpen bij het integreren van de prioriteiten van boeren in natuur- en sociaalwetenschappelijke overwegingen ten aanzien van onderzoek naar beheer van bodemvruchtbaarheid.

Curriculum vitae

Michael Misiko was born on May 14, 1973 in Kakamega, Kenya. He attended Ingavira Primary School, Kabras and Nyang'ori High School, Vihiga where he obtained the Kenya Certificate of Primary Education in 1987 and Kenya Certificate of Secondary Education in 1991 respectively. He joined the University of Nairobi in 1993 and obtained a Bachelor of Arts in Anthropology in 1997. He worked as a Research Assistant at the Tropical Soil Biology and Fertility (TSBF) Programme in 1995, and between 1997 and 1998. In 2001, he graduated with a Master of Arts in Anthropology from the University of Nairobi. Between 2001 and 2003, he worked as a social science research assistant at the TSBF Programme which later became the TSBF Institute of CIAT. In September 2003, he joined Wageningen University's Technology and Agrarian Development under the Participatory Approaches and Up-scaling programme funded by the Rockefeller Foundation.

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CERES Ph.D. Education statement form

Completed Training and Supervision Plan M. Misiko

Description	Department/Institute	Month/year	Credits
I. Orientation			
CERES Introductory Courses	CERES Utrecht University	May 2004	4
II. Scientific and Professional skills			
Techniques for writing and presenting scientific papers	Wageningen Graduate School – Language Centa	April 2004	4
PAU workshop on Peer Learning	PAU in Baarlo, the Netherlands	November 2003	1
Sharing experiences on PhD research and discussion of findings	PAU programme in Malindi, Kenya	13-18 June 2004	1
Learning in PAU: Support to Analysis and PhD thesis write up	PAU programme in Jinja Uganda	24-28 January 2006 .	1
"Food Security" workshop and symposium	Law & Governance Group, Wageningen at de Wageningse Berg', Wageningen	Dec 14-15, 2006.	1
IV. Research Methods and Techniques			
Ph.D. course, Socio-cultural field research methods.	Mansholt GS and CERES, in Wageningen University.	February 6 to March 2 2004..	4
V. Presentations			
"Improving Human Welfare and Environmental Conservation by Empowering Farmers to Combat Soil Fertility Degradation" (Paper presented: Integrated Soil Fertility Management technologies: review for scaling up)	African Network for Soil Biology and Fertility (AfNet) of Tropical Soil Biology and Fertility (TSBF) Institute of CIAT under the auspices of the Ministry of Scientific and Technical Research of Cameroon and the Forum for Agricultural Research in Africa (FARA). In Yaoundé, Cameroon.	May 17 – 22, 2004.	4
"Participatory Approaches to Research and Scaling Up (PRSU) Training Workshop (Papers presented:	AfNet of Tropical Soil Biology and Fertility (TSBF) Institute of CIAT, Nairobi, Kenya	Sep 19 – 30, 2005	4
1. "Cult": a not so successful case in participatory agricultural research in western Kenya	2005. TSBF Institute, Nairobi, Kenya		
2. "Opting out": explaining rejection of participatory soil fertility processes among smallholder farmers	2005. TSBF Institute, Nairobi, Kenya		
VI. Seminars			
Advanced Research Seminars.	TAO, PPS & RDS (Wageningen University Chairgroups)	Sept 2003 – June 2004. April, May, Nov and Dec 2006	1
Total			**25**

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Farmers and TSBF's Mukalama, J. assess signs of low soil fertility on a collective experiment in Butula, Kenya.