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EXPERIENCES WITH FARMER PARTICIPATORY MOTHER-BABY TRIALS AND WATERSHED MANAGEMENT TO IMPROVE SOIL FERTILITY OPTIONS IN MALAWI

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1.0 INTRODUCTION

Participatory research approaches are increasingly becoming the foundation of integrated nutrient management. Until recently there has been almost no farmer uptake of soil fertility recommendations in Malawi. This has reduced the confidence of researchers and advisors. Recommendations have tended to prescribe relatively high rates of fertilizer countrywide, without taking into account the bio-economic context. This includes farmer priorities for soil and crop management, other nutrient resources in the farming system, profitability of fertilizer use, and agroecozone differences in cropping system response to inputs. New approaches are needed. Soil fertility specialists and agronomists in Malawi are working together to develop practical participatory methods that document the indigenous technical knowledge that many farmers possess, improve how well agronomists understand farmer decision-making to generate more appropriate nutrient management technologies, and facilitate farmer experimentation.

Farmer involvement in technology generation has been limited in the past. Farming systems research has been conducted for over 15 years in Malawi, and much of the soil fertility research of the National Research Program in the Malawi Ministry of Agriculture and the University of Malawi is conducted on-farm (Heisey and Waddington, 1993). However, the priority for much of the soil fertility management work is often assumed to be maximization of yield or economic return. Smallholder farmers may often be more interested in prioritising the best return from a very small investment, or reducing risk related to food security (Ahmed *et al.*, 1997). An in-depth understanding of farmer soil fertility management and decision-making is the key to developing and deploying technologies that will find use.

Few studies exist that document the effectiveness and practicality of different participatory methods. Tools are required that address both short term time-frames, where best bet technology options are ready for testing with farmers, and longer time-frame participatory research to address more intractable problems. Information is also limited on the correlation of scientific perspectives on integrated nutrient management and soil fertility characteristics compared with farmer perspectives and indicators (Onduru *et al.*, 1998).

The studies reported on here are Soil Fert Net endeavours that are part of a long-term programme primarily funded by the Rockefeller Foundation, to improve food security in Malawi through raised soil productivity for smallholder farmers. The main objectives were to:

1. Document farmer indigenous knowledge of soil characteristics and management techniques.
2. Evaluate farmer participatory methods through case studies of action research conducted in Malawi.
3. Compare short-term participatory approaches targeting rapid farmer evaluation and dissemination of best-bet management options, and long term watershed based approaches linking community participation with research.
4. Reprioritise Malawi research on soil fertility technology generation to take into account the priorities of smallholder farmers.

2.0 BACKGROUND AND CONTEXT

2.1 Malawi agro-ecosystems

The sub-humid tropical agroecosystems of Malawi are characterized by a long dry season, with a unimodal precipitation pattern between November and April. In southern Malawi, precipitation sometimes occurs over a long period, with sporadic showers in May, June and July. Dominant ecosystems were originally high altitude grasslands and mid altitude Miombo woodlands. Malawi soils are generally deep profile Alfisols or Ultisols of moderate fertility (Young and Brown, 1962). Very low fertility soils are also present, including weathered Oxisols and shallow, eroded soils on steep, deforested sites. Soil fertility has declined with continuous maize production, minimal use of fertilizers and a growing human population that has precluded the use of traditional fallow systems (Kumwenda *et al.*, 1997). Soils in the Malawi smallholder sector generally have low to moderate organic carbon levels, and very low nitrogen contents (Table 1 and see Snapp, 1998).

Because of the high human population density (> 80 persons/km), land is continuously cropped and farm size is generally about 1.0 to 2.0 ha per farm family (Table 1). The poverty of the smallholder sector is indicated by extraordinarily high levels of malnutrition among preschool aged children, and a hungry period of about six months among the poorest third of households (Kanyama-Phiri *et al.*, 1998; Sahn *et al.*, 1992).

2.2 Maize-based cropping systems

Maize dominates the landscape in subsistence agriculture of southern Africa, and nowhere more so than in Malawi where maize is grown on 80% of smallholder farm land (Wendt *et al.*, 1994). The diversification of maize-based cropping is targeted by recent government initiatives, and there has been some growth in smallholder production of burley tobacco and soyabean (Kumwenda *et al.*, 1997). The primary cash crops grown by smallholders are tobacco and, in the dry lakeshore area, cotton (Table 1). The most widely grown legume in Malawi cropping systems is groundnut. It is grown as an intercrop with maize and as a sole crop.

In the 1970s, groundnut was an important export crop in Malawi, but now it is grown primarily for household consumption and local markets. Other important legumes are pigeonpea (in the South), common bean (widely grown in higher altitude areas) and, more recently, soyabean (Table 1). Cassava is grown in some areas as a subsistence crop, primarily in the Southern Region and the Northern Malawi lakeshore.

Four agroecosystems in Malawi cover about 70% of smallholder agricultural production (Figure 1). These include the following areas, where the names of the study sites are indicated in parenthesis:

1. Central Malawi sub-humid tropical mid-altitude plain (Lilongwe and Kasungu).
2. Central Malawi sub-humid hills (Dedza).
3. Southern Malawi semi-arid zone (Mangochi).
4. Southern Malawi mid-altitude sub-humid plateau (Zomba).

Table 1. General comparative information of the sites where participatory research was conducted. (Data from Kamanga, 1999, Kanyama-Phiri *et al.*, 1998 and Snapp *et al.*, 1998).

Variables	**Central Malawi sub-humid tropical mid-altitude plain (Lilongwe and Kasungu)**	**Southern Malawi mid-altitude sub-humid plateau (Zomba)**	**Southern Malawi semi-arid zone (Mangochi)**	**Central Malawi sub-humid hills (Dedza)**
Household size (number of persons)	5.4	5.6	6.7	5.5
Land holding size (ha)	2.6	0.56	1.5	0.8
Main crops	Maize, tobacco, groundnut, bean, soyabean	Maize, pigeon pea, cassava, groundnut, bean	Maize, cotton	Maize, bean, potato
Residue incorporation (% of farmers doing)	14	93	5	55
Annual rainfall (mm)	600-800	1000-1200	600-800	800-1000
Rainfall duration (months)	Dec-Apr	Oct-May, sporadic June-Aug	Oct.-March	Nov-Apr
Agroecozones	Sub-humid mid altitude plain	High rainfall sub-humid mid altitude zone	Low rainfall, semi-arid low altitude	High rainfall sub-humid high altitude
Altitude range (masl)	1000-1300	1000-1200	200-500	1400-1700
Soil texture and types	Sand, loamy sand	Sandy loam, loamy sand, sandy clay loam	Sand, loamy sand	Sandy loam, Loam sand, clay sand
Total nitrogen in soil (ppm)	0.51	0.34	0.57	0.22
Soil organic carbon (mg/kg)	15	11	14	12
Soil pH	6.4	6.6	6.9	5.5

In general, Central Malawi agroecosystems are less populated and have a high proportion of sole cropped maize, with some tobacco and groundnut production, compared to the high population density and intercropped maize based systems of Southern Malawi.

Soil fertility is becoming widely depleted in Malawi but the poverty of the smallholder farmers, and limited profitability of fertilizer has precluded wide scale use of fertilizer, although many farmers have experience of using it. Soil fertility management strategies of small-scale farmers involve limited use of fertilizers (Table 2), and the incorporation of crop residues, to varying extents. As shown in Table 1, residue incorporation is widespread in the Southern Region and limited in the Central Region. Residues are generally of low quality, consisting of maize stover and weeds. This may be the biological underpinning of a common farmer preference for burning the residues in Central Malawi, rather than incorporation (Snapp *et al.*, 1998). The Central Region experiences a longer dry season than the South (Table 1) and incorporation of low quality residues under these climate conditions can immobilize nitrogen during critical early growth stages of maize.

In contrast to the problems sometimes associated with incorporation of maize residues, the incorporation of grain legume residues has the potential to enhance soil nitrogen status. Improved agronomy and residue management is of critical importance to derive soil fertility benefits from legume production. At research stations, grain yields of legumes are consistently over 2 t/ha, while farmer grain legume yields remain around 0.6 t/ha (Crop estimates 1997, Malawi Government Ministry of Agricul-

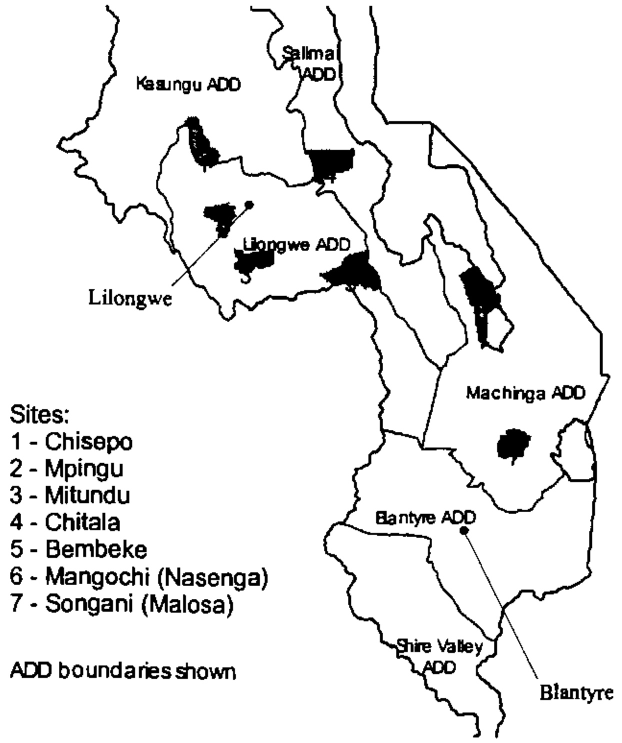


Figure 1. Map of Central and Southern Malawi with case study sites indicated by extension planning area (EPA) designation. The EPA is an extension administrative sub-unit of the eight agricultural development divisions (ADD) in the country. Sites 1-5 are located in Central Malawi, and 6-7 in Southern Malawi.

ture and Irrigation, Famine Early Warning System, Lilongwe, Malawi). Residue yields follow a similar pattern. Legumes are often grown as low density intercrops with less than one legume plant per maize plant in the field (Kanyama-Phiri *et al.*, 1998; Shaxson and Tauer, 1992). Low-density planting, low growth rate and minimal management all contribute to current low yields from grain legumes and limited production of residues.

Researchers have conducted many experiments to develop alternative organic nutrient sources for smallholder farmers in Malawi, including agroforestry systems, green manures and legume rotations (MacColl, 1989; Kanyama-Phiri *et al.*, 1998).

Farmer uptake of these technologies has been effectively nil to date, although biologically some of these systems have been shown to enhance soil productivity through nitrogen fixation, carbon input and conservation of nutrients (Snapp *et al.*, 1998). High labour and skilled management requirements, as well as limited profitability in the

Table 2. Fertility management extension recommendations in field guides: survey of field staff recommendations and fertilizer use by farmers in two agroecozones of Malawi. Note that fertilizer is applied by farmers primarily to tobacco. Data from survey conducted in June 1998 n=67.

Recommendation Source	Hybrid Maize kg/ha	Tobacco kg/ha
Current Recommendation (Extension Guide to Agriculture Blanket recommendation for Malawi)		
	DAP 80 + Urea 175 -or- 12.5 t/ ha khola manure	Compound C 300 + CAN 200
Proposed New Recommendation*		
Kasungu (mid-altitude, medium textured soils)	23:21:0:4S 100 + Urea 100	NA
Mangochi (lakeshore, light textured soils)	32:21:0:4S 100 + Urea 150	
Survey response of extension field staff		
Kasungu	23:21:0:4S 100-280 + Urea 100-280	Compound D 200-280 + CAN 200-280
Mangochi	32:21:0:4S 100-150 + CAN 100-150	Compound D 200-280 + CAN 200-280
Survey response of farmers		
Kasungu	32:21, Urea, CAN 58 kg/ha 10% of farmers use manure	
Mangochi	Primarily CAN 54 kg/ha 7% of farmers use manure	

*Benson, T. 1997. The 1995/96 Fertilizer Verification Trials in Malawi, Economic Analysis of Results for Policy Discussion, report by Action Group 1, Maize Productivity Task Force, Ministry of Agriculture and Irrigation, Government of Malawi, Lilongwe, Malawi, mimeo.

short term, appear to be significant barriers to farmer acceptance of organic-based technologies (Kumwenda *et al.*, 1997).

This situation, however, has recently changed. Farmers have experienced a marked increased in the real price of fertilizers due to devaluation of the local currency and removal of fertilizer subsidies, and a reduction in the maize to fertilizer price ratio. Farmers have responded by increased experimentation with alternatives. Those tried by farmers include the use of goat manure, crop residue incorporation and crop rotations (Table 3). However, Malawi's low livestock densities (Kumwenda *et al.*, 1997) limit the potential for significant fertility inputs from animal manure. Furthermore, increasing the proportion of legumes in the current maize dominated and densely cropped landscape is challenging. It is important to note that historically the introduction of a new crop has tended to be as a substitute for another crop, not as an additive function, and maize density remains the same in the cropping system (Shaxson and Tauer, 1992).

We hypothesize that legume-intensified systems must increase maize yields and returns more than the current widely grown and relatively low-labour demanding maize-based systems. Trends during the late 1990s suggest that a window of opportunity is opening in Malawi. The market and policy environment is becoming more favourable for grain legumes and other crops, with increased privatisation, and changes with government policies that had historically favoured maize (Sahn *et al.*, 1992).

2.3 Background of farmer participatory research in Malawi

Low or nil uptake of organic recommendations is a widespread problem in subsistence agriculture around the globe. An extensive literature on farmer participatory research methods has been a response, in part, to farmer non-adoption (Chambers and Ghildyal, 1985; Fischler, *et al.*, 1996). The new participatory methods are suggested to be more effective and efficient in developing varieties and technologies that interest farmers (Sperling, *et al.*, 1993; Versteeg and Koudokpon, 1993). Yet, currently researchers based in public institutions such as the Malawi Ministry of Agriculture, Department of Agriculture Research and Technical Services, and University of Malawi, Bunda College of Agriculture, rarely use participatory approaches. Agronomists often voice scepticism of participatory methods, which are characterized as time-consuming and providing mostly qualitative data that biological scientists are unfamiliar with and cannot readily integrate with quantitative data.

Farmer input and consultation does occur in Malawi. In recent years reconnaissance surveys have

Table 3. Experimentation by farmers in Kasungu and Mangochi, from reconnaissance survey in 1997, n=40 (D. Rohrbach and S. Snapp, personal communication, 1997). If a farmer was trying out the practice this was considered experimentation, but not if it was an alternative soil fertility management practice generally used by the farmer.

Soil fertility technology experimentation	Percentage of farmers interviewed*	
	Kasungu	Mangochi
Manure (primarily goat or pig manure, targeted to planting station of vegetables, maize and tobacco)	10	25
Compost (targeted to planting stations of maize, vegetables and tobacco)	20	0
Combined use of fertilizer with manure or residues (organic + inorganic nutrient sources)	10	15
Legume rotation, for soil fertility improvement (soyabean, mucuna)	10	20
Furrow for soil fertility improvement	10	0
Residue incorporation (maize residues)	15	20
Farmers not experimenting	30	35

*Some farmers experimented with more than one technology so total sum is greater than 100%

been used to help prioritise research and trials are often located on farmer's fields. Fertilizer recommendations for maize are being revised, with the involvement of about 2000 extension field assistants conducting on-farm trials in a verification exercise (Benson, 1997). Extensive on-farm research has included the study of variety adaptation, crop rotations and agroforestry systems (Heisey and Waddington, 1993). However, there is still a lack of practical methods to allow rapid and quantitative documentation of farmer perceptions of new technologies. Researchers often conduct informal discussions with farmers to assess technologies and they may incorporate unacknowledged bias. For example, an assessment of bean research in Malawi suggested that historically researchers and extension staff have worked with male farmers, missing perceptions of women farmers. Yet, women are generally responsible for growing beans and have a high degree of indigenous knowledge about bean varieties (Ferguson, 1994).

Agronomists can most readily adopt participatory methods that are relatively inexpensive and provide feedback in a rapid manner. Farmer expert panels and farmer-led research groups have been suggested by researchers in Botswana and Rwanda as ways to incorporate farmer input to drive researcher agendas, and to take the next step, to improve farmer experimentation (Norman *et al.*, 1988; Sperling, *et al.*, 1993). This has proved an effective approach to improve varieties. However, we note that soil management decisions and investment in soil fertility are made on an individual farm family basis in the Southern Africa region, not by village groups (Ahmed *et al.*, 1997), and in the two case studies presented here the work was carried out primarily with individual farmers. Consultation occurred at the community level through village wide meetings and field days carried out at frequent intervals.

Near term and longer term approaches to farmer participatory research are presented in this paper. Practical tools are discussed that, through two case examples from Malawi show how agronomists can incorporate farmer input, early and often. These include documentation of farmer indigenous knowledge and decision-making concerning soil management. Building on this foundation, researchers used novel trial designs and a consultative approach to facilitate the generation and testing of appropriate technologies.

3.0 STUDY APPROACH, MATERIALS AND METHODS

Two studies from Malawi soil fertility research are presented to show how practical, participatory methodology was developed. We highlight problems encountered and lessons learned. Case study number one reports on a near-term "mother/baby" trial approach (Figure 2). It involves farmer and researcher partnerships in selected villages representative of four major agroecosystems in central and southern Malawi (Table 4). The goal is rapid development, testing and deployment of "best bet" soil fertility options for smallholder farmers. Case study 2 focuses on a watershed where farmers and researchers worked together through every step from problem identification to experimentation (Table 4).

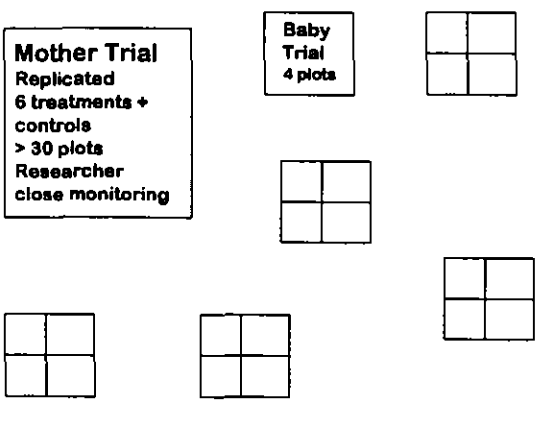


Figure 2. Design of farmer participatory methodology to evaluate soil fertility best bet technology options: Mother trial plus 10 or more satellite baby trials.

3.1 Case Study 1: Mother Baby Trial Approach

3.1.1 Site characterization

Case Study 1 was done in Chisepo, Dedza and Mangochi. The area is relatively dry with an average annual rainfall of 600 mm and high potential for agricultural production. Maize-based cropping systems dominate agricultural activities in the area. The main road from Lilongwe to Kasungu facilitates accessibility by researchers to the areas. Site characterization in Chisepo included socio-economic information on smallholder crop management systems from recon-

Table 4. Comparison of two case studies of farmer participatory research approaches.

	Near-Term FPR	Medium-Term FPR
Selection of location	Selection of representative, clustered villages in agroecosystems of interest.	Selection of representative watershed in agroecosystem of interest.
Problem identification	Researchers, with farmer input through reconnaissance survey.	Farmers and researchers, through group identification of resources, problems and opportunities.
Design of best bet technology options to test with farmers	Researchers, based on past on-farm research results and farmer problem identification.	Researchers, based on research results and farmer problem identification.
Objectives with research with farmers	1. To assess best bet performance on-farm 2. To quantify farmer assessment of best bets 3. To improve farmer experimentation by providing information and better technology options.	1. To assess best bet performance on-farm 2. To quantify farmer assessment of best bets 3. To improve understanding of process (nutrient cycling, growth of introduced species) and design better technologies.
Site Characterization	Early season sampling of topsoil and analysis of pH, texture and nitrate.	Farmer knowledge of natural resources characterized by transect walks, farmer and researcher classification of soils through analyses, matrix ranking.
Design of on-farm trials	Mother/baby trials: Within-site replicated RCB "mother" trials (1 per location and one-farmer, one-replicate baby trials (-30 per location).	Transects-one-farmer, one-replicate trials, stratified with 10 per landscape position. Randomized complete block design.
Biological data monitored	Trial operation dates, plant populations, grain yield, residue biomass and quality analysis, soil analyses.	1. Trial operation dates, plant populations, grain yield, residue biomass and quality 2. Dynamics of soil N and water.
Socio-economic data monitored	1. Farmer survey to assess socio-economic groups 2. Farmer assessment of best bet technologies through: matrix ranking, rating of positive and negative technology trials 3. Economic analysis-gross margin analysis.	1. Socioeconomic survey of farmers 2. Economic analysis of technology performance.

naissance surveys (Table 3; D. Rohrbach and S. Snapp, unpublished, 1997) and chemical and physical analysis of the topsoil (Table 1). The surveys helped to obtain information about agriculture in the area.

3.1.2 Prioritising topics for farmer/research investigations

Although not initially anticipated, a similar topic was chosen for both case studies: 'Partnerships to develop improved soil fertility options for farmers'. Researchers defined the focus of case study one initially, as the development of soil fertility technologies within the expertise and mandate of collaborating researchers. Survey information was used to identify the soil fertility problems in the area. This choice was supported by NGO participatory surveys (CARE International, 1998), and research showing that soil fertility was a high priority topic in many rural Malawi communities (Kanyama-

Phiri *et al.,* 1998). Community meetings and a reconnaissance survey were used to choose representative villages. The researchers then met with farmers to discuss the problem identified through the survey. Farmers confirmed the problem and agreed to participate in the research using legumes.

Goals of researchers included the evaluation of technologies from the perspective of farmers, in conjunction with monitoring biological performance of the technologies under on-farm conditions (Table 4) and helping farmers to improve experimentation. Potential soil enhancing technologies were assessed for effectiveness, cost and practicality, and the best bets determined through a consensus process among researchers. Several years of data on technology performance from on-farm trials and researcher experience were called upon to design the technology options that performed well across a range of environments and that required minimal inputs.

3.1.3 Design of trials in Case Study 1

The mother-baby trial approach allows quantitative data from researcher managed on-farm 'mother trials' to systematically be cross-checked with farmer-managed 'baby trials' with similar themes (Figure 2). A novel trial design was initiated to meet both farmer and researcher objectives. The design included simple 'one-farmer, replicate' trials as satellites to 'within-site replicated' trials carried out by the researchers (Figure 2). This trial design was named "mother and baby trials'' by a farmer working with researchers in the Dedza area. The mother trials tested eight different technologies with full replication, whereas the baby trials tested a subset of three technologies at a site, plus a control.

Each plot was 10m by 8 ridges in the mother trials while plots were 10m by 10m in the baby trials. Thirty-two farmers were chosen at a meeting on a voluntary basis and with help from the village headman in each of the two villages. Purposeful farmer selection was also done to include resource-poor as well as well-off farmers, and male and female-headed households (Mutsaers *et al.,* 1997). The best-bet technologies were designed by the researchers with the goal of improving soil productivity, with minimal cash and labour inputs. Due to the limited use of fertilizers by smallholder farmers (Table 2), the 'best bet' technologies initially targeted legume-intensification and integrated management of manure and small amounts of fertilizers (Table 5). Mucuna, pigeon pea, groundnut, *Tephrosia* and soyabean were used in the trials for rotations or intercropping with maize resulting in eight 'best bet' treatments. The case study was developed from what was initially a researcher-led effort to synthesize survey information and years of results from on-farm research. These best-bet options attempted to take into account the resource limitations of the majority of smallholder farmers in Central and Southern Malawi. Monitoring was carried out on spontaneous farmer experimentation that emerged among farmers.

The one-farm, one-replicate model has been recommended for on-farm technology testing in the smallholder farm agriculture sector (Fielding and Riley, 1998; Mutsaers *et al.,* 1997). A simplified trial design with a maximum of four plots and no replication within a farmer's field fits limited field size, and simplified the design, which improved the ability of farmers to evaluate the technologies. Replication within each farmer's field is not always the most efficient approach for comparing cropping system technologies, as there are tradeoffs between many replicates across sites versus a few sites replicated within each site (Mutsaers *et al.,* 1997). However, replication within a site and intensive, uniform management is important for research on biophysical processes and rigorous testing of biological performance. Thus, the mother-baby trial design allows both sets of objectives to be met by linking both types of trial. The trial design also allows the farmers to gain experience with a few of the best-bet options and rigorously assess them, as they carry out the baby trials.

3.1.4 Performance of best bet trials and farmer evaluation

Farmers from different socioeconomic groups evaluated technology performance across a range of agroecozones. In the first year, all legumes gave good amounts of biomass, with mucuna leading. All legumes were incorporated at 50% flowering. Response of maize to legume residual nitrogen in the following year was encouraging in all the treatments. The highest performance was recorded in mucuna/maize rotations with pigeonpea/groundnut/maize rotation second (Table 5). Based on maize yield as an indication of improved soil fertility, mucuna was ranked one by all the farmers in Chisepo

Table 5. Soil fertility improving technologies: description in terms of biological and farmer considerations. Case study one evaluated technologies 1 – 3, case study two evaluate all technologies except 2 and 3.

Technology	Population density (X1000)	Biological characteristics	Farmer perceptions of characteristics
1. Maize control	Maize: 37	Maize hybrid MH18, three maize plants per planting stations, 0.9m X 0.9 m.	Current farmer practice throughout Malawi, productive with minimal labour.
2. Maize + relay intercrop Sesbania sesban	Maize: 37 Sesbania: 7	Maize hybrid MH18 three maize plants per planting stations. 0.9m X 0.9m. Sesbania sesban planted at first weeding in the furrow between maize-planted ridges. Sesbania grows for 10 month before leaves are incorporated.	Sesbania sesban seedlings establish well in furrows, underutilized space in the cropping system.
3. Maize + relay intercrop Sesbania sesban +N 45 kg fertilizer	Maize: 37 Sesbania: 7	Maize hybrid MH18, three maize plants per planting stations, 0.9m X 0.9m. Sesbania planted as above. Fertilizer 45 kg N per ha.	Residues from Sesbania are combined with fertilizer to support higher maize production.
4. Maize + pigeonpea (PP) intercrop	Maize: 37 Pigeonpea: 37	Temporal compatibility. PP variety ICP 9145 planted at the same time as maize, 3 plants per planting station spaced halfway between each maize station. PP grows slowly, which reduces competition with maize.	PP is a bonus crop. Low density system minimizes impact on maize yield.
5. G'nut + PP intercrop year 1, rotation with maize year 2.	Groundnut: 74 PP: 37	Groundnut variety JL 24 or CG 7 was grown as a single row on ridges spaced at 0.9m spacing. To enhance residue biomass quantity and quality, a' bonus' PP crop is intercropped with the short-duration grain legume.	Legume seed density takes into account expense of groundnut seed and farmer-adaptable seedling rates. PP is a bonus crop.
6. Soybean + PP rotation with maize year 2.	Soybean: 444 PP: 37	Same as groundnut + PP, except a double of 5 cm spaced soybeans planted along each ridge. Indeterminate variety Magoye that does not require inoculum (nodulates with indigenous *Rhizobium*) use, to minimize performance under on-farm condition.	High density of seed is possible given that seeds are smaller and cost is cheaper than groundnuts. PP is a bonus crop.
7. Maize + tephrosia relay intercrop	Tephrosia: 20 kg/ha Maize: 37	Temporal compatibility enhanced by planting Tephrosia at 1st weeding. Tephrosia has an initially slow growth habit. Green manure screening studies have shown the widespread adaptability of Tephrosia to Malawi agroecosystems, producing about 2 t/ha as a relay intercrop.	For green manure system to be adapted by farmers, it must minimize labor requirement. Seed is broadcast along ridge and incorporated by weeding operation.
8. Mucuna	Mucuna: 74	Mucuna has a wide spread adaptation as green manure or grain legume, it produces about 5 t/ha residue biomass and 1.8 t/ha seed yield for most agroecosystems.	Farmers eat or sell Mucuna seed in some parts of Malawi Weed suppression may be a major benefit of mucuna.
9. Manure + 17 kg N fertilizer	Maize: 37	Manure is applied at the rate of 2 handfuls per planting station (-5 t/ha) combined with a small amount of fertilizer.	Farmers often have only small amounts of nutrients from different sources. Combined use may optimize benefits.

and Mangochi. However, farmers pointed out that the mucuna/maize practice needed more land. Preference was given to maize/pigeonpea intercrop because the same land grows two crops at a time.

Evaluation based on calories produced allowed comparison of technologies that primarily produce maize and those that produce maize and grain legumes. All of the technologies produced as many calories as sole maize in the first year. This indicates that the initial objectives were met for the best bets, to produce as many calories as unfertilised maize. In two more years it will be possible to determine if the other objectives were met, to produce more calories over time through incremental contribution to soil fertility. Note that soil fertility benefits from these short-term best bets are gradual, compared to the soil rehabilitating features of, say, improved fallows or green manure rotations. These are a minimal risk strategy that reliably meets the food security requirements of the smallholder farmers. Over time, the relay intercrop maize-*Tephrosia* system is expected to produce the highest maize yields. The maize-pigeonpea intercrop system is expected to remain the lowest risk system, consistently producing maize plus a bonus pigeonpea crop. Thus, soil fertility benefits are expected to be the lowest from this system. The intermediate option is the double-up grain legume system, producing both legume and maize yields, and moderate soil fertility benefits.

The double-up legume system was the outstanding performer in the first year of testing; it consistently produced more calories than any other system. However, this rotation system requires the investment of land in legume production that could otherwise be in maize production. Among farmers with small land holdings, this may be a constraint to adoption. Until recent market liberalization in Malawi, limited returns were realized from legume production. This has reinforced the dominance of maize, and constrained uptake of grain legume based rotations. The recent increase in private traders has introduced a dynamic market for grain legumes. Prices vary markedly, but groundnut, soyabean and pigeonpea are consistently obtaining 50 to 100% higher prices than maize, suggesting the potential for the substantial economic benefits from the double up grain legume system in the current market context (Giarrizzo and Barlow, 1998).

Farmers' evaluation of the best-bet trials provided quantitative feedback to researchers through pairwise rating of technologies, and qualitative feedback through farmer-researcher meetings and comments recorded at field days. Farmers were also assessing the wider range of technologies. Farmer's assessment was thus integrated into on going research efforts. The criteria used by farmers to evaluate the technologies include yield of maize after legume, legume grain production, labour demands of the legume, suitability in the cropping systems, uses of the legumes and seed availability. Figure 3 presents the ranking results for male and female farmers, as an average for each research site. For male farmers, sole maize was ranked fourth, with a score of one or less at all sites. The two pigeonpea intensification technologies were the highest ranked, with a score of over two in all the cases.

Ranking by female farmers is represented in Figure 3, from interviews with female heads of households who conducted trials. Research in Malawi and Kenya has suggested women-headed households tend to prioritise the production of food for consumption by children (Kennedy and Cogill, 1987; Sahn *et al.*, 1992). Our results confirm these earlier findings. Female farmers consistently ranked maize-*Tephrosia* lower than did male farmers.

Women prioritised the best-bet grain legume intensification and control technologies that emphasised food production, over the soil-fertility enhancing and unproven maize-*Tephrosia* 'best bet'.

Farmers at different locations had surprisingly similar assessments of the best-bet options (Figure 3). This suggests that the best bets are able to perform well for different agroecozones and socioeconomic groups. The consistency of expert farmer rankings of plant breeding materials has been documented in earlier farmer participatory research (Kitch *et al.*, 1998; Sperling *et al.*, 1993). Our work is the first report we are aware of showing consistency of farmer evaluation of soil types and climates in earlier work (Snapp *et al.*, 1998). Pigeonpea and *Tephrosia vogelii* were chosen for their ability to produce at least 2t/ha biomass for a wide range of soil types and climatic conditions, as well as their ideal intercrop characteristics of temporal compatibility (initially slow growth) and long duration, and indeterminate growth habit. Further, crop species used in the doubling up legume technology were targeted by agroecozone.

3.2 Case Study 2: Watershed Based Farmer/ Researcher Partnerships

3.2.1 Site characterization

In Songani, characterization involved an intensive exercise to document farmer knowledge of soils (Kamangira, 1997). Site landscape position and soil analytical characterization of the profile were also determined. In this watershed approach, it was felt that understanding soil characteristics from the farmer's perspective enhanced the ability of research to communicate with farmers and to develop technologies that are more appropriate.

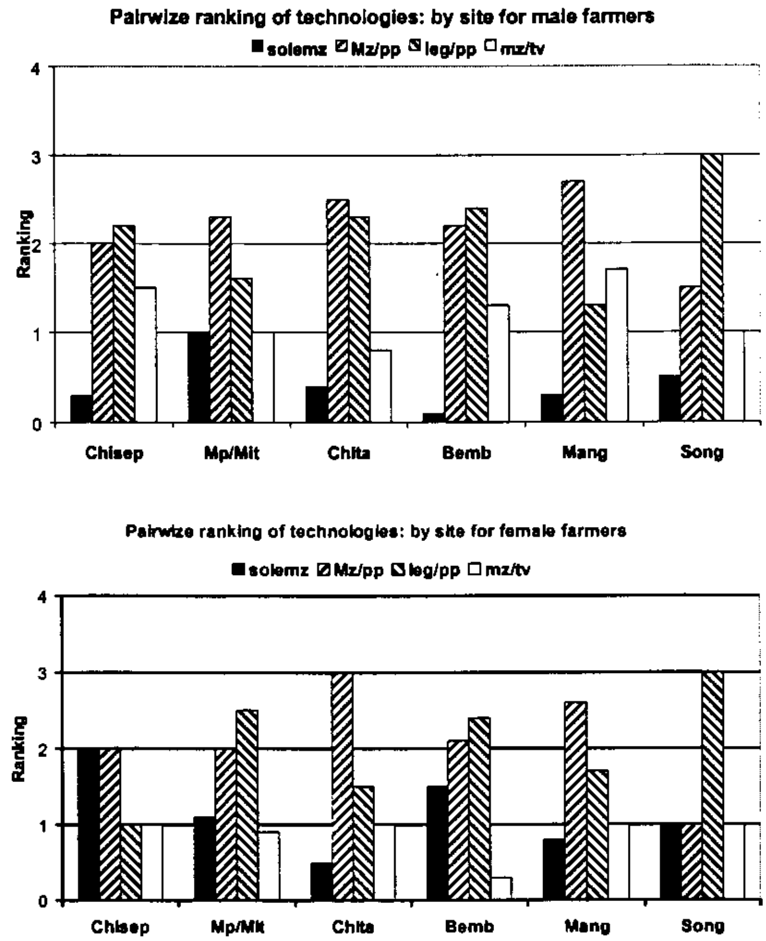


Figure 3. Ranking of soil fertility technologies by male and female farmers at sites in Malawi.

Problem identification involved a high degree of community participation in case study two. Researchers met with groups of farmers from the Songani watershed and used resource mapping and other visual aids to discuss and prioritise the problems faced by the community (Kanyama-Phiri, *et al.,* 1998). Initially researchers thought soil conservation would be an important issue in Songani, but farmers prioritised soil fertility related issues as major community-wide problems, namely; lack of access to inputs due to increasing costs, land shortages and declining soil fertility (Tables 4 and 5). Community meetings were held to define natural resources and prioritise problems and opportunities (Kanyama-Phiri *et al.,* 1998; Wellard, 1996). Transects were defined across the watershed (Figure 4) and in-depth interviews conducted with farmers in them. Tools such as transect design and resource mapping, combined with on-farm trials, allowed a unique approach to linking research on processes (e.g., N dynamics) with farmer participatory trials (Phiri *et al.,* 1999). Indigenous knowledge of soils was evaluated in relationship to chemical analyses of soil samples (Table 4; Kamangira, 1997). This information was used to develop a research initiative on resource efficiency on a landscape basis linked to trials that tested organic matter technologies, carried out with farmers at different landscape positions (Figure 4).

The watershed has been characterized biophysically and socio-economically, and this platform is being used by the researchers that have committed themselves to work over time to involve communities in problem definition as well as thinking about long term solutions (Kamangira, 1997). Developing alternative soil fertility technologies that require minimal cash was identified as a top priority topic for a farmer/researcher initiative.

3.2.2 Design of best-bet trials

Case study two was conducted in a carefully chosen, representative watershed, which acted as a platform for farmers and researchers learning together. The case study included testing of the best bet technologies by farmers chosen at random from previously described transects, to represent different landscape positions in the Songani watershed (Figure 4). Forty-eight farmers were chosen for the

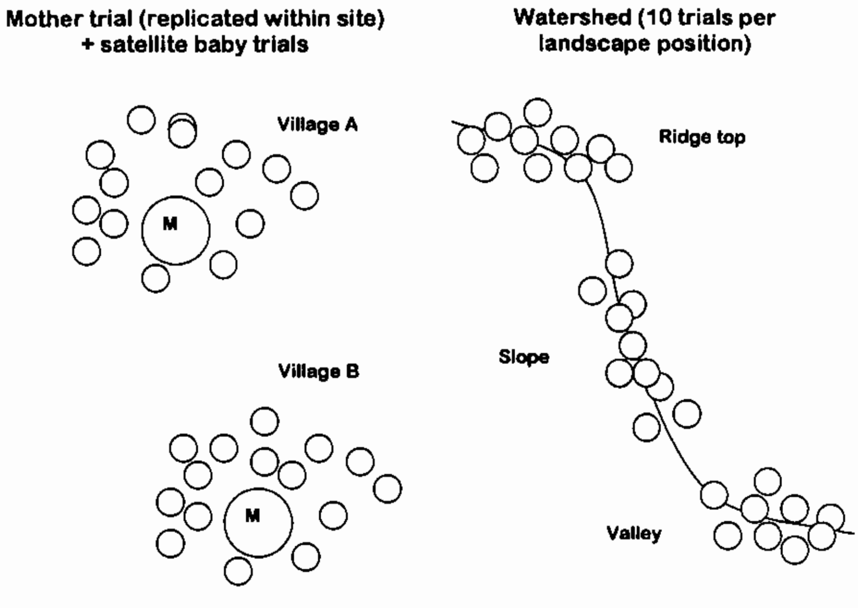


Figure 4. Mother and Baby trials, and a watershed approach.

study at random following the survey-sampling frame. In discussions with farmers, a *Sesbania* relay system, pigeonpea, *Tephrosia* intercropping systems and sole maize (control) were identified and tried in all landscape positions. Each farmer had four plots each measuring 10m by 10m. The *Sesbania* relay intercrop was compared to sole crop maize, maize intercropped with a long-duration grain legume (pigeonpea) and a maize-relay intercrop green manure system (*Tephrosia vogelii*). These are technologies 1, 4 and 7 in Table 5. The legume intensification systems were tested in the presence and absence of 48 kg fertilizer N per ha at different landscape positions in Songani watershed. Labour monitoring and socioeconomic surveys were conducted to allow evaluation of the returns farmers realized per unit of labour and cash invested.

The design of soil fertility-improving technologies in this area was a challenge. Land use is intensive and farm size is small in the Songani watershed. This is typical of the mid-altitude plateau of Southern Malawi (Table 1). Intercropping with maize and legumes is commonly practiced in Southern Ma-

Table 6. Farmer perceptions of environmental change and problems limiting crop production and community sustainability in Songani catchment, Zomba, Malawi (Adapted from Kamanga, 1997 and Wellard, 1996).

Environmental change	**Indicators identified by farmers**	
General	Decline in soil fertility, food supplies decreasing, low yield, and erratic rains	
Signs associated with decreasing soil fertility	1. Soils changing colour from dark to light. Low yields 2. Weeds indicating soil infertility increasing: witchweed (Striga) and chiundu 3. Soils have dried up and become dilute 4. Soils need fertilizers to produce crops	
Problem definition	**Top priority problems** (% of 157 farmers)	**Potential solutions identified by communities** (*researchers agreed to help farmers address)
Lack of inputs	30.9	1. Government lower input costs 2. Low cost technologies to increase productivity*
Land limitation	28.5	1. Increase use of steep slope areas 2. Increase productivity of existing land*
Declining soil fertility	17.0	1. Increase efficiency of fertilizer used* 2. Increase benefits from legume-intensification systems* 3. Increase access to fertilizers, manure, fallow land
Soil erosion	13.0	1. Boundary marker ridges constructed on the contour 2. Waterways/planting trees and grass in gullies 3. Construct stone lines
Other	10.6	

lawi, in contrast with the sole crop production that dominates elsewhere in Malawi. The consequences of introducing a green manure legume relay intercrop system could be displacement of grain legumes intercropped with maize, and inadvertent reduction of the system productivity (Shaxon and Tauer, 1992). The system was examined for an under-exploited niche. A ridge/furrow system is ubiquitous in Songani, as it is throughout the smallholder sector of Malawi.

The furrow provides an entry point for the introduction of a relay green manure that does not compete with the main crops; however, the furrow is not a conducive environment for seedling establishment. The subsoil exposed in the furrow experiences intermittent flooding and it is a compacted, low nutrient media. Research on the nearby station suggested that *Sesbania* seedlings could be readily established in the furrow and produce sufficient residues over 10 months to contribute about 100 kg N per ha (Maghembe *et al.,* 1997). Thus, an opportunity was identified: establish a relay intercrop of *Sesbania sesban* in the furrow, between the existing maize based cropping system (Table 5).

3.2.3 Performance of trials in case study two

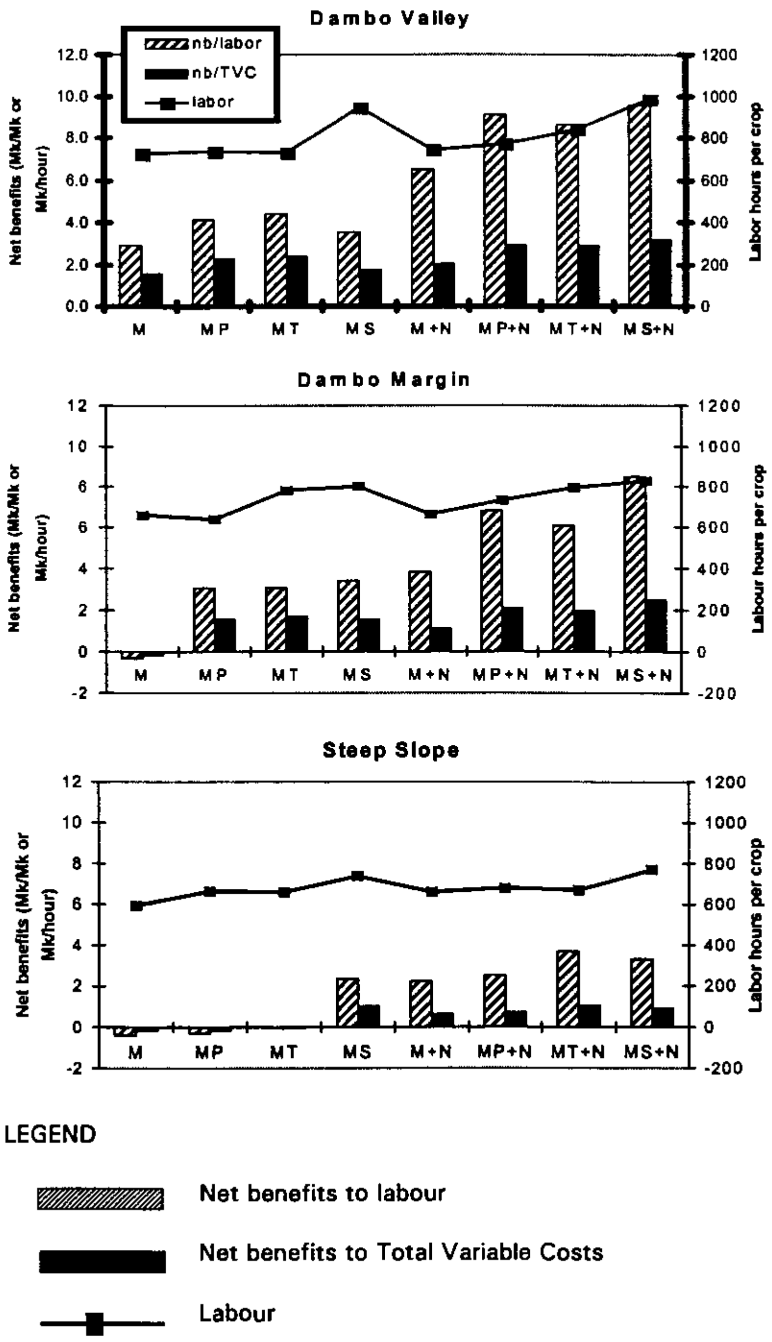
Intensive monitoring was carried out of labour requirements and farmer socio-economic criteria, as well as on-farm performance of the technologies at different landscape positions (Kanyama-Phiri *et al.,* 1998, Kamanga, 1999). Biomass production was quite encouraging in the first year with the *Sesbania* treatment giving the highest yield. Pigeonpea and *Tephrosia* produced relatively low amounts of biomass because they were planted in furrows and were susceptible to waterlogging. Maize growth in the early stages was visually good but slight yellowing in the later stages of growth followed that. Maize yields in the legume treatments were higher than the sole maize. Forty-eight kg of N per hectare was used in the third season as top dressing fertilizer. Response in the third year was greatly improved.

Benefits from the technologies were calculated for the 1997/98 growing season, as return to labour invested, and return to cash invested (Figure 5). The return depended on technology performance, which was minimal at the steep slope landscape position. Performance of current farmer practice on eroded slopes was particularly low, as show by the negative returns for sole crop maize and the maize/pigeonpea intercrop. Labour requirements were similar across landscape positions, only slightly higher for the higher potential "dambo" valley and margin positions. Minimal performance and similar labour requirements meant that benefits per unit of labour invested were lowest at the steep slope position (Figure 5). The combination of legume intensification systems plus 48 kg N/ha provided consistent benefits at all landscape positions. Benefits were highest at the higher potential "dambo" positions, low in the landscape. Substantial benefits were documented in terms of both return for labour invested and returns for cash invested.

Farmers were presented with information on yield performance of the different technologies, using local units of bags produced per acre. The researchers also indicated how many bags of maize grain they would need to be produced to feed an average family of 5.8 members, from an average small-scale farmer landholding of 0.54 ha. This led to a discussion about the potential of each technology to feed the family or produce a surplus. The farmers were very interested in the results presented in their own terms. They were not surprised by the results than only the combination of inorganic and organic nutrient sources could produce sufficient maize to feed a family on 0.54 ha (Figure 5). Farmers in the Songani watershed allocate a large proportion of their annual income to invest in fertilizer, even if they can only afford half of a bag. The value of fertilizers is known in this area. The challenge is to combine it with the best-bet organic technologies to obtain the best return from the investment. Integrated nutrient management technologies are a key emerging concern of communities in the watershed and will be the focus of future on-farm work.

4.0 CONSTRAINTS AND LESSONS FROM THE CASE STUDIES

Farmer assessment of legumes indicated that there is a potential for adoption of some of these legumes mainly for food and not for soil fertility. For example in Southern Malawi, pigeonpea is a main intercrop in the maize systems because of its potential to provide grain that is used for food or sale. In



M	= Maize without fertilizer
MP	= Maize with Pigeon peas
MT	= Maize with tephrosia
MS	= Maize with Sesbania
M+N	= Maize with fertilizer
MP+N	= Maize with Pigeon peas fertilised
MT+N	= Maize with Pigeon peas fertilised
MS+N	= Maize with Sesbania fertilised

Figure 5. Gross Margins for four cropping patterns by landscape positions in Songani, Zomba.
Source: Kamanga et al., 2000.

Central Malawi, adoption is low because the crops have just been introduced and most farmers are not familiar with them. The assessment in these areas showed that it is not the food that is important but the benefits towards soil fertility as compared to inorganic fertilizers. One problem in the case study was that mixed classes of farmers viewed. the importance differently. Those farmers who were the well off were able to purchase fertilizer and hence paid little attention to the legumes. On the other hand, those farmers who had difficulties in obtaining inputs found them encouraging. They continued with the trials with the view of increasing maize yield. What is important here is that there is a need to help the farmers realise that the grain from legumes is good protein food. This would help to increase the care and adoption of the legumes.

Challenges highlighted by this work include the difficulty of establishing and obtaining results from organic matter technologies on steep slopes. This is of particular concern because families that are most at risk, including female-headed households, young families and the poorest families, are largely confined to the steeper sites in the Songani watershed (Wellard, 1996). Substantial benefits were demonstrated from integrated use of N fertilizer and maize/long-duration legume relay intercrop systems. However, farmer perception of these best bets included the high labour demand of growing and transplanting *Sesbania* seedlings, and continuing concerns that land is being lost to maize production through the growth of some perennial legumes (Kamanga, 1999). This is a concern, despite researcher attention to designing systems that addressed the problem by establishing legumes in the furrow and side of the ridge.

Future work will include researcher facilitation of farmer experimentation complemented by researcher/

farmer creative interactions to design and test further best bets. A priority for best-bet options will be integrated nutrient management technologies that fit farmer requirements.

5.0 THE NEXT STEP: IMPROVING FARMER EXPERIMENTATION

In addition to testing best-bet technologies, longer-term goals include the development of additional best bets and gaining experience with novel legume species, innovative cropping system patterns and integrated nutrient management strategies. An iterative process is documented here where researchers reprioritised research areas and technology design, based on farmer assessment. Survey instruments and matrix rating (Table 7) are used to quantify evaluation from different farmer perspectives, including local expert opinion.

Table 7. Illustrative example of farmers' matrix rating[1] of soils on their farm. Soils were collected from relatively uniform spots in the field as a joint farmer/researcher exercise, the soil sample was heaped on the matrix board at the top of a column, and then the farmer would rate the soil represented by that mound.

Criteria description	Soil 1	Soil 2	Soil 3
Supports vigorous growth	2	4	3
Retains water	1	3	2
Blackness of the soil	1	3	3
Relative amount of sand	4	2	2
Contains decaying material	2	4	2

[1]Maize kernels were used to conduct the rating, where the scale was 1 – 4. A rating of 4 indicated that the soil had strong characteristics of the given criteria (Kamangira, 1997).

In the next few years, farmer experimentation will be facilitated through the synthesis of information and feedback provided by researchers. Further, farmers will have gained experience with researcher-designed best bet technologies through conducting baby trials and exposure through field days to a wide range of best bets. Seed banks in case study areas have also been set up by researchers, extension and NGOs working together to improve farmer ability to experiment with new soil fertility options and build on indigenous knowledge.

Researchers in both case studies will continue to monitor the levels and types of farmer-led experimentation to learn more about farmer priorities and soil management decision-making. Initial results from the monitoring of farmer experimentation suggested that grain legume-intensification systems are of general interest among both resource poor and relatively well-off farmers, whereas manure and fertilizers-based experimentation is limited to a small number of the resource-endowed farmers in Malawi (unpublished data, S. Snapp, 1999).

6.0 CONCLUSIONS

The case studies presented here illustrate how researchers, extensionists and farmers can work together to address challenging soil fertility problems. These approaches have shown the complexity of socio-economic issues interacting with soil productivity factors. Shorter-term methods to develop and test "best bet" soil fertility options can be complemented by longer-term approaches. Case study 1 elucidated issues through a trial design that met both farmers and researchers agendas, and cross-checked biological performance and farmer assessment. Longer-term approaches were demonstrated in the watershed platform of case study 2. These are important for problematic areas such as eroded, degraded sites and small land holdings typified by the Songani watershed in Southern Malawi.

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