Managing Africa's Soils No. 11

Towards integrated soil fertility management in Malawi:

incorporating participatory approaches in agricultural research

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About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa – Nutrient networks & stakeholder perceptions.* It is a partnership of fifteen organisations that come from six African and two European countries: INERA from Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, from Kenya; IER from Mali; Environment Alert & Makerere University, from Uganda; IES from Zimbabwe; IIED & IDS from the United Kingdom; and AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, from The Netherlands. NUTNET was conceived with the primary aim of bringing together the three following research programmes:

- *The dynamics of soil fertility management in savannah Africa*, co-ordinated by IIED and IDS/UK;
- *Spatial and temporal variation of soil nutrient stocks and management in sub-Saharan Africa systems* (VARINUTS), co-ordinated by SC/DLO in The Netherlands;
- *Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda* (LEINUTS), co-ordinated by LEI/DLO in The Netherlands.

NUTNET has been made possible by generous funding from the Government of The Netherlands.

Acknowledgements

This research was made possible by the support of Dr. Malcolm Blackie, Dr. Bharati Patel and colleagues at the Rockefeller Foundation, and by their long-term commitment to Malawian smallholder farmers. A great debt of gratitude is owed to the farmers and extension staff of the Songani watershed, and the villages of Chisepo, Mitundu, Mpingu, Mangochi, Bembeke and Chitala. We would also like to thank our colleagues, researchers and support staff, in the Crops and Soils Department at the University of Malawi, the Maize Commodity Team at the Ministry of Agriculture and Irrigation, and ICRISAT, Lilongwe, Malawi. The Rockefeller Foundation provided financial support for this study.

Design and production by Eileen Higgins and Bridget Tisdall
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Summary

In order to effectively develop integrated soil fertility management strategies and disseminate the resulting technologies, we need new approaches that will enable farmers and researchers to build working partnerships. Participatory research is one option, but it is often considered too time-consuming and criticised for not generating quantitative data. Researchers in Malawi have taken up the challenge to overcome these constraints, and have developed both a short-term and a longer-term approach to participatory research. This paper describes the various steps followed in two case studies that followed each approach.

The short-term approach tested and disseminated 'best bet' technologies in target villages in four different agro-ecological zones. Over three years researchers developed a 'mother & baby' satellite trial that was designed to meet both their own and farmers' requirements. They used innovative trial designs and consultative methods, and in many sites obtained promising results from on-farm trials with intensified cropping systems incorporating legumes. Biological performance was measured against the farmers' assessments of the new technologies, and farmers also stressed the importance of testing a range of options, such as a wide range of legumes grown with small amounts of mineral fertiliser.

The longer-term programme was implemented over a period of more than five years. This involved a participatory, community-oriented approach to work in a watershed located in a densely populated area of southern Malawi. The research addressed the problem of eroded slopes used by farmers with limited access to resources. It was difficult to make progress on these degraded sites: maize generally performed very poorly on the steep slopes, and without nitrogen fertiliser the legume-based technologies were not very productive. In flatter areas and valleys the *Sesbania sesban* inter-crop system produced the highest yields, but the drawback of this system was that it required the highest investment in terms of labour. We believe that it is important for researchers and farm advisors to have a long-term commitment to working with farm communities, particularly for problematic areas such as the eroded, degraded sites and small land holdings typified by the Songani watershed in Southern Malawi.

Our findings indicate that there is considerable scope for using participatory research methods to develop more appropriate technologies. These two case studies show how farmers' input can be incorporated regularly into the early stages of research. Policy makers may need to be drawn into this work as well, as there appear to be no easy answers to the problems posed by degraded sites. Dissemination of 'best bet' technologies for other, better-endowed sites may also benefit from policy interventions.

French summary

Résumé

De nouvelles approches sont nécessaires pour établir des partenariats entre agriculteurs et chercheurs afin de développer des stratégies de gestion intégrée de la fertilité des sols et diffuser les technologies améliorées qui en résulteront. La recherche participative est une option mais elle est souvent considérée comme trop lente et ne produisant pas de données quantitatives. Au Malawi, les chercheurs ont relevé le défi que ces obstacles posaient et développé une approche à la recherche participative à court terme et une autre à long terme.

Pendant trois ans, l'approche à court terme a testé et diffusé les technologies les "plus prometteuses" dans les villages ciblés qui étaient situés dans quatre zones différentes au point de vue agro-écologique. Un concept d'essai satellite appelé "mère-enfant" a été développé pour répondre aux besoins tant des agriculteurs que des chercheurs. Les performances biologiques de ces technologies ont été comparées aux évaluations faites par les agriculteurs. Les rendements des essais sur le terrain de l'approche à court terme ont donné des résultats encourageants, en ce qui concerne les systèmes de culture intensifiée incorporant des légumineuses. Les agriculteurs ont souligné l'importance de tester plusieurs options telles que toute une série de légumineuses en association avec de petites quantités d'engrais minéraux.

L'approche à long terme était plus participative, plus tournée vers la communauté. Cette approche "bassin versant" a été menée pendant une période de plus de cinq années. Le bassin versant se trouve dans une région densément peuplée et avait des problèmes de pentes érodées, utilisées par les agriculteurs ayant des ressources limitées. Nous avons trouvé qu'il était difficile de faire des progrès sur les sites érodés et dégradés. L'association ou rotation du maïs avec des légumineuses en l'absence d'apport d'azote, n'étaient pas très productives : les rendements en maïs étaient réduits. L'association maïs-*Sesbania sesban* produisait les meilleurs rendements dans les zones plus plates et les vallées, mais il nécessitait également le plus gros investissement en main-d'œuvre. Nous pensons qu'un engagement à long terme des scientifiques et des conseillers agricoles prêts à travailler avec les communautés paysannes est particulièrement important dans les zones difficiles comme les sites érodés et dégradés et les petites exploitations telles qu'on en trouve dans ce bassin versant. On pourrait aussi faire appel aux décideurs car il semble ne pas y avoir de solutions faciles pour les sites dégradés.

Nos résultats indiquent que les méthodes de recherche participative ouvrent des perspectives considérables lorsqu'il s'agit de mettre au point des technologies mieux adaptées. Les deux études de cas montrent comment les agronomes peuvent incorporer les apports des agriculteurs – plus tôt et plus souvent dans leurs recherches – à partir de concepts d'essais originaux et en adoptant une démarche consultative.

1 Introduction

Participatory research in Malawi

Research on improved integrated nutrient management is increasingly based on participatory approaches. Until recently soil fertility recommendations in Malawi were made on a national basis, generally proposed high levels of fertiliser input and took no account of variations in topography or of differences in farmers' circumstances. Smallholders farm across a wide range of agro-ecological zones. They have different priorities for soil and crop management, and variable access to nutrient resources and markets. Research approaches need to take account of local knowledge and priorities, so that soil fertility options can be developed in partnership with farmers.

The response to agronomic recommendations for subsistence agriculture is globally very poor, and many technologies developed by research institutes have not been adopted by the farmers that they were designed to help. The emergence of participatory research methods is partly due to the low implementation of techniques developed through traditional research (Fischler et al., 1996; Onduru, et al., 1998). Various studies have suggested that participatory research methods are more effective and efficient for developing varieties and technologies that interest farmers (Sperling, et al., 1993; Versteeg and Koudokpon, 1993). Despite this, participatory approaches are rarely used by researchers in Malawi based in public institutions such as the Department of Agricultural Research and Services of the Ministry of Agriculture, or the Bunda College of Agriculture at the University of Malawi. Agronomists are often sceptical about participatory methods, claiming that they are time-consuming and that they provide mostly qualitative data that natural scientists are unfamiliar with, and cannot readily integrate with quantitative data sets.

It is now over ten years since research started on farming systems in Malawi, and much of the soil fertility research done by the Ministry of Agriculture and the University of Malawi is conducted on-farm (Heisey and Waddington, 1993). However, some research programmes fail to understand or take account of farmers' real priorities. Researchers often assume that farmers' production priorities focus on maximising yields or financial returns, while in reality they may be concentrating on getting the best return from a very small cash investment, or on securing and maximising food security (Ahmed, et al., 1997).

To a certain extent, farmers are consulted and involved in research in Malawi. On-farm research has included studies of variety adaptation, crop rotations and agro-forestry systems (Heisey and Waddington, 1993). However, in the past, farmers' involvement has been limited. There was almost no quantitative documentation of farmers' perceptions of on-farm research. Researchers often had informal discussions with farmers to assess technologies, but these were open to a certain amount of unacknowledged bias. For example, an assessment of bean research in Malawi suggested that researchers and extension staff have generally worked with male farmers. As it is usually women who are responsible for growing beans, the researchers not only failed to take account of female farmers' ideas and perceptions, but also missed out on their considerable indigenous knowledge about bean varieties (Ferguson, 1994).

Testing new approaches to participatory research

This working paper documents the development of two participatory approaches to research on soil fertility management in Malawi. Both research programmes were implemented by soil fertility specialists and agronomists. The longer-term programme was conducted with communities in a watershed in Southern Malawi. In this case the major challenges to enhancing soil management and system productivity were eroded natural resources and small farms. The shorter-term programme was conducted across a range of agro-ecosystems. The aim here was to make farmers aware of the 'best bet' soil fertility options, and to facilitate experimentation with these technologies. Researchers in both programmes intended to document farmers' indigenous technical knowledge and to improve their understanding of how and why farmers make decisions. This information was then to be used by agronomists to generate more appropriate soil fertility management technologies.

These studies are part of a research programme that is aimed at improving food security and soil productivity for smallholder farmers in Southern Africa. Over the last decade this programme has tried to increase farmers' involvement in research. However, the agronomists and soil scientists involved were concerned about the time and resources required by the participatory approaches described in various publications. Very few studies document the effectiveness and practicality of different participatory research methods. There are also likely to be methodological differences between research programmes designed quickly to show farmers the impact of certain technologies, and those that are part of a longer time-frame, and which focus on more intractable problems. Finally, only a limited amount of information is available on how to correlate farmers' perspectives and indicators with scientific perceptions of integrated nutrient management and soil fertility characteristics (Onduru, et al., 1998).

The objectives and design of the study

This paper analyses two related exercises in using participatory research methods to learn about farmer's perspectives and improve the development and deployment of integrated soil fertility technologies in Central and Southern Malawi. The main objectives of the two case studies were:

1. To document farmers' indigenous knowledge of soil characteristics and management technologies.
2. To evaluate the effectiveness of participatory research methods by comparing a short-term approach aimed at rapidly evaluating farmers' knowledge and disseminating 'best bet' technology options, with a longer-term, watershed-based approach linking research to community participation.
3. To articulate the priorities of smallholder farmers in order to improve future research and the development of soil fertility technology in Malawi.

Case study 1 is a short-term 'mother & baby' trial. It involves partnerships between farmers and researchers in villages that were selected as being representative of four major agro-ecosystems in Central and Southern Malawi. This study used a satellite trial design consisting of 'baby' trials in a village that were clustered around one or more 'mother' trials (Fig. 1). Case study 2 used a long-term approach, in which a watershed is used as a platform for learning and development for both farmers and researchers. The trials are sited along a transect that represents three different landscape positions: steep slope, dambo1 margin and dambo[1] valley.

This paper presents and discusses the methods of these two approaches to participatory research with farmers, highlighting the problems and the lessons learned during the process.

The sites

The four agro-ecosystems chosen for participatory research are located in Central and Southern Malawi (Figure 2), where about 70% of smallholder agriculture is located. The agro-ecosystems are listed below, with the study sites in parentheses:

1. Central Malawi: sub-humid, tropical, mid-altitude plain (Chisepo, Mitundu and Mpingu)
2. Central Malawi: high-altitude, sub-humid hills (Bembeke)
3. Malawi lakeshore: semi-arid zone (Chitala and Mangochi)
4. Southern Malawi: mid-altitude, sub-humid plateau (Songani). The Songani watershed is the location for both 'mother & baby' trials and the longer-term, watershed approach.

[1] Dambo is the local name for wetlands.

Figure 1. Trial design used in the two participatory research approaches

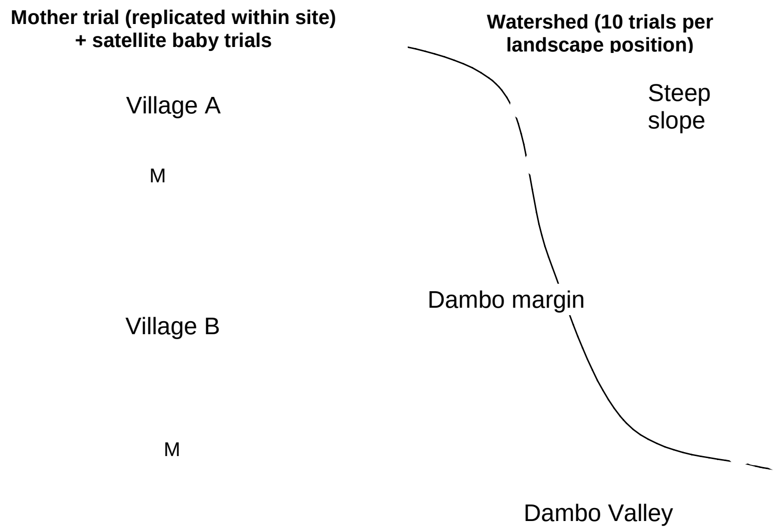
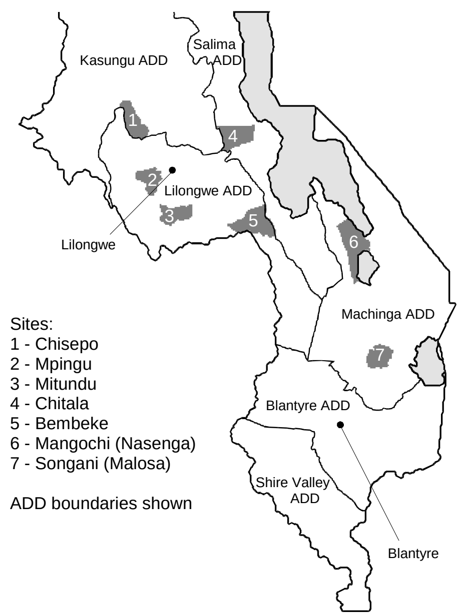


Figure 2. Map of Central and Southern Malawi with research sites



Key: EPA = Extension Planning Area (EPA); ADD = Agricultural Development Division

2 Changes in farming systems

Agro-ecosystems

The sub-humid tropical agro-ecosystems of Malawi are characterised by a long dry season, with an unimodal rainfall pattern between November and April (Table 1). In Southern Malawi precipitation sometimes occurs over a longer period, with sporadic showers in May, June and July. The dominant vegetation was originally grasslands at high altitude and mambo woodlands at mid-altitude. Soils are generally Alfisols or Ultisols, which are moderately fertile and have deep profiles (Young and Brown, 1962). Soils in the Malawi smallholder sector generally have low to moderate levels of organic carbon, and are moderately acid (Table 1). Soil fertility has declined as a result of continuous maize production, minimal use of fertilisers and the abandonment of traditional fallow systems caused by increasing population densities (Snapp, 1998).

Table 1. Biophysical characteristics of selected case study sites

Agro-ecological zone	Altitude range (masl)	Annual rainfall Range (mm)	Rain-fall pattern	Soil texture	Soil organic C (mg/kg)	Soil pH
Central Malawi – mid-altitude	1000-1300	600-800	Nov-April	Sand, sandy loam, loamy sand	15	6.4
Central Malawi – high altitude	1400-1700	800–1000	Nov-April	Sandy loam, loamy sand, clay loam	12	5.5
Malawi – lakeshore	200-500	600-800	Oct-March	Sand, loamy sand	11	6.1
Southern Malawi– mid-altitude	1100-1600	1000-1200	Oct–May	Sandy loam, loamy sand, sandy clay, loam	11	6.6

Soil characteristics refer to averages of analyses from topsoil samples (0-20 cm) collected from participatory research trial fields in 1997/1998.
Source: Benson, 1997 and own survey.

Land is continuously cropped because of the high population density (over 100 people per km^2). The average farm size is between 1 and 3 ha per household, but less in Southern Malawi (Table 2). Agro-ecosystems in Central Malawi generally have larger farms and a higher proportion of maize as a sole crop than the systems in Southern Malawi, where farms are small, with maize based inter-cropping. The poverty of the smallholder farming sector is demonstrated by extraordinarily high levels of malnutrition among pre-school rural children, and by the fact that a third of rural households (generally those in the poorest section of society) endure a hungry period that lasts for about six months (Kanyama-Phiri, et al.,1998; Sahn, et al., 1992).

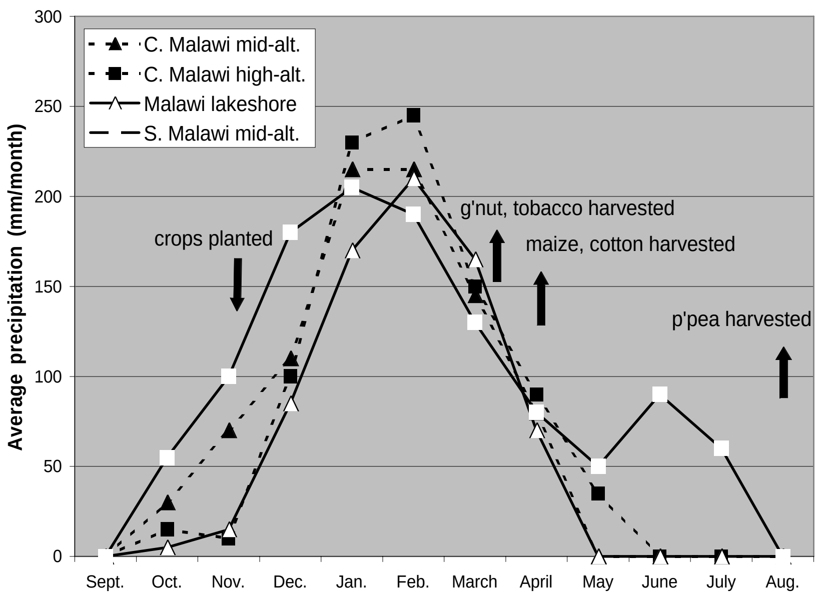
Maize dominates in the subsistence oriented agricultural systems of Southern Africa, and nowhere more so than in Malawi, where 80% of the land farmed by smallholders is under maize. Recent government initiatives have focused on diversifying maize-based cropping, and there has been some growth in smallholder production of burley tobacco and soybean (Kumwenda, et al., 1997). The primary cash crops grown in the smallholder sector are tobacco and cotton (Table 2). Maize and cash crops are planted at the start of the rainy season (Figure 1).

Table 2. Characteristics of cropping systems in selected sites

Agro-ecological zone	**Farm size (ha)**	**Adults per Farm**	**Highest labour demand**	**Major field crops***	**Duration of crop cover**	**Incorporating crop residue (%)**
Central Malawi mid-altitude plateau	2.6	3.4	Dec.	Maize, tobacco, groundnut, soybean, common bean	Jan. – May	14
Central Malawi high altitude region	1.2	3.1	Nov.	Maize, common bean, potato, soybean	Dec. – May	5
Malawi lakeshore	1.4	2.5	Nov.	Maize, cotton, minor production of legumes	Nov. – April	55
Southern Malawi mid-altitude plateau	0.8	2.2	Oct.	Maize, Pigeon pea, cassava, tobacco, groundnut, common bean	Nov. – May (Nov. – Aug. for pigeon pea or cassava)	93

*Common bean (*Phaseolus vulgaris*), cotton (*Gossypium hirsutum*), groundnut (Arachis hypogaea), maize (*Zea mays*), pigeon pea (*Cajanus cajan*), potato (*Solanum tuberosum*), soybean (*Glycine max*), tobacco (*Nicotiana tabacum*); Legumes: Mucuna sp., cowpea (*Vigna unguiculata*), Bambara groundnut(*Voandzeia subterranea*).
**: Percentage of farmers that routinely incorporate maize and legume residues into the soil.
Source: Snapp and Rohrbach, 1997.

Figure 3. Rainfall pattern and timing of farm operations in the four agro-ecosystems



The most widely grown legume in Malawian cropping systems is groundnut, which is inter-cropped with maize and also grown as a sole crop (Figure 3). In the 1970s a significant amount of groundnut was grown for export, but it is now produced primarily for household consumption and for the local market. Other important legumes are pigeon pea in the South, common bean in areas of higher altitude, and more recently, soybean (Table 2). Legumes are often inter-cropped with maize at a density of less than 1 legume plant per maize plant (Kanyama-Phiri, et al., 1998; Shaxson and Tauer, 1992). Low density planting, slow growth rates and minimal management all contribute to the current patterns of low grain legume yields and the limited production of residues. Cassava is grown as a subsistence crop in some areas, primarily in the Southern region and on the Northern Malawi lakeshore.

Changes in soil fertility management

The economic context of farming and soil fertility management has recently changed. Farmers have experienced marked increases in the real price of fertilisers, and a reduction of the maize to fertiliser price ratio due to devaluation of the local currency and the removal of fertiliser subsidies. Soil fertility is declining in Malawi. At the moment small-scale farmers' soil fertility management strategies involve only limited use of

Table 3. Use of fertiliser in the villages of Kasungu and Mangochi in1996/97 (N=40)

Level of fertiliser use	Kasungu Central mid-altitude zone (% of farmers interviewed)	Mangochi Southern lakeshore (% of farmers interviewed)
Did not use fertiliser	42	66
Used less than one bag of fertiliser/ha	28	24
Used more than one bag of fertiliser/ha	30	10

Source: Snapp and Rohrbach, 1997.

fertilisers. Mineral fertilisers used to be widely used, but poverty and the limited profitability of farming mean that less than 50% of smallholders use any fertiliser, and about 70% use less than one bag of fertiliser per hectare (Table 3).

Incorporating residues into the soil can help to maintain fertility. This practice is widespread in the Southern region, but limited in Central Malawi (Table 2). Crop residues mainly consist of maize stover and weeds, which are poor quality residues that reduce nitrogen availability in the short-term. The dry period lasts longer in the Central region than in the South (Figure 1), and incorporating poor quality residues in these climatic conditions may immobilise nitrogen during the critical early growth of a maize crop. This may be the biological reason why farmers in Central Malawi prefer to burn residues rather than incorporate them into the soil (Snapp, et al., 1998). While there are sometimes problems associated with incorporating maize residues, legume residues can potentially enhance the soil's nitrogen status. Unfortunately legume yields are generally very low in Malawi, which limits their potential to contribute to improving soil fertility.

Farmers are now increasingly experimenting with alternative sources of nutrients as substitutes for expensive fertilisers. They have tried using goat manure, incorporating crop residues and rotating crops (Table 4). However, the potential for significant nutrient inputs from manure is limited, given the very low livestock densities in Malawi (Kumwenda, et al., 1997). Only 1% of households in the research sites own cattle, and 30% have goats (Snapp and Rohrbach, 1997).

It will be a considerable challenge to increase the proportion of legumes in the present maize-dominated farming system, which is already densely cropped. Historically, new crops have tended to be introduced as a substitute for another crop, rather than as an additional variety. Maize density has remained the same in the cropping system (Shaxson and Tauer, 1992).

In the past, farmers in Malawi did not prioritise grain legume production, despite the substantial potential yield noted in participatory on-farm trials (Figure 4). Legumes therefore occupy only a small percentage of the total cropped area: about 5% in the Southern Lakeshore and 15% in Central Malawi (Snapp and Rohrbach, 1997). Until the recent liberalisation of the market in Malawi, farmers could only get limited economic returns on grain legume production. This reinforced the dominance of maize, and was a disincentive to cultivating rotations based on grain legumes.

However, the economic trends of the late 1990s suggest that a window of opportunity is opening in Malawi. With increased privatisation and changes in government policies that previously favoured maize cultivation, the market and policy environment is becoming more favourable for grain legumes and other crops (Sahn et al., 1992). The government also no longer controls groundnut prices, which used to be kept at low levels. The recent increase in the number of private traders and the ending of government monopoly have resulted in a more dynamic market for grain legumes. Prices vary, but returns from groundnuts, soybean and pigeon pea have recently increased to about 150% of the price of maize, which will improve the potential earnings from intercropping with legumes (Giarrizzo and Barlow, 1998).

Table 4. Percentage of farmers in Kasungu and Mangochi experimenting with soil fertility management practices (N=40)

Soil fertility technology	Kasungu (Central mid-altitude zone) %*	Mangochi (Southern lakeshore) %*
Manure (primarily goat or pig) applied to vegetables, maize and tobacco	10	25
Compost applied to vegetables, maize and tobacco	20	0
Combined use of mineral fertiliser with manure or crop residues	10	15
Legume rotation (soybean, mucuna)	10	20
Fallow	10	0
Incorporating crop residues (maize)	15	20
Farmers not experimenting	30	35

* Farmers trying out a practice were considered to be experimenting. The total sum is greater than 100% because farmers may try more than one technology.
Source: Snapp and Rohrbach, 1997.

Research on organic fertilisers and the adoption of new technologies

Smallholder farmers in Malawi use limited amounts of mineral fertiliser (Kumwenda, et al., 1997), and researchers have been seeking alternative technologies for managing soil fertility. Over the last few decades they have experimented extensively to develop organic sources of nutrients for smallholders, looking at agro-forestry systems, green manure and legume rotations (MacColl, 1989; Kanyama-Phiri et al., 1998). However, although it has been demonstrated from an agronomic perspective that some of these systems improve soil productivity through nitrogen fixation, additional carbon inputs and by conserving nutrients, to date virtually no farmers have adopted them (Snapp, et al., 1998). The most significant blocks to farmers' acceptance of the new methods seem to be the high labour requirements, the need for skilled management and the limited profitability in the short term. However, the increased cost of mineral fertiliser and the changing economic context of farming and soil fertility management may well generate new interest in grain legumes and green manure.

3 Tests with trial designs for participatory research

'Mother & baby' trials

The 'mother & baby' trial got its name from one of the farmers involved in the trials. It is a rapid method of enabling farmers to test 'best bet' soil fertility technologies identified by researchers. The 'mother' trials test many different technologies, while the 'baby' trials test a subset of three technologies, plus one control per site (Snapp, 1999). The design makes it possible to collect quantitative data from on-farm 'mother trials' managed by researchers, and systematically to cross-check them with 'baby trials' on a similar theme that are managed by farmers (Figure 1). Table 5 below lists the steps followed in these trials.

This study started in 1996, when soil scientists and agronomists from the University of Malawi and the Malawian Department of Agriculture and Irrigation met to synthesise published information and the results of years of on-farm research in Malawi. Researchers identified and designed 'best bet' technology options requiring minimal cash and labour input to improve soil productivity. They hypothesised that smallholder farmers have limited resources, use small amounts of mineral fertiliser, and experiment with new legumes, manure and crop residues as alternative sources of nutrient inputs. In mid-1997 these assumptions were confirmed by reconnaissance surveys conducted with an open-ended questionnaire (Table 4). The 'best bet' technologies selected for the on-farm trials were aimed at intensifying farming systems through the incorporation of legumes (see Table 6).

Representative villages in key agro-ecosystems were chosen on the basis of information from community meetings, consultations with extension staff and by reviewing government statistics on population density and agro-climatic data (Fig. 2). A trial design was developed for all sites, geared to meet both farmers' and researchers' objectives - which are by no means identical. The design included relatively simple 'one-farmer, one-replica' trials that would be managed by farmers, and act as satellites or 'baby' trials to a central 'mother' trial that had 'within-site replications' and was managed by researchers from the Ministry of Agriculture and the University of Malawi (Figure 1).

Table 5. Comparison of two participatory research approaches and timeframe

Steps	'Mother & baby' trial approach Short-term	Watershed-based approach Long-term
Selection of location	Representative clustered villages in agro-ecosystems of interest (2 months)	Representative watershed in agro-ecosystem of interest (1 year)
Identification of problem	Researchers, with input from farmers gathered from reconnaissance survey (1 month)	Farmers and researchers jointly identify problems & opportunities (1 year)
Selection of technology options	Researchers using results of previous on-farm research, and problems identified by farmers (3 months)	Researchers using results of previous research, and problems identified by farmers (3 months)
Objectives of research with farmers	• Assess on-farm performance of 'best bet' technologies • Quantify farmers' assessment • Improve farmers' experimentation by providing information and better technology options	• Assess on-farm performance of 'best bet' technologies • Quantify farmers' assessment • Improve understanding of processes (nutrient cycling, growth of introduced species) • Design better technologies
Identifying characteristics of sites	Sampling topsoil early in the season, analysing pH, texture and nitrate content (3 months)	Based on farmers' knowledge of natural resources and soils identified during transect walks and matrix ranking (6 months)
Design and implementation of on-farm trials	'Mother & baby' trial design: replicated within-site, randomised complete block 'mother' trials (1 per location) One farmer-one replica 'baby' trials; ~30 per location (2 years)	One farmer-one replica trials: stratified according to transect: 10 per landscape position Randomised complete block design (2 – 4 years)
Data monitored	• Biophysical: date & duration of trial, plant populations, grain yield, residue biomass and quality analysis, soil analyses • Socio-economic: farmer surveys, matrix ranking, rating of technology, economic gross margin analysis	• Biophysical: date & duration of trial, plant populations, grain yield, residue biomass and quality analysis. Dynamics of soil N & water • Socio-economic: farmers' surveys, economic gross margin analysis
Feedback	Meetings for farmers/extension agents/researchers to discuss findings and plan future research (4 months)	Meetings for community/ researchers to discuss findings for the watershed, and plan the future (10 months)

Table 6. Test technologies for improving soil fertility

Technology	Type of trial*	Plant density/ha (X1000)	Biological characteristics **	Farmers' perceptions of characteristics
Maize as sole crop	M&B W	Maize: 37	3 maize plants per hole, 0.9 m X 0.9 m.	Farmers' current practice, productive with minimal labour inputs.
Maize + relay inter-crop Sesbania	W	Maize: 37 Sesbania 7	3 maize plants per hole, 0.9 m X 0.9 m. Sesbania planted at first weeding in furrow between maize-planted ridges. Sesbania grows for 10 months before leaves are incorporated.	Sesbania seedlings become well-established in furrows; space in the cropping system under-utilised.
Maize+ relay inter-crop Sesbania + 45 kg N	W	Maize: 37 Sesbania 7	3 maize plants per hole, 0.9 m X 0.9 m. Sesbania planted as above. Fertiliser: 45 kg N per ha.	Residues from Sesbania are combined with mineral fertiliser.
Maize + Pigeon pea (Pp) inter-crop	M&B	Maize: 37 Pp: 37	Temporal compatibility: Pp planted at the same time as maize, 3 plants per hole spaced halfway between each maize hole. Pp grows slowly, which reduces competition with maize.	Pp is a bonus crop; low plant density minimises impact on maize yields.
Groundnut + Pp year 1, rotation with maize year 2	M&B	G'nut: 74 Pp: 37	G'nut (15 cm spacing) grown in single row on ridge spaced at 0.9 m; Pp crop is inter-cropped to improve quantity and quality of residue biomass.	Legume seed density takes account of cost of g'nut seed and appropriate seeding rates. Pp is a bonus crop.
Soybean + Pp year 1, rotation with maize year 2	M&B	Soybean: 222 Pp: 37	Same as g'nut + Pp design above, but groundnut replaced with double row of soybeans planted along each ridge at 15cm intervals.	Higher seed density is possible because soybean seeds are smaller and cheaper than groundnut. Pp is a bonus crop.
Maize + *Tephrosia* relay intercrop	M&B	*Tephrosia*: 20 kg/ha Maize: 37	Temporal compatibility enhanced by planting *Tephrosia* at 1st weeding as a relay intercrop. *Tephrosia* initially grows slowly and can produce about 2 t green manure per ha.	Green manure system with minimal labour requirements. Seed is broadcast along ridge and incorporated during weeding.

*M&B = 'mother & baby' trial approach; W= Watershed approach.
**: Maize: MH18; Pigeon pea: ICP 9145; Groundnut: JL 24 or CG 7; Soybean: *Magoye* variety.

The one-farm, one-replica design has been recommended for on-farm technology testing for agricultural smallholdings. Replication within each farmer's field is not always the most efficient way of comparing cropping system technologies, as there are tradeoffs between having many replicates across sites and having a few treatments replicated within each site (Fielding and Riley, 1998; Mutsaers, et al., 1997). A trial design with a maximum of four plots and no replication within the farmer's field is appropriate when field size is limited. It also simplifies the design and makes it easier for farmers to evaluate the technologies. Having many replicates across sites makes it possible to sample wider variations in farm management and environment. However, replication within a site and intensive, uniform management are essential for research into biological processes and for rigorous testing of a technology's performance. The 'mother & baby' trial design allows both sets of objectives to be met by linking on-farm trials managed by researchers with experimentation on similar technologies managed by farmers (Snapp, 1999).

The selected trial design allowed the farmers who were implementing 'baby-trials' to gain experience with a few of the 'best bet' options, and to assess them rigorously. Farmers initially chose their test technologies on the basis of researchers' descriptions of the 'best bet' options. The farmers provided quantitative feedback to researchers through surveys, paired matrix rating and by ranking the technologies. Qualitative feedback was obtained from meetings between farmers and researchers, and from comments recorded at field days.

Farmers were also involved in assessing the wider range of technologies tested in the 'mother trials'. This was done at field days and at meetings between farmers and researchers. The 'mother trials' were evaluated more informally during discussions held during field days. This made it possible to integrate the farmers' assessment into ongoing research (Table 5).

Watershed-based partnerships between farmers and researchers

The long-term approach to participatory research was tested in a watershed in Songani, Southern Malawi. This approach is based on building a partnership between farmers and researchers so that they can learn together. In 1994 researchers from the University of Malawi selected a watershed that was representative of the challenging conditions in Southern Malawi, covering steep, eroded slopes and with a high population density.

The researchers organised community meetings so that they could understand how resources are used and assess farmers' problems and opportunities. They attempted to include representatives of all sections of the farming community, including households headed by women and farmers with very few resources. The researchers and villagers then prioritised problems that could be addressed collaboratively (Kanyama-Phiri et al., 1998; Wellard, 1996).

Over the course of an extensive series of community meetings, the participants drew up resource maps and set priorities for research. The researchers had hypothesised that a field's position in the landscape would influence how its soil fertility was managed. They therefore laid out transects across the watershed and walked along them. They selected sites that were representative of three positions in the landscape: steep slopes, dambo

Table 7. Farmers' perceptions of environmental change, problems faced and possible solutions in the Songani catchment area

Environmental change	**Indicators identified by farmers**	
Indicators of environmental change	• Declining soil fertility • Decreasing food supplies • Falling yields • Erratic rains	
Indicators of declining soil fertility	• Soil colour changing from dark to light • Falling yields • Appearance of certain weeds (*Striga* and *chiundu*) • Soils are drying out, become dusty • Unable to produce crops without fertilisers	
Main Problems	Top priority for farmers % (N=157)	Possible solutions identified by the communities (*italics when researchers could offer assistance)
Lack of inputs	31%	• Government to lower input costs • *Low cost technologies to increase productivity**
Limited land	29%	• Increase use of steep slopes • *Increase productivity of existing land**
Declining soil fertility `	17%	• *Use fertiliser more efficiently** • *Increase benefits from legume-intensification systems** • Increase access to fertilisers, manure and fallow land
Soil erosion	13%	• Construct boundary marker ridges on the contour • Install waterways, plant trees and grasses in gullies • Construct stone lines
Other	11%	—

Source: Adapted from Kamanga, 1997 and Wellard, 1996.

margin and dambo valley (Figure 2). Field sites were randomly selected along the transects, and almost all of the farmers who cultivated the selected fields were willing to participate in the trials. Over the next four years, the researchers worked with these farmers, conducting surveys, analysing indigenous knowledge of soils and implementing participatory research trials (Table 6).

In 1996, a participatory exercise was carried out to evaluate indigenous knowledge of soils across the watershed (Kamangira, 1997). Given the history of rather top-down research and extension in the region, this was an empowering experience that highlighted farmers' expertise and knowledge of their resources and farming systems. Open-ended interviews with the farmers who had participated in the transect, were used to define criteria to describe soils. The researchers then conducted in the field a matrix rating exercise adapted from Mascarenhas (1991). Fifty farmers were asked to list the criteria they use to characterise a soil's fertility. They all cited vigorous growth of grass on a site. Other criteria included dark coloration (listed by 78% of farmers), soft and easy to hoe (50%), containing decaying material (10%), containing a mixture of sand, clay and black soil (10%), containing low sand content and expanding clay (10%), containing sufficient sand for water percolation which prevents water logging (4%) (Kamangira, 1997). Soil was then collected from relatively uniform spots in each field and heaped on the matrix board at the top of a column. Each mound represented one type of soil, and the farmers were asked to rate their common soil types according to the listed criteria: productivity, water holding capacity, colour, texture and organic matter content (see Table 8).

Table 8. Example of matrix rating of soils by farmers

Soil criteria	Soil 1	Soil 2	Soil 3
Supports vigorous growth of grass	2	4	3
Retains water	1	3	2
Black soil	1	3	3
Relative amount of sand	4	2	2
Contains decaying material	2	4	2

Scale of 1 to 4, with 4 indicating strong characteristic.
Source: Kamangira, 1997.

The researchers then conducted a paired ranking of soils that linked chemical analytical data with the farmers' criteria. The only positive correlation was between soil organic C and farmers' overall soil fertility score (Pearson's correlation 0.3, $p = 0.001$). This information was used to develop integrated soil fertility management technologies for different soil types, which farmers tested in different positions within the landscape (Kanyama-Phiri et al., 1998; Phiri, et al., 1999).

The watershed-based process took place over a longer time-scale and required more resources than the 'mother & baby' trials, particularly for setting up the initial community meetings and laying out the transects (Table 5). The researchers were breaking new ground by working together with farmers on how to address problems of very low yields and eroded slopes. They took a holistic approach, involving the community in identifying problems and developing solutions to them. This approach also linked research on biological processes to understanding indigenous knowledge about land use. The technologies developed with farmers in the Songani watershed should also be appropriate for other regions similarly affected by erosion and pressure on land, such as Southern Malawi and the Shire highlands (Kanyama-Phiri, et al., 1998). However, testing 'best bet' technologies may not be the only answer to the many challenges faced by communities in degraded watersheds. Resources are intensively used and most land is already inter-cropped because of high population pressure, making it less feasible to introduce alternative legumes into the cropping systems of the Songani watershed.

Comparing the two approaches

Both approaches followed a similar sequence of steps, which is illustrated in Table 5.

Choosing representative sites

The initial step in both cases was to identify representative sites. This would enable researchers to extrapolate the results to other comparable agro-ecological zones. Survey data were used to identify villages for the 'mother & baby' approach, where trials were clustered in a set of selected villages to reduce travel time and associated costs (Figure 1). The selected villages had to be representative of the four major agro-ecological zones in Southern and Central Malawi, and also in terms of population density and access to markets. For the second approach, a considerable investment was made to identify a representative watershed in Southern Malawi, to define transects across the watershed and to characterise community resources and soils at certain points in the landscape (Kanyama-Phiri, et al., 1998). There was an overlap between both approaches, as some 'mother & baby' trial clusters were located in the Songani watershed.

Choosing priority topics for investigation

Both approaches involved working with farmers to develop improved soil fertility options that would require minimum cash investments. Because of the expertise and mandate of the collaborating researchers, the 'mother & baby' trials focused on developing technologies to improve soil fertility. With the watershed approach, it was possible to identify problems collaboratively with the community. The researchers met with groups of farmers, and used resource mapping and other visual aids to discuss and prioritise their problems (Kanyama-Phiri, et al., 1998). The researchers initially thought that soil conservation would be the most important issue in Songani, but the farmers actually chose issues related to soil fertility as their main priority, such as lack of access to inputs due to increasing costs, shortage of land and declining soil fertility (Table 7).

Determining the characteristics of the sites

The characteristics of the sites for the 'mother & baby' trial clusters were determined by using reconnaissance surveys to collect socio-economic information about smallholder crop management systems, and by doing chemical and physical analysis of the topsoil. The watershed approach used an intensive exercise with farmers to document their knowledge about soils (Kamangira, 1997). Researchers also determined the site's position within the landscape, and analysed the characteristics of the soil profiles. With this approach it was felt that understanding soil characteristics from the farmers' perspective would improve the researchers' ability to communicate with them, and to develop more appropriate technologies.

Developing and testing options to improve soil fertility

The goals of both case studies were to evaluate technologies from the farmers' perspective, and to monitor biological performance of the selected technologies under on-farm conditions (Table 5). The researchers selected potential 'best-bet' technologies for improving soil fertility, which were then tested with farmers. They were judged according to a set of criteria determined during discussions with colleagues (researchers & extension workers) and by assessing the results of previous on-farm trials. These criteria included performance across a range of environments, the amount of cash and labour required, and feasibility for smallholders.

Selecting farmers

The researchers involved in the 'mother & baby' trial selected the 'test' farmers during a meeting attended by everyone who had volunteered to host trials. They were careful to include both well-off farmers and those with few resources, as well as households headed by women. In both approaches, the farmers provided most of the labour for planting, weeding and managing the plots, with occasional limited help from field assistants hired by the researchers. The only reward for the farmers who managed these trials was the harvest produced on the small plots, and a small amount of free inputs provided by the researchers (such as the seed for improved groundnut varieties grown in some of the plots). There was also a certain amount of prestige involved in having their plots visited by researchers and other farmers, and knowing that their trial was helping to develop 'best bet' soil fertility options.

The hands-on experience gained during 'baby' trials enabled the farmers to evaluate the test technologies, and matrix ranking and survey rating exercises were used to establish quantitative assessments. The researchers summarised data on yields and on how the farmers evaluated the performance of different technologies across the sites, and then reported back to farmers, extension workers and NGO staff (Table 4). During these discussions the farmers' observations generally concurred with those of the researchers. Farmers also often highlighted the secondary benefits provided by various technologies, such as the fact that the maize-*Tephrosia volgii* inter-crop suppresses weeds. However, this system was also criticised because of the extra labour required to cut the woody stems and incorporate the residues of the Tephrosia as green manure.

The programme in the Songani watershed tested ‘best-bet’ technologies with farmers who worked at different points in the landscape. These farmers had been selected as part of the initial exercise to define the transect. The researchers used resource maps, assessment of farmer knowledge about soils, matrix ranking and on-farm trials to monitor the farmers’ socio-economic situation and labour requirements, as well as the performance of technologies on-farm (Kanyama-Phiri, et al., 1998; Kamanga, 1999). They also intensively monitored soil N, and went on to link research on processes (such as N dynamics) with participatory approaches involving farmers (Phiri, et al., 1999). The Songani watershed became a platform for learning and action research for researchers from the university, who have continued to work with these communities on defining their problems and developing long-term solutions to them.

The next step: improving experimentation by farmers

In addition to testing ‘best-bet technologies’, a longer term goal for both case studies was to improve farmers’ capacity to experiment. The researchers realised that although demonstrating technologies is the first step in exposing farmers to new ideas, the farmers are the “experts” on their own problems and circumstances, and should be able to carry out further experimentation to adapt technologies to their specific conditions. It was hoped that through their involvement in participatory research, farmers would learn about new legume species, innovative cropping patterns and integrated nutrient management strategies. Both approaches involved iterative processes in which researchers discussed and tested potential ‘best-bet’ technologies with farmers, and also learned about farmer priorities and how to develop more practical options. Seed banks were set up in the case study sites to enable farmers to experiment with new crops. Researchers in both programmes plan to continue to monitor farmer experimentation so that they can learn more about their priorities and how they make decisions about soil management.

3 'Best bet' technologies

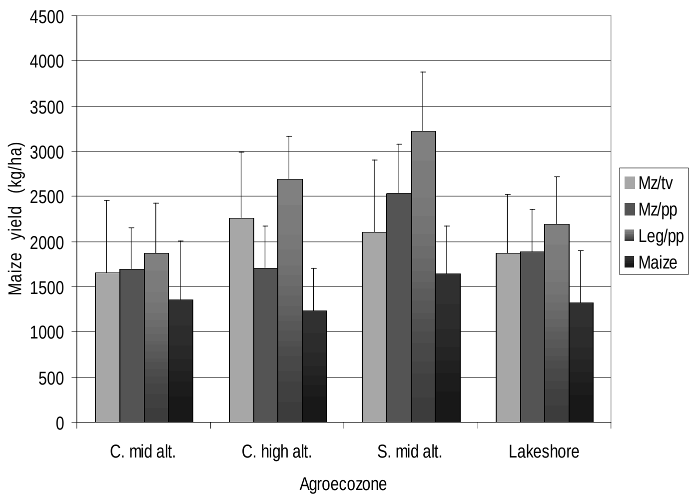
Technologies tested in the 'mother & baby' trials

All of the 'best-bet' technologies tested in on-farm participatory trials involved maize. Maize performance was considered to be a good indicator of the system's productivity, as this crop is the 'staff of life' in Malawi. Maize yields for the 1998/1999 growing season are presented for the 'best bet' technologies tested with 67 farmers in four agro-ecosystems (Figure 4). Maize production was not expected to benefit immediately from interaction with legumes, as it takes time for nitrogen from the legume residues to become available to the crop. This is why the results of the first year are not given in this paper. However, even the yields in the first year were promising, as none of maize grown as inter-crop with legumes produced lower yields per hectare than a sole maize crop. This suggests that researchers correctly assumed that these 'best bet' technologies would create minimal risks for farmers' food security.

It was expected that the maize-*Tephrosia volgii* relay inter-crop would produce the highest maize yields, as its green manure residues should have a higher nitrogen content than the grain legume residues. However, this was not the case, and it seems to take more than two years for the benefits of this green manure to have an effect on maize yields. In year two, the highest yields were produced by the legume-pigeon pea inter-crop systems grown in rotation with maize (see Table 6). Farmers gave this system the highest ranking (Figures 4 and 5). However, it does require the land to be left for a year to produce legumes, which may make it unfeasible for farmers with small land holdings, who have to devote their entire field to maize production each year. The maize-pigeon pea inter-crop system may therefore be the 'best bet' option for the poorest farmers, as it produces maize every year, plus a bonus crop from the Pigeon pea grain, if it is harvested. This system was also given a high ranking by farmers (Figure 5).

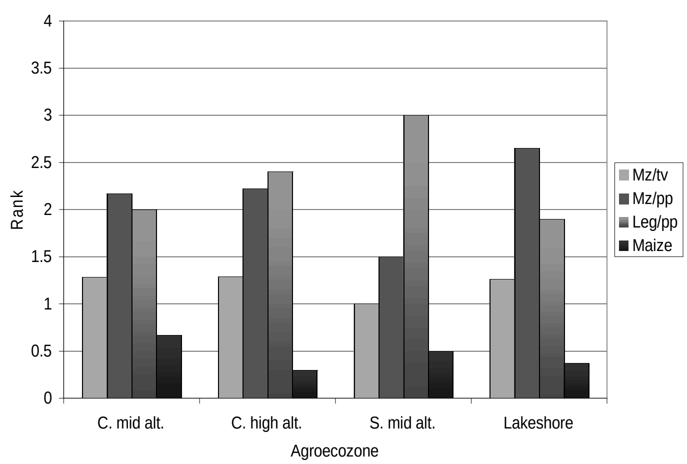
The way the farmers ranked the systems in late 1998 was consistent with yield performance. Farmers in different locations had surprisingly similar assessments of the 'best-bet' options, suggesting that these technologies perform well for a range of agro-ecological zones and socio-economic groups. This also indicates that the farmers who carried out the trials in different locations assessed the results according to similar criteria, despite differences in their cultural background, priorities and environment. The consistency of the way in which 'expert' farmers rank plant breeding material has been documented in earlier participatory research with farmers (Sperling et al., 1993).

Figure 4. Maize yields for tested technologies in four agro-ecological zones



*Data relate to the second year of the trial, carried out with 67 farmers. The tested technologies are: maize-*Tephrosia volgii*, maize-Pigeon pea, maize rotation after a legume-Pigeon pea inter-crop, and a continuous sole crop of maize.

Figure 5. Farmers ranking of the tested technologies in four agro-ecological zones



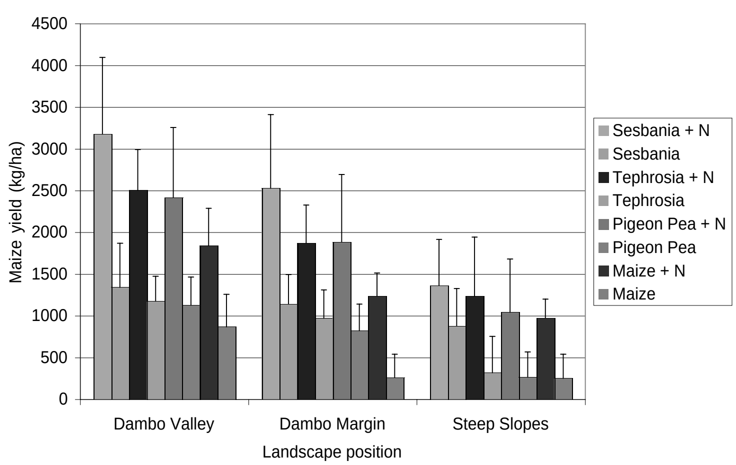
*Data relate to the second year of the trial (1998), carried out with 67 farmers. The tested technologies are: maize-*Tephrosia volgii*, maize/Pigeon pea inter-crop, maize rotation after a legume-Pigeon pea inter-crop, and a continuous sole crop of maize.

‘Best bet’ technologies in the watershed approach

The design of the ‘best-bet’ technologies for improving soil fertility in the Songani watershed proved to be particularly challenging. Fertilisers have become more expensive since the recent devaluation of the Malawian currency, making them increasingly inaccessible to smallholder farmers. This was a key concern raised by community members at watershed meetings. Farms in the area are small, land is used intensively (Table 2) and maize is commonly inter-cropped with legumes, in contrast to the sole maize production system that dominates elsewhere. Introducing a green manure legume into the system, as a relay inter-crop, may displace the grain legumes currently inter-cropped with maize, and inadvertently reduce food security (Shaxson and Tauer, 1992).

The researchers looked at the cropping systems in Songani to see if they could pinpoint any under-exploited niches. The ridge/furrow system predominates here, as it does elsewhere in Malawi. Ridges are prepared by hand, with crops planted along the top, while the furrows remain bare and unproductive. Researchers saw the opportunity for introducing a relay green manure into the furrow, which would not compete directly with food crops. In fact, the furrow was not a good place to establish seedlings because the subsoil was compacted, low in nutrients and intermittently flooded. However, research on
DC

Figure 6. Maize yields from four technologies in the Songani watershed.



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ISSN 1560-3520