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FARMER AND RESEARCHER PARTNERSHIPS IN MALAWI: DEVELOPING SOIL FERTILITY TECHNOLOGIES FOR THE NEAR-TERM AND FAR-TERM

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SUMMARY

In Malawi, intensive production of maize (*Zea mays*) is pursued on over 60% of smallholder land, yet application of nutrients is almost nil. To improve adoption of soil productivity-enhancing technologies, two participatory methods were pursued: (i) a novel 'mother-and-baby' trial design and (ii) participatory action research with communities in a southern Malawi watershed. The central 'mother trial' was managed by researchers (replicated within a site) and systematically linked to farmer-managed 'baby' trials to cross-check biological performance with farmer assessment. The watershed approach involved a partnership of researchers and farmers addressing soil management. Technologies tested in both approaches integrated legumes into existing maize-based systems, sometimes in combination with inorganic fertilizers. Across methods, legume intensification increased yields by approximately 40% (net benefit increase of approximately US$50 ha^{-1}) and fertilizer increased yields by approximately 70% compared with continuous maize grain yields of about 1100 kg ha^{-1}. Farmer assessment prioritized technologies that included secondary benefits, such as weed suppression, grain legume yields, and low-labour-demanding fertilizer. A survey indicated that participating researchers and extension staff had reservations about the amount of time required to interact with farmers, and no clear consensus emerged regarding the best approach. There has been wider adoption of the mother-and-baby trial method by scientists in neighbouring countries, indicating the value of systematically incorporating farmers' input.

INTRODUCTION

Declining soil fertility and productivity is a significant problem in southern Africa, where many farmers live at the margins of survival. Adoption of fertilizers and organic-matter-based technologies has been minimal (Kumwenda *et al*., 1997).

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Government extension and agricultural research institutions in the region have the mandate to reach millions of smallholders and help improve soil management and farm productivity. Yet, in general, resource-poor farmers reap few benefits from public services (Chambers *et al.*, 1989).

One problem is the limited relevance of many fertilizer recommendations and organic matter technologies to local priorities (Fujisaka, 1993; Okali, *et al.*, 1994). Participatory research methods have been advocated as a means to improve relevance and adoption (Chambers *et al.*, 1989). Institutionalizing a more participatory process, including documentation of farmer perceptions early in the research and development process, is expected to improve the relevance of technologies (Ashby and Sperling, 1995). There are relatively few examples of agronomists using farmer-participatory approaches, however. Participatory research is considered too time-consuming and is criticized for not generating quantitative data (Johnson *et al.*, 2001).

Participatory research to improve the variety selection process has shown promising results. Examples include plant breeders working with farmer expert panels to develop bean varieties in Rwanda and cowpea (*Vigna unguiculata*) varieties in West Africa (Kitch *et al.*, 1998; Sperling *et al.*, 1993). Involvement of farmers in selection of soil fertility technologies has proved more problematic, with few successful models (Kanyama-Phiri *et al.*, 1998). Highly varable performance of technologies is one challenge; local adaptation may be necessary to optimize performance in a heterogeneous environment. Soil management technologies also require substantial farmer investment in the form of land, labour or cash. This can be a barrier to local experimentation. By contrast, participation in variety trials involves limited risk and it can be relatively easy to involve many stakeholders (Banziger and de Meyer, 2001).

The challenge of conducting participatory research with many clients is particularly acute for natural resource management. Frequently, the participatory development process is conducted on a small, project scale (Defoer *et al.*, 1998). Working intensely with many partners over a large area can require prohibitive levels of financial and human resource investment. In Malawi, there is interest in practical and cost-effective means to involve many farmers. It is now over twenty years since the farming-system approach was initiated in this country, and agronomy research by the public sector is conducted primarily on-farm (Heisey and Waddington, 1993). Some research programmes, however, fail to understand or take account of farmers' real priorities. Farmers' production priorities are often assumed to focus on maximizing yields or financial returns while, in reality, they may be concentrating on gaining the best return from a very small cash investment, or on maximizing food security.

Complementing the extensive research on fertilizer recommendations, Malawi researchers have developed organic sources of nutrients for smallholders through investigating agro-forestry systems, green manures and legume rotations (MacColl, 1989; Maghembe *et al.*, 1997). It has been demonstrated that some of these systems improve soil productivity through nitrogen fixation, additional carbon inputs and by conserving nutrients (Snapp *et al.*, 1998). To date, however, virtually no farmers have adopted them (Snapp *et al.*, 2001). The most significant blocks to farmers' acceptance seem to be the high labour requirements, the need for skilled management and the limited profitability in the short term. Recent changes in the economic climate, however, include the increased cost of mineral fertilizer and broader market opportunities. This context may generate new interest in grain legumes and green manures.

Participatory research methodology

Examples of participatory approaches can be seen as a continuum, from researcher-led (farmers as contractors) to collaborative arrangements that are client-driven (farmer-led) (Chambers *et al.*, 1989). To expand this typology, the authors consider the 'scale of operation' as well as the 'farmer-researcher partnership typology'. For example, demonstration trials operated on a large scale frequently carried out over an entire country. Extension trials generally limit farmers' participation to assistance with implementation (Benson, 1997). Farmer field schools involve farmers actively and train them to develop their own recommendations. To be carried out on a large scale, however, farmer field schools require a massive investment in education to train many farmers in the principles of experimentation and agro-ecology (Ooi, 1996; Braun, *et al.*, 2000).

In this paper the authors discuss five years experience of experimenting in Malawi with two participatory approaches. Both methods are less costly than farmer field schools and, potentially, are practical for public-sector researchers and extension agents to adopt. The methodologies presented address the challenges of working in marginal environments with poor farmers. One approach was a near-term strategy, based on a novel mother-and-baby trial design to systematically link assessment of technologies by farmers and biological performance (Snapp, 1999). The other approach evaluated was a long-term strategy of watershed-based, participatory action research. This involved a major investment in building community and researcher ties, joint priority setting, and technology development. Preliminary reports have been published (Kanyama-Phiri *et al.*, 1998; Snapp, 1999). The objectives were to: (i) document and compare the participatory methods; (ii) evaluate technology performance, in terms of biological productivity, farmer perceptions and economic performance; and (iii) assess the interest of researchers and extension workers in these approaches.

MATERIALS AND METHODS

The sites

The sub-humid tropical agro-ecosystems of Malawi are characterized by a long dry season, with an unimodal rainfall pattern between November and April. In southern Malawi, sporadic showers occasionally continue through July. Soils are generally Alfisols or Ultisols, which are moderately fertile and have deep profiles (Young and Brown, 1962). Soils under smallholder production generally have low

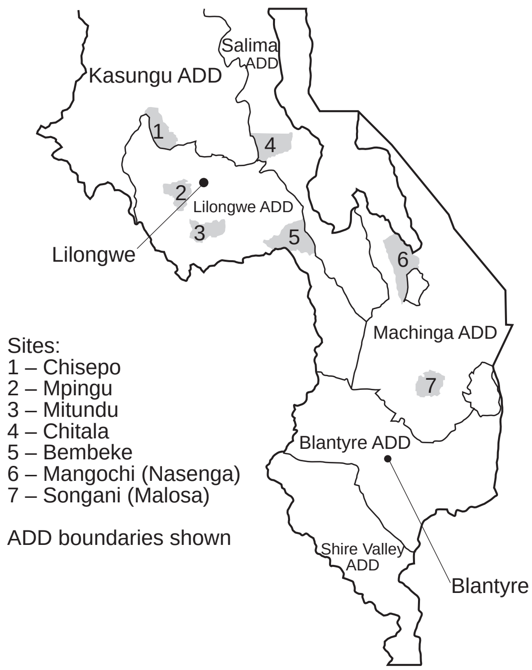

Figure 1. Map of central and southern Malawi with research sites indicated by extension planning area (EPA) designation. The EPA is an extension administrative sub-unit of the eight agricultural development divisions (ADD) in the country. Sites 1–5 are located in central Malawi, and 6–7 in southern Malawi. At Songani (site 7) both mother- and baby trials and participatory watershed research was conducted.

levels of organic carbon (11–15 mg kg^{-1}), and are moderately acid (pH = 5.5–6.6) (Snapp, 1998). Soil fertility has declined as a result of continuous maize (*Zea mays*) production, minimal use of fertilizers and the abandonment of traditional fallow systems. The four agro-ecosystems chosen for participatory research are located in Central and southern Malawi (Figure 1), where about 70% of smallholder agriculture is practised. The agro-ecosystems are listed, with the study sites in parentheses:

1) Central Malawi: sub-humid, 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- and baby trials and the watershed approach.

Mother-and-baby trial design

The 'mother-and-baby' trial got its name from one of the farmers involved in the trials. The 'mother' trials test many different technologies, while the 'baby' trials test a subset of three (or fewer) technologies, plus one control (Snapp, 1999).

The design makes it possible to collect quantitative data from mother trials managed by researchers, and systematically to cross-check them with baby trials on a similar theme that are managed by farmers (Figure 2). The design is flexible: mother trials reported on here were located on-farm at central locations in villages, but they can be located at nearby research stations (Snapp, 1999). The level of farmer participation in baby trial design and implementation can vary from consultative to collaborative. A consultative process for baby trial management is discussed here, yet the role of farmer participation in the baby trials has expanded at the Bembeke site, to the extent that farmers design their own baby trials (R. Mwanza, personal communication).

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 synthesize published information and results from years of on-farm research (Figure 3A). A reconnaissance survey helped form the hypotheses that smallholder farmers have limited resources, use small amounts of mineral fertilizer, and experiment with alternative sources of nutrients such as legume residues (Rohrbach and Snapp, 1997). Researchers designed ‘best bet’ technologies to improve soil productivity that required minimal cash and labour (Table 1). 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 (Figure 1). The selected villages had to be representative of four major agro-ecozones, and also in terms of population density and access to markets.

The researchers involved in the mother-and-baby trials selected the test farmers in collaboration with community members at a meeting. They asked for volunteers and stressed the need to include both well-off farmers and those with few resources, as well as households headed by women. The implemented trial design was geared to meet both farmers’ and researchers’ objectives – which are by no means identical. Relatively simple ‘one-farmer, one-replication’ trials were managed by farmers to act as satellites or ‘baby’ trials to a central ‘mother’ trial managed by researchers that had ‘within-site replications’ (Figure 2). A trial design with a maximum of four plots and no replication within the farmer’s field fits a limited field size, it simplifies the design and makes it easier for farmers to evaluate technologies. Having many replicates across sites makes it possible to sample wider variations in farm management and environment (Mutsaers, *et al.*, 1997; Fielding and Riley, 1998). However, replication within a site and intensive, uniform management improves research on biological processes. The mother-and-baby trial design is the first attempt of which the authors are aware that systematically links ‘replicated within a site’ researcher-led trials with ‘one site, one replication’ farmer-led trials (Figure 2).

Technology evaluation in the mother-and-baby trial approach

Farmers initially chose their test technologies on the basis of introductory community meetings (Figure 3A). Descriptions of promising technology options

Table 1. Description of test technologies for improving soil fertility.

Technology	Trial*	Plant density ($\times 10^3$)	Biological characteristics†	Farmers' perceptions of characteristics
Maize as sole crop (+ 69 kg N ha^{-1} fertilizer in mother trials)	W, M&B	Maize: 37	Three maize plants per hole, 0.9 × 0.9 m.	Farmers' current practice, productive with minimal labour inputs
Maize + relay inter-crop *Sesbania sesban*	W	Maize: 37 Sesbania: 7	Three maize plants per hole, 0.9 × 0.9 m. Sesbania planted at first weeding in furrow between maize-planted ridges. Three sesbania grown for 10 months before leaves are incorporated.	*Sesbania sesban* seedlings become well-established in furrows; space in the cropping system under-utilized
Maize + relay inter-crop sesbania + 45 kg N ha^{-1} fertilizer	W	Maize: 37 Sesbania: 7	Three maize plants per hole, 0.9 × 0.9 m. Sesbania planted as above.	Residues from sesbania are combined with mineral fertilizer
Maize + tephrosia relay intercrop (with and without 45 kg N ha^{-1} fertilizer in the watershed trials)	W, M&B	Maize: 37 Tephrosia: 20 kg ha^{-1}	Temporal compatibility enhanced by planting tephrosia at first weeding as a relay intercrop. Tephrosia initially grows slowly and can produce about 2 t ha^{-1} green manure.	Green manure system with minimal labour requirements. Seed is broadcast along ridge and incorporated during weeding.
Maize-pigeonpea intercrop (with and without 69 kg N ha^{-1} fertilizer in mother trials)	M&B	Maize: 37 Pigeonpea: 37	Temporal compatibility. Pigeonpea planted at the same time as maize, three plants per hole spaced halfway between each maize hole. Pigeonpea grows slowly, which reduces competition with maize.	Pigeonpea is a bonus crop; low plant density minimizes impact on maize yields.
Groundnut-pigeonpea inter-crop year 1, rotation with maize year 2	M&B	Groundnut: 74 Pigeonpea: 37	Groundnut (150 mm spacing) grown in single row on ridge spaced at 0.9 m; 'bonus' pigeonpea crop is inter-cropped to improve quantity and quality of residue biomass	Legume seed density takes account of cost of groundnut seed and appropriate seeding rates. Pigeonpea is a bonus crop.
Soyabean-pigeon pea intercrop year 1, rotation with maize year 2	M&B	Soyabean: 222 Pigeonpea: 37	Same as groundnut + pigeonpea design above, but groundnut replaced with double row of soyabeans planted along each ridge at 150 mm intervals.	Higher seed density is possible because soyabean seeds are smaller and cheaper than groundnut. Pigeonpea is a bonus crop.
Mucuna year 1, rotation with maize year 2	M	Maize: 37 Mucuna: 74	Mucuna has widespread adaptability as a green manure or grain legume, it produces about 4 t ha^{-1} residue biomass and 1.5 t ha^{-1} seed yield for most agro-ecosystems in Malawi	Farmers consume or sell mucuna seed in southern Malawi. Weed suppression a major benefit.

* W = watershed approach; M&B = mother-and-baby approach; M = mother trial.
† Maize hybrid is MH18; pigeonpea variety is ICP 9145; groundnut variety is JL24 or CG7; soyabean variety used is indeterminate Magoye, which does not require Rhizobium inoculum.

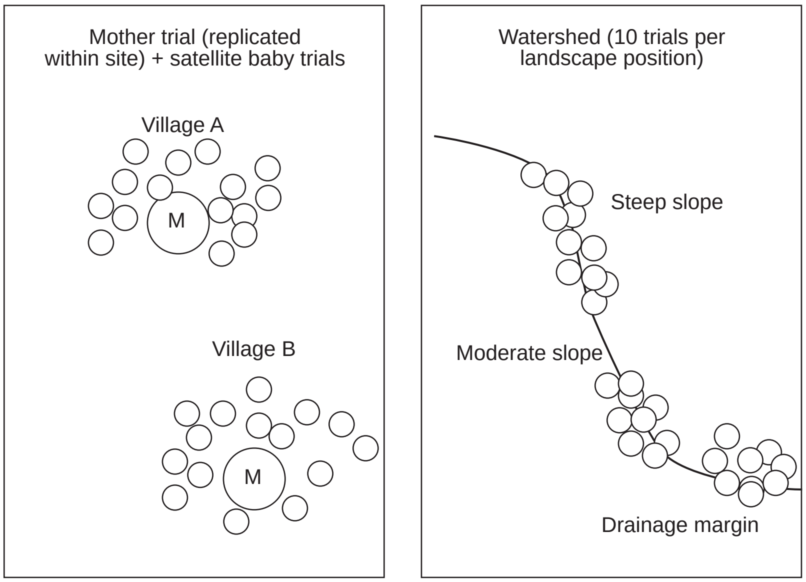

Figure 2. Illustration of site trial design for two participatory research approaches. Case study one: the mother-and-baby trial design consists of baby trials clustered in a village, with one or more mother trials centrally located. Case study two: is a watershed-based approach with trials sited along a transect including three different landscape positions: steep slope, moderate slope and drainage margin.

were presented, and visits to research station trials arranged where possible. Researchers and assistants provided supervision and interaction through monthly visits to sites. Enumerators were based at each site to assist in trial set up and measurements, in collaboration with local extension or NGO staff and farmers (Figure 3B). Training in participatory approaches and survey techniques to reduce bias was conducted at annual project meetings.

Plot size for mother-and-baby trials was approximately 8×8 m. Ridges were prepared by hoe and placed about 0.9 m apart, following conventional practice. Maize was planted three seeds per planting station, spaced at 0.9 m along the ridge-row for a final plant population density of 37 000 ha^{-1}, in a 0.9×0.9 m grid. Seeding rates and planting arrangements for different technologies are described in Table 1. The mother trials were planted by extension staff with assistance from enumerators, within 10 d of the arrival of the rainy season. This varied across the sites, from late-November to mid-December of 1997 and 1998. Farmers were very timely at planting their baby trials: in many cases they were planted before mother trials.

Data collected from trials included: plot size measurements, planting date, emergence date and population density at emergence, early weed cover, dates when plot was weeded (plots were weeded twice, approximately five and ten weeks after planting), above-ground biomass of a sub-sample of legumes measured at flowering, harvest plant population and grain yields at harvest. Fresh weight

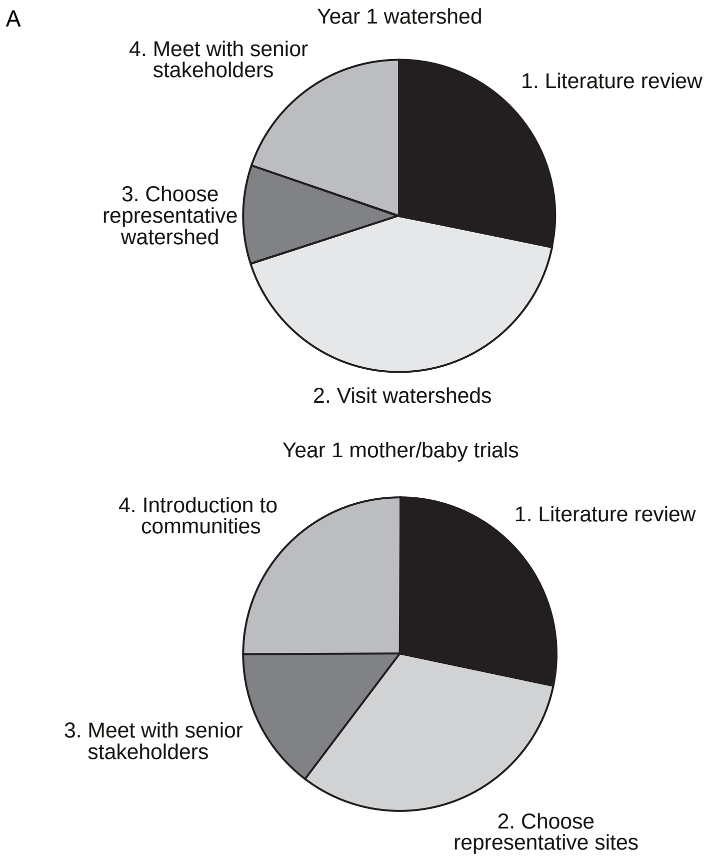

Figure 3. Sequence of steps is presented for designing and implementing participatory research and extension. 3A: Approximate time allocation for activities in year one of watershed-based and mother-and-baby trial approaches.

measurements were conducted in the field, and sub-samples of 5 to 15 kg were collected to determine grain moisture content and dry weight to fresh weight conversions. Soil samples from the top 0–200 mm were collected at all sites in October 1997, and soil pH, organic carbon, inorganic nitrogen and texture analyses were conducted. A baseline characterization report describes the methodology and soil physical and chemical attributes at three of the seven sites (Snapp *et al.*, 2001). Overall, soils were sandy in texture, tended to be moderately acid and organic carbon levels were low, varying from 6 to 15 mg kg^{-1}.

The farmers provided quantitative feedback on their evaluation of technologies to researchers through surveys, paired matrix ranking and by rating technologies. Qualitative feedback was obtained from meetings between farmers and researchers, and comments recorded at field days. The mother trials were evaluated more informally during discussions held during field days. This made it possible to integrate the farmers' assessments and improve research priority setting (Figure 3C). Meetings were also held with senior stakeholders, conducted as part of an

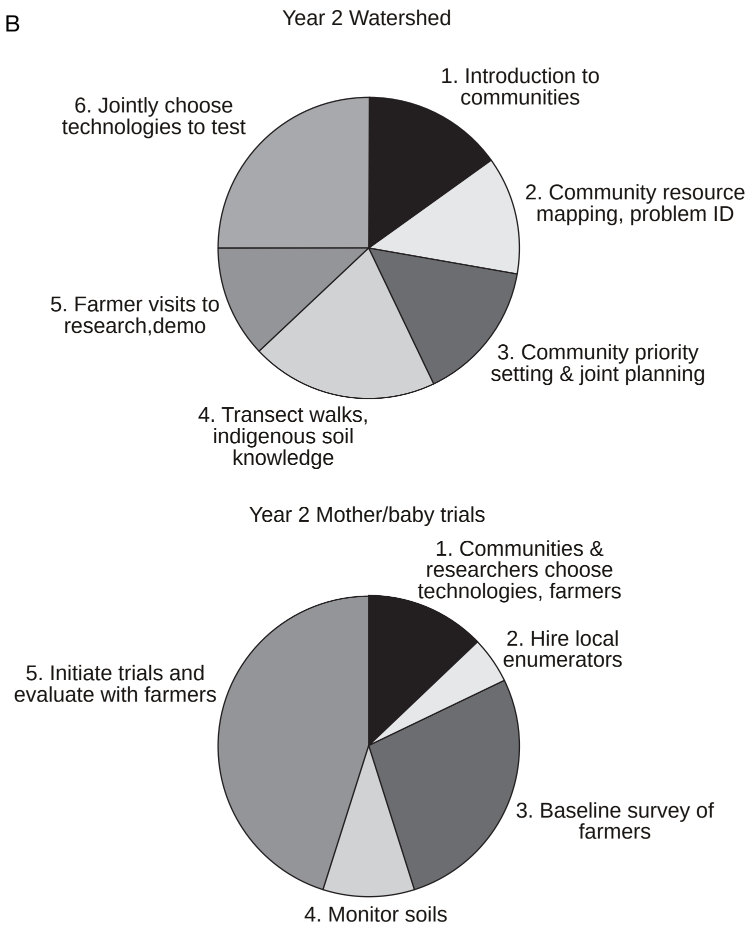

Figure 3B. Time allocation in year two.

iterative process to maintain support and inform priority setting at every level. This included policymakers, supervisors of extension and NGO staff, senior researchers and industry representatives (Figure 3C).

Watershed-based partnerships between farmers and researchers

The foundation of this approach was building partnerships that facilitated farmers, researchers and extension advisors learning together through action research (Carberry, 2001). In 1994 University of Malawi staff and students extensively reviewed the literature and visited sites to select a watershed with intensive land use in a highly populated district of Malawi (Figure 3A). The Songani watershed includes steep, eroded slopes and approximately 250 inhabitants km^{-2}, representative of southern Malawi districts (Orr *et al.*, 2000). The researchers organized community meetings to define how resources are used and to assess with farmers local constraints and opportunities. Inclusion of representa-

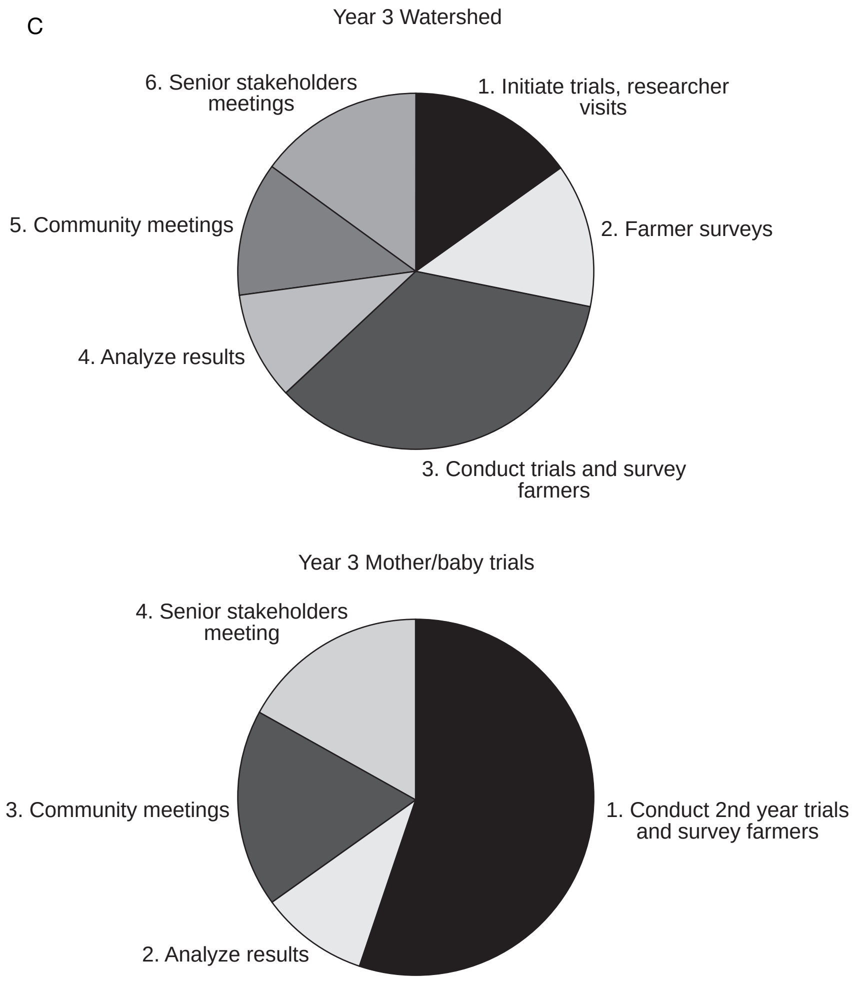

Figure 3C. Time allocation in year three.

tives from the whole community, such as households headed by women and farmers with very few resources, was stressed (Kanyama-Phiri *et al.*, 1998). The researchers and villagers then prioritized problems that could be addressed collaboratively (Table 2).

Over the course of extensive community meetings the participants drew up resource maps and set priorities (Table 2). Researchers hypothesized that a field's position in the landscape would influence how its soil fertility was managed. Transects were laid across the watershed and walks along these conducted with community members (Figure 2). Sites were selected that were representative of three positions in the landscape: steep slopes, moderate slopes and along drainage margins (locally termed, *dambo*). Field sites were randomly selected along transects, and most of the farmers who cultivated the selected fields participated in the trials.

Table 2. Farmers' perceptions of environmental change, and problems and their potential solutions in the Songani catchment area.

Environmental change	Indicators identified by farmers	
General	Declining soil fertility, decreasing food supplies, low yields and erratic rains.	
Declining soil fertility	Soil colour changing from dark to light; low yields; the appearance of certain weeds (striga and *chiundu*); soils drying out, becoming dusty and unable to produce crops without fertilizers.	
Problem	Top priority for individual farmers (n = 157)	Potential solutions identified by communities
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 fertilizer more efficiently** **Increase benefits from legume-intensification systems** Increase access to fertilizers, manure and fallow land
Soil erosion	13%	Construct boundary marker ridges on the contour Install waterways and plant trees and grasses in gullies Construct stone lines
Other	11%	–

Source: Adapted from Wellard, 1996
Bold script indicates when researchers could offer assistance

Over the next five years the researchers worked with these farmers in an iterative manner, conducting surveys, analysing indigenous knowledge and implementing participatory research trials (Kamangira, 1997; Kamanga, 1999). An intensive exercise with farmers documented their knowledge to improve the researchers' ability to communicate (Kamangira, 1997).

Compared with the mother-and-baby trials, the watershed-based process involved considerable investment of time and resources for building collaborative relationships, particularly in the initial year (Figure 3A). The researchers were breaking new ground by working together with farmers on how to address problems of very low yields and eroded slopes. This approach also linked research on biological processes to understanding farmers' indigenous knowledge about land use and developing technologies that had wider relevance for regions similarly affected by erosion and pressure on the land (Kamanga, 1999; Phiri *et al.*, 1999). The Songani watershed has became a platform for learning and action research for researchers from the University who have continued to work with communities on defining their problems and developing long-term solutions.

Technology evaluation in watershed approach

Researchers identified the farmers associated with the selected fields along the transects (Figure 3B). The data presented is from a subset of 30 farms, where integrated nutrient trials were successfully implemented over two seasons.

Choosing technologies to test with farmers was a challenge as farm size was small and the consequences of introducing a green manure legume relay intercrop system could be displacement of grain legumes intercropped with maize on the planting ridges, and inadvertent reduction of food security (Shaxson and Tauer, 1992).

An under-exploited niche, the furrow in the ridge-and-furrow system, was identified as an opportunity for integration of a relay green manure. However, the furrow was not conducive to plant establishment; the exposed subsoil was intermittently flooded, compacted and low in nutrients. Research at a nearby station demonstrated that *Sesbania sesban* seedlings could be established in the furrow and produce residues that contained over 100 kg ha^{-1} a^{-1} N (Maghembe *et al.*, 1997) (Table 1). Farmers who visited the research station were interested in testing this relay intercrop, and initial investigations were begun in 1995 (Kanyama-Phiri *et al.*, 1998). However, farmers expressed concern about the labour requirements of starting and transplanting sesbania seedlings. Researchers introduced *Tephrosia vogelii*, another short-lived perennial legume similar to sesbania but potentially less labour-demanding as it can be established from direct seeding (Table 1). Farmer interest in integrated nutrient management strategies informed a redesign of the trials as well, to incorporate the use of N fertilizer combined with legumes (Kamanga, 1999). The N fertilizer rate used was 45 kg ha^{-1}, chosen to match the resources of the farmers and less than the recommended rate of 69 (Benson, 1997) or 92 kg ha^{-1} (Kanyama-Phiri *et al.*, 1998).

Maize was planted in test plots along transects in mid-December 1996 and 1997 and legumes were planted or transplanted in mid-late January. Legume residues were incorporated in October 1997 and 1998. Plot size was approximately 10×10 m, with a split plot design where N fertilizer was applied to one-half of each plot. Fertilizer was applied as a split application, half at the same time as maize was planted, and half as a side-dressing when maize had reached about 600 mm in height. Trial data collected included: planting and transplanting dates, emergence date, above-ground biomass of a sub-sample of legumes measured at incorporation, harvest plant population and grain yields at harvest. Fresh weight measurements were conducted in the field, and sub-samples of about 6 kg were collected to determine grain moisture content and dry weight to fresh weight conversions. Graduate students surveyed farmers and conducted on-site monitoring of labour requirements to document evaluation of technologies and economic assessments by farmers (Kamangira, 1997; Kamanga, 1999). Soil sampling procedures and results have been reported previously (Phiri, *et al.*, 1999).

Statistical analysis

Statistical analyses were conducted for both approaches using the analysis of variance module of a statistical package (StatSoft for Windows, 1995). The authors evaluated the response of maize yield grain in year two of the trials: a two-way analysis of variance conducted for technology and location. Where technology effects were significant in the analysis of variance, a planned non-orthogonal comparison was used to evaluate mean technology effects, compared with the control, continuous maize without nutrient inputs. Descriptive statistics were conducted for farmer rating data, and means compared using paired T-tests (Taplin, 1997).

Economic analysis

Economic analysis of net benefits for both approaches was conducted after two years, to compare performance of intercrop systems to two-year rotation treatments. The difference was computed between the value of maize and legume grain yields (total price benefits) accruing from fertilizer and legume seed inputs and costs (CIMMYT, 1988). Benefits were calculated using average prices for grain yield of maize (US\$0.13 kg^{-1}), groundnut (*Arachis hypogaea*) (US\$0.3 kg^{-1}), pigeonpea (*Cajanus cajan*) (US\$0.21 kg^{-1}) and mucuna (*Mucuna pruriens*) (US\$0.08 kg^{-1}), obtained in village surveys. Costs that vary included fertilizer average at farm gate (US\$0.3 × 200 kg = 60 ha^{-1}), estimated labour for fertilizer application (US\$1.0 ha^{-1}), and seed of improved groundnut (US\$15.0 ha^{-1}), pigeonpea (US\$3.0 ha^{-1}), mucuna (US\$5.0 ha^{-1}), *Tephrosia vogelii* (US\$1.5 ha^{-1}), *Sesbania sesban* (US\$5.0 ha^{-1}). Labour to establish and transplant sesbania seedlings was estimated at US\$16.00 ha^{-1} (Kamanga, 1999).

Survey of researchers and extension staff

To document the perceptions of researchers and extension personnel involved the authors surveyed 39 participants at two project workshops, held in April and June 1999. The participants included frontline field staff (research assistants and extension staff who work directly with farmers) and senior staff who made field trips to the sites and were involved from inception in either approach. A formal survey was conducted of all participants, including descriptive characteristics such as education level and work responsibilities. An open-ended question elicited the top three methods that the participant believed were effective at reaching farmers and facilitating adoption of improved practices. The number of times a method was mentioned was reported as a percentage of all methods volunteered (Kitch *et al.*, 1998). Participants were also asked to rate on a scale of 1 (ineffective) to 5 (effective) specific methods to improve adoption of technologies, including conventional dissemination approaches and farmer participatory research and extension.

RESULTS AND DISCUSSION

Comparing methods

In Malawi, researchers have accumulated a body of knowledge about soil management through decades of on-farm work, yet disseminating and adapting soil-improving technologies to farmer circumstances has proved challenging. A novel aspect reported here was the attention paid to involving poorer farmers and female-headed households in technology assessment (Figure 3A). In general wellresourced farmers have been the prime actors in on-farm research, as they are best able to invest in risky and long-term technologies, such as rehabilitating degraded areas with legumes in North Syria (Ghassali, *et al.*, 1999). Yet understanding the unique barriers faced by farmers with few resources could improve researcher efforts to develop appropriate technologies. A mother-and-baby trial design can be used to test and disseminate technology options rapidly. The participatory watershed approach also integrated farmer and researcher assessment of technologies, although the time investment required was considerable – an additional year compared to the mother-and-baby trials (Figure 3B).

Both participatory methods allowed farmers to rigorously assess technologies, and facilitated agronomists' integration of data on biological performance and farmer perceptions. The researchers summarized data from different sites, and reported back to farmers, extension workers and NGO staff (Figure 3C). During these discussions the farmers' observations generally concurred with those of the researchers. Farmers also often highlighted secondary benefits, such as weed suppression by tephrosia. However, tephrosia and sesbania intercrops were also criticized by many farmers, due to high labour requirements. This inspired new interest by researchers in developing improved weed control and residue management options (Johnson *et al.*, 2001). Both participatory research approaches appeared to encourage iterative thinking about priority setting in research and extension (Figure 3C), one of the keys to institutionalizing a more participatory and accountable process (Ashby and Sperling, 1995; Carberry, 2001).

Assessing technology performance

In agreement with early findings from these sites, the technologies were robust and performed well across different agro-ecosystems, from the semi-arid lakeshore to sub-humid, high altitude zones (Table 3; Kanyama-Phiri *et al.*, 1998). The yield of control plots, maize without added nutrients, in the Songani watershed was less than 750 kg ha^{-1}. On-farm measurements of maize yield at sites further south found similar low maize yields of less than 900 kg ha^{-1} (Orr *et al.*, 2000). Our maize yields were 20 to 80% higher at other sites (Table 3). Another countrywide study found that maize varieties grown without inputs produced about 1500 kg ha^{-1} (Jones and Wendt, 1994). Maize yields in our trials were highly variable and often lower, suggesting a wide range of management. This was expected given the attention we paid to including resource-poor farmers.

Interestingly, performance of technologies in baby trials was predictive of performance in mother trials, and in some cases the yields were approximately 30% higher under farmer management (Table 3). Legume-based technologies with groundnut, pigeonpea or sesbania increased grain yields by about 45% after two years, across a range of environments (Table 3). However, the yields of continuous maize and legume-maize systems were very low on some of the degraded sites in the watershed approach (Phiri *et al.*, 1999). Yields were generally highest for technologies that included fertilizer, 40–110% increases over non-fertilized technologies. Estimation of net benefits subtracted costs that varied and

Table 3. Yields, costs and benefits of best bet technologies, reported on the basis of two years performance. Standard deviation of yield average reported in parentheses. Technologies are described in Table 1. Fertilizer applied in the Mother trials was new recommended rate for maize, 69 kg ha^{-1} N, 21 kg ha^{-1} $P_2 0_5$ and in the Watershed trials was 45 kg N ha^{-1} (Benson, 1997). Source of costs and prices is from S. Snapp, unpublished survey, 1999.

Trial type	Technology		Yield	Maize benefit	Legume benefit	Costs that vary	Net benefits
	Year 1	Year 2	kg ha^{-1} two years^{-1}	$ ha^{-1} two years^{-1}			
Mother	Maize	Maize	2630 (670)	342	0	0	342
	Maize+ fertilizer	Maize+fertilizer	4660 (670)	606	0	122	484
	Maize-pigeonpea	Maize-pigeonpea	2180 (320)	283	82	6	359
	Maize	Groundnut†-pigeonpea	2330 (130)	148	332	18	463
	Groundnut†-pigeonpea	Maize	2760 (690)	262	211	18	456
	Maize-tephrosia	Maize-tephrosia	2620 (550)	340	0‡	3	37
	Mucuna	Maize	3250 (450)	201	137	5	333
	Maize	Mucuna	2840 (510)	155	132	5	282
Baby	Maize	Maize	2720 (287)	354	0	0	354
	Maize-pigeonpea	Maize-pigeonpea	3340 (280)	434	80	6	508
	Groundnut†-pigeonpea	Maize	3900 (290)	308	433	18	723
	Maize-tephrosia	Maize-tephrosia	3140 (440)	409	0‡	3	406
Watershed	Maize	Maize	1520 (450)	198	0	0	198
	Maize+fertilizer	Maize+fertilizer	3280 (490)	426	0	61	365
	Maize-sesbania	Maize-sesbania	2850 (310)	371	0	16	355
	Maize-sesbania+fertilizer	Maize-sesbania+fertilizer	4450 (610)	579	0	77	502
	Maize-tephrosia	Maize-tephrosia	2250 (450)	293	0‡	7	286
	Maize-tephrosia+fertilizer	Maize-tephrosia+fertilizer	3910 (630)	508	0‡	68	440

† Groundnut was replaced by soyabean in cooler areas
‡ Tephrosia seed may occasionally be sold to researchers; this benefit was not included.

indicated that fertilizer-based technologies performed similarly to legume technologies: \$175 to \$250 ha^{-1} a^{-1}, compared with \$100 to \$160 ha^{-1} a^{-1} for unfertilized maize controls (Table 3). Market returns for legume products appeared to be highly variable and it was a challenge to document accurately labour inputs and net benefits (Kamanga, 1999). This difficulty concurs with findings of a baseline survey carried out at the Chisepo, Mangochi and Bembeke sites (Snapp *et al.*, 2001).

Farmer evaluation of technologies was rigorously assessed in both participatory methods. Farmers who conducted baby trials rated technologies as follows: maize rotation with grain legume-pigeonpea intercrop > maize-pigeonpea intercrop > maize-tephrosia = continuous maize (Figure 4). Economic assessment was a predictor of farmer acceptance for the baby trials, as the farmer rating order was similar to the net benefits rating order (Table 3). This did not hold for technologies tested in the watershed trials, where farmers rated fertilizer-integrated technologies highly compared with all other technologies (Figure 4). Farmers were apparently not deterred by the requirement to purchase fertilizer. Supplying small amounts of fertilizers at no charge could have influenced farmer assessment of technologies in the watershed research. However, over two-thirds of farmers in the area had historical experience of using fertilizer and should be able to realistically assess the cost (Rohrbach and Snapp, 1997). We felt it was necessary to provide some subsidization as trial farmers were taking on risk, and many farmers were at the margins of survival (Wellard, 1996). Trade-offs need to be evaluated between subsidization – to facilitate experimentation – and the ability of researchers to document farmers' realistic assessment of technology costs and benefits (Orr *et al.*, 2000).

Initially researchers saw the baby trials as the appropriate venue for farmer comment and evaluation. Over time it became clear that farmers were assessing technologies they saw in the mother trials, as well as the ones with which they had gained first-hand experience through baby trials (Johnson *et al.*, 2001). This was illustrated by the mucuna experience. Seed constraints limited this technology initially to mother trials; yet, despite the complicated design, farmers observed the considerable biomass of mucuna (2–4 t ha^{-1}, even on sandy, dry sites) and demanded seed for baby trials by the third year. The baby trials appeared to be accessible to all, whereas male farmers and relatives of chiefs or extension staff appeared to have the greatest access to mother trials (S. Snapp, personal observation).

Promising technologies from both participatory research experiences are being promoted more widely in Malawi. In a recent brochure, pigeonpea, groundnut and tephrosia intercrops with maize and mucuna rotation systems are highlighted as cost-effective soil management options for smallholders (Malawi Ministry of Agriculture and Irrigation / ICRISAT, 2000). As well, countrywide efforts are disseminating tephrosia-maize intercrops to rehabilitate soils (Hayes *et al.*, 2000). In agreement with on-farm research findings from Benin, farmers in Malawi indicated that weed suppression was a promising attribute of tephrosia and

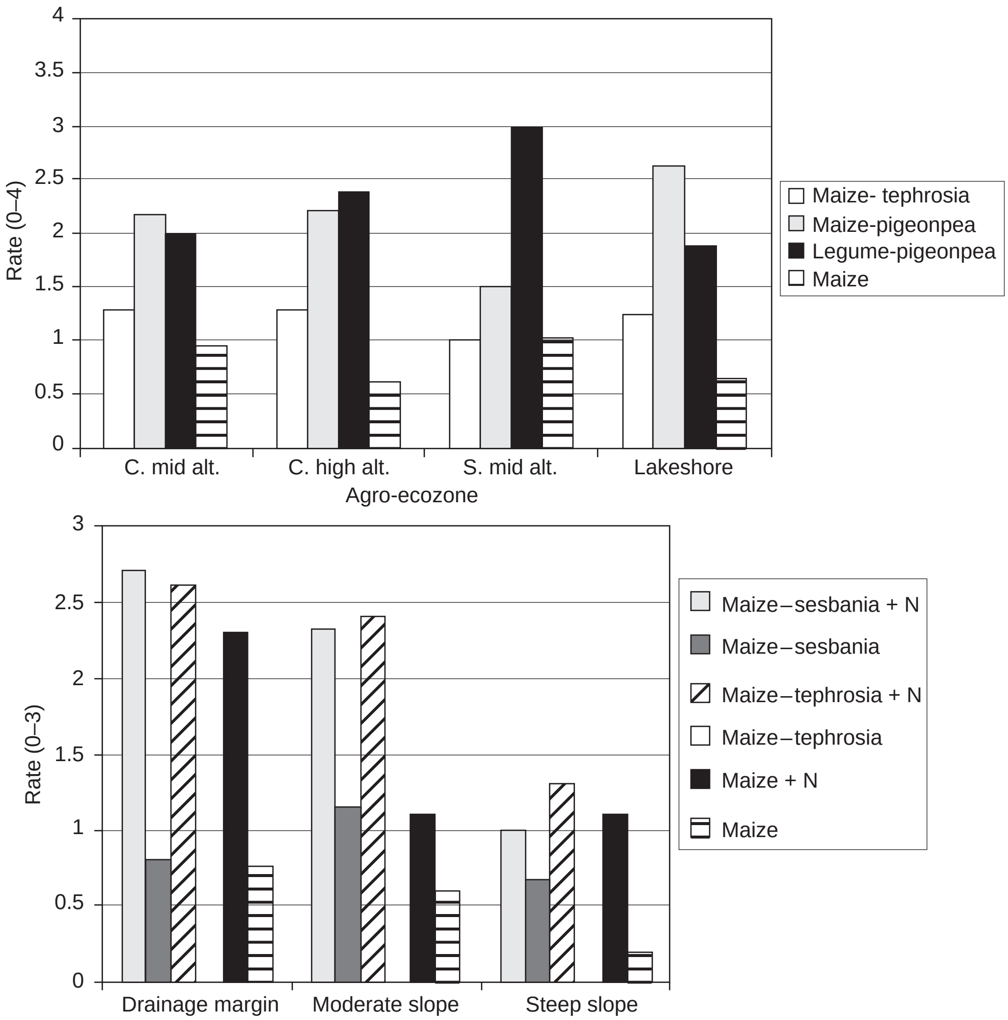

Figure 4. Farmer rating of technology performance, averaged across sites representing four agro-ecosystems in Malawi mother-and-baby trials and three landscape positions in Songani watershed, southern Malawi. Scale 1–5, low to high rating.

mucuna; this could be a missed opportunity if extension efforts focus only on soil fertility (Versteeg, *et al.*, 1998, Snapp *et al.*, 2001).

Researcher assessment of farmer participatory approaches

The mother-and-baby trial design is meeting acceptance by some researchers in the region. In 2000, CIMMYT scientists adopted the method and conducted over a 1000 mother-and-baby trials in six countries in southern and eastern Africa (Banziger and de Meyer, 2001). There was widespread interest in the trial design at the Participatory Research and Gender Awareness III International seminar

'Uniting Science with Participation' held in Nairobi, Kenya in November 2000. Ten participants from seven countries indicated that they were currently using the mother-and-baby trial design or were in the process of adopting it – which frequently included adapting it to local circumstances (Morrone and Snapp, 2001). The primary reason cited for interest in the approach was the ability to involve many farmers systematically and to rapidly elicit evaluation of technologies and varieties.

In contrast, staff from the Malawi Ministry of Agriculture and Irrigation have not widely adopted participatory methods. A survey documented negative and positive comments by participants in the mother-and-baby trials and watershed work. Asked to list the three most effective means to develop and disseminate technologies, 20% of responses included participatory research and extension methods (Table 4). Demonstration trials were mentioned more frequently. Participants were asked to rate the following approaches: farmer participatory research and extension, research and demonstration trials, media campaigns, farmer field schools, targeted recommendations and market-linked development. All methods were rated about equally, between 2.3 and 2.7 on a scale of 1–5. It appears that no consensus has formed around any one approach. Over 90% of researchers and extension staff surveyed agreed with the statement that farmer participation tends to improve technology adoption. At the same time, 63% of the participants raised concerns about cost-effectiveness and prohibitive time requirements of participation. Similar points had been raised earlier by some of the same scientists about farming systems research in Malawi (Jones and Wendt, 1994). Almost all participants surveyed indicated that they were more willing to ask farmers for feedback than they were in 1994, at inception of these projects.

CONCLUSIONS

Farmers in Malawi have to contend with rising fertilizer costs, limited farm sizes and a long hungry season each year. In the face of these challenges, researchers and extension staff are attempting to introduce and test alternative cropping systems and nutrient management practices through participatory trials. By facilitating hands-on experience for farmers, the clustered mother-and-baby trials provided a relatively rapid approach to developing 'best bet' options. The linked trial approach provided researchers with tools for quantifying feedback from farmers, and generated new insights, such as the need to widen the research focus beyond soil fertility to include secondary benefits such as weed suppression. Some extension staff and researchers expressed reservations about the time requirements for participatory approaches; however, the success of the approach is reflected in the uptake of the mother-and-baby trial design by researchers in seven neighbouring countries (Morrone and Snapp, 2001).

The watershed approach attempted to address the challenges faced by communities with highly intensified cropping systems on eroded slopes. The community's involvement in defining the problems steered researchers away from soil con-

Table 4. The most effective methods to develop and disseminate technologies as indicated by a survey of researchers and extension staff involved in participatory research and extension approaches in Malawi.

Methods to develop and disseminate technologies	Responses† (%)	
	Researchers	Extension staff
Farmer empowerment	20.7	4.9
Farmer field schools	15.9	7.8
Demonstration trials	22.0	34.1
Drama	7.3	4.9
Mass media	2.4	14.6
Farmer participatory research and extension	21.9	17.1
Market access	7.3	0.0
Brochures	2.4	17.1

† Respondents were requested to list top three methods where the frequency of response for each method is presented as a percentage of total number of responses for researchers (82) and extension staff (41).

servation, shifting the focus to developing integrated technology options that improved food security and soil fertility. Participatory research indicated that soil available N could be enhanced by inter-cropping legumes and maize, and this would initially increase maize growth. Yet maize yields turned out to be disappointing unless fertilizer was applied. It also proved to be costly to set up the watershed approach and to carry out trials along transects, compared to the cluster approach used in the mother-and-baby trials. Policy makers may need to be drawn into this work, as there appear to be no easy answers to the problems posed by degraded sites and the intensive cropping systems of southern Malawi.

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