Soil Fertility Management for Smallholder Farmers

Ministry of Agriculture and Irrigation

MALAWI

International Crops Research Institute for the Semi-Arid Tropics

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Cost-Effective Soil Fertility Management Options for Smallholder Farmers in Malawi

Ministry of Agriculture and Irrigation
Government of Malawi

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Introduction

There is a widespread decline in soil fertility in Malawi, and food security is a pressing issue. The Guide to Agricultural Production published by the Ministry of Agriculture (MOA 1991) provides guidelines to improve productivity in a wide range of crops. This brochure is meant as a complement to the Guide, for use by extension workers, NGO farm advisors, and anyone interested in expanding the range of options for farmers. It describes a number of low-cost options suitable for the resource-poor smallholder farmer, who cannot always afford the recommended fertilizer rates.

Surveys have shown that many small-scale farmers in Malawi have only a small amount of money to invest in fertility management. Farmers often have to prioritize and make choices among a few options. They may have to choose non-optimal options that require less cash or are less time consuming. For example, they may have to choose among the following: buy one bag of fertilizer, or buy one bag of seed of an improved legume variety to intercrop with maize, or hire labor for weeding, or hire labor for incorporation of green manure residues. Farmers need advice on how best to use their limited resources. Our objective therefore should be to offer farmers a wider range of effective but low-cost options, from which they can choose the best for a particular set of circumstances.

Options for Improving Soil Fertility

This brochure focuses on cost-efficient options, to maximize returns from minimal investments of say MK 500-1000, approximately the cost of one bag of fertilizer at today's prices. Practicality is also important: technologies must not be too labor or cash demanding, and must fit within the resources and capabilities of the majority of farmers.

The technologies described in this brochure should be presented to farmers as options. Extension field staff and farmers can further modify these technologies to fit local circumstances. These recommendations are not blueprints providing the only way to improve soil fertility. Rather, they are they are a set of options that farmers can evaluate, modify where needed, and choose one or more options that best suit their needs. This is part of an educational process to improve awareness about nutrient management, harness local initiative, and encourage experimentation. To assist the extension worker and farmer, tables are included that describe and compare various options, based on common problems that farmers encounter.

Integrated Nutrient Management

Low-cost fertilizer options

Nitrogen is usually the nutrient most deficient for maize production (Fig. 1). As a general rule of thumb, farmers who can afford to buy only one bag of fertilizer should buy a fertilizer that is rich in nitrogen, such as urea or calcium ammonium nitrate (CAN). Urea has a high nitrogen content and is generally the cheapest source of nitrogen, but it requires careful management compared to many other fertilizers. It must be applied only when rainfall is sufficient. Apply urea when the soil is wet or during a heavy rain. This will prevent nitrogen losses and protect maize from being burned by urea. CAN fertilizer is another good source of nitrogen. It is easier to manage, but not as rich in nitrogen as urea.

If a farmer can buy two bags of fertilizer, we generally recommend one bag of 23:21 and one bag of urea (Benson 1997). However, if the soil is heavy textured – sandy clay loam – two bags of N-rich fertilizer (urea or CAN) may be more cost effective. Note that there are a few areas in Malawi with special fertilizer requirements. Soils in the Dedza high-altitude area are generally deficient in zinc and phosphate, as well as nitrogen (Kumwenda et al. 1997).

Figure 1. Behind the scientist is maize that received nitrogen-rich fertilizer. In front of him is yellow, nitrogen-deficient maize which was not fertilized.

Fertilizer application and timing

The recommended practice is to apply fertilizer to planting stations. This is the general farmer practice in Malawi; it is called the dollop method. A potentially faster and less labor intensive method is the banding method, i.e., fertilizer is applied in a line or band along the ridge.

If the farmer can afford to buy only a small amount of fertilizer, then a split application should be used. This will reduce fertilizer losses, particularly from heavy rains. Generally, half the fertilizer should be applied early in the season, i.e., at crop emergence or soon after. The other half should be applied about one month later, as a side-dressing.

Targeting fertilizer

If a farmer has only a limited amount of fertilizer, the fertilizer should be carefully targeted. It should be applied to a field or part of a field containing the healthiest plants, which can give a good response to the fertilizer. That is, fields with early-planted crops, good stand establishment and good weed control (where the farmer plans to weed at least once or preferably twice). Fertilizer should not be applied to areas that are often flooded with water in the furrows, or other areas where plants do not look healthy. Apply fertilizer to healthy crops that can use the added nutrients to produce a good harvest.

Farmers often apply fertilizer to a sole maize crop. But it may be more profitable to apply fertilizer to an intercrop of maize and a grain legume, e.g. maize/bean, maize/groundnut, etc (Snapp et al. 1998a). Intercropping with one or more legumes is common in Malawi, with maize being the dominant crop, and the legume(s), generally planted at low density, being a "bonus" crop. The advantage of applying fertilizer to an intercrop is that both crops can benefit. For example, 4 years of research in Dedza showed that maize yield increased by 30% while legume yield increased by 50-100% when two bags of 23:21 were applied to a maize/bean intercrop.

Legumes do not always require N fertilizer since they can biologically fix nitrogen and make it available to other crops. However, on sandy and low fertility soils, legumes will benefit from some amount of N fertilizer. Farmers who grow grain legumes such as common bean, groundnut or soyabean on a commercial or semi-commercial scale should consider using 23:21 or di-ammonium phosphate (DAP) fertilizer.

Soil phosphorus deficiency

Low phosphorus is not a country-wide problem in Malawi, but in certain areas there are definite phosphorus problems. In such areas farmers should use fertilizer that contains phosphorus (23:21 or DAP), or organic sources of phosphorus such as manure or pigeonpea residues.

Symptoms of phosphorus deficiency can be seen on maize leaves.

Figure 2. Maize/bean intercrop in Dedza, Central Malawi. Note purple coloring on maize leaves, a symptom of low phosphorus. Farmer needs to apply a fertilizer containing phosphorus and nitrogen, e.g. 23:21.

A distinctive purpling of the leaf is a good indicator (Fig. 2). Small leaf size and stunted legume plants also indicate phosphorus problems. In red acidic soils, if legumes do not grow well, this often indicates phosphorus deficiency.

A profitable option is to rotate maize with a legume. Apply a fertilizer containing phosphate and N (e.g. 23:21) to maize. In the next season, grow a grain legume in rotation with the fertilized maize. Phosphate has long-term residual benefits in soil, and this will generally improve yields of the rotation legume.

Combined fertilizers

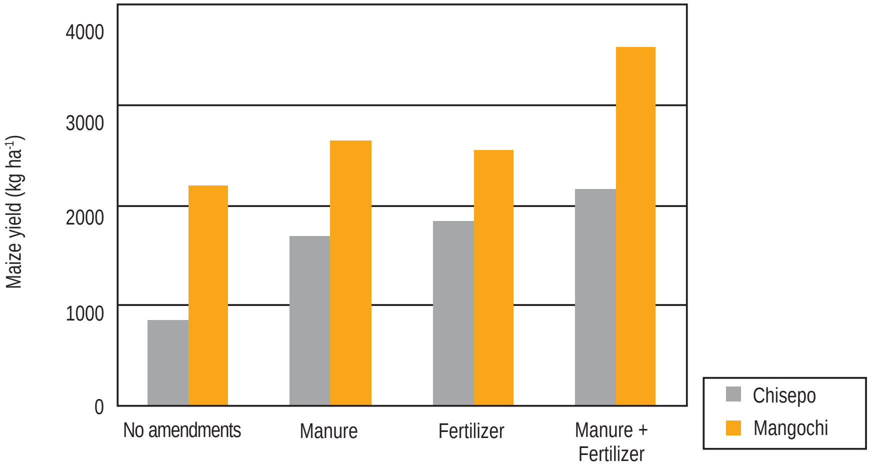
Fertilizers can be combined with legume residues or manure to improve crop response and farmers' profits. Use of fertilizer on maize will increase yields, but the yield increase is much higher when fertilizer and legume residues are used together (Table 1).

Figure 3 shows that the benefits from combining manure with 17 kg N ha^{-1} of fertilizer (three-quarters of a bag of urea) are much greater than use of manure alone or urea alone. Table 2 summarizes the benefits and challenges from applying small amounts of fertilizer alone or in combination with manure.

Improved Manure Management

For the best crop response, use high-quality manure and apply it directly onto planting stations. Two handfuls of high-quality manure per maize planting station will improve yields in the first year of application, as shown for goat manure (Fig. 3). Manure varies in quality. Generally, chicken manure is the best, followed by goat manure. Cattle manure is of

Figure 3. Maize grain yield response to small amounts of manure and fertilizer.



Goat manure 5 t ha^{-1}, targeted application of 2 handfuls per planting station. N fertilizer 17 kg ha^{-1}. Data averaged from 10 on-farm trials at Chisepo (Central Malawi) and Mangochi (Southern Malawi), 1998.

lower quality. Do not apply manure when it is very fresh, or it will burn the crop. Manure should be allowed to age (mature) for at least 3 months before being used.

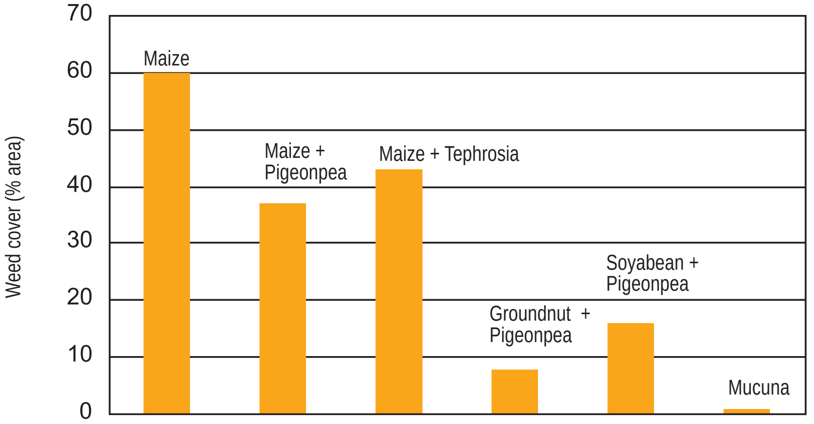
To improve manure quality, store it in a pit or in a covered *boma* (for example, goat manure, where the *boma* is often covered by a thatch roof). If manure is stored in the open and exposed to rain, many of the nutrients will be washed away. To improve both quality and quantity of manure, a compost can be made. This can be as simple as mixing manure with crop residues or cut grass (make sure there are no weed seeds!) to produce a heap, or mixing manure in the furrows of the field.

Legume Rotations

Legume rotations are important not only to improve soil fertility, but also to reduce pests. For example, witchweed (Striga) can be reduced by rotating different crops. Figure 4 shows the reduction in weeds with different intercrop and rotation systems, all of which have fewer weeds than continuous maize. Grain legumes can also provide diversified sources of income and nutrition, and thus improve food security.

One general rule of thumb is that only legumes that produce at least 2 t ha^{-1} of residues will significantly increase subsequent maize yields.

Figure 4. Weed cover (% area) under different crop combinations.



Weed cover measured at end of 1997/98 season, country-wide average.

Long-season grain legumes, such as long-duration pigeonpea or indeterminate soyabean, will produce more residues and contribute to soil fertility. Short-season legumes do not build up soil fertility. Also, a high legume population density is required (Chiyembekeza et al. 1998). Best bet options of legume-maize cropping system combinations are described below, but keep in mind that only high plant population densities and long-duration legumes will improve soils and subsequent maize yields.

Grain legume – maize rotation

Consider a situation where the farmer harvests a good legume crop of groundnut, soyabean or common bean (1.2 t ha^{-1} at least, where over 2 t ha^{-1} of residues are produced), and incorporates the residues into the soil. If maize is grown after these legume residues are incorporated, yields generally increase by 300-600 kg ha^{-1}, compared to continuous maize (unpublished data, ICRISAT-Lilongwe 1998).

Remember that in order to obtain visible improvements in maize yield, there must be a large quantity of legume residues available for incorporation. That is why a minimum yield of 1.2 t ha^{-1} was cited in the previous paragraph, and the crop combinations described in Table 3 are recommended. If enough quantities of residues are incorporated, the benefits can be substantial.

Table 4 shows the potential N contribution of grain legumes to maize and illustrates how to calculate the amount of fertilizer needed. For example, on a medium textured sandy loam soil, about 34 kg ha^{-1} of N is needed for a maize yield of 3 t ha^{-1}. However, the incorporated legume residues provide 23 kg ha^{-1} of N. The additional requirement is 11 kg ha^{-1} of N, i.e. half a bag of urea fertilizer.

To maximize soil fertility contribution and ground cover by grain legumes, plant at the rates shown in Table 3, or higher rates if the farmer can afford the seed. Farmers often do not plant at recommended levels because groundnut, soyabean or common bean seed is not available or too expensive. In such cases, farmers can obtain soil fertility benefits by planting a "doubled-up legume intercrop", i.e. intercrop maize with pigeonpea plus another grain legume. This double intercrop will enhance the benefits of a legume rotation and improve subsequent maize yields, as discussed in the following section. Pigeonpea is particularly suitable for this system because seed is cheap, the crop grows slowly which makes it a good intercrop, and it produces large amounts of residues so the organic N benefits are high for a minimal investment.

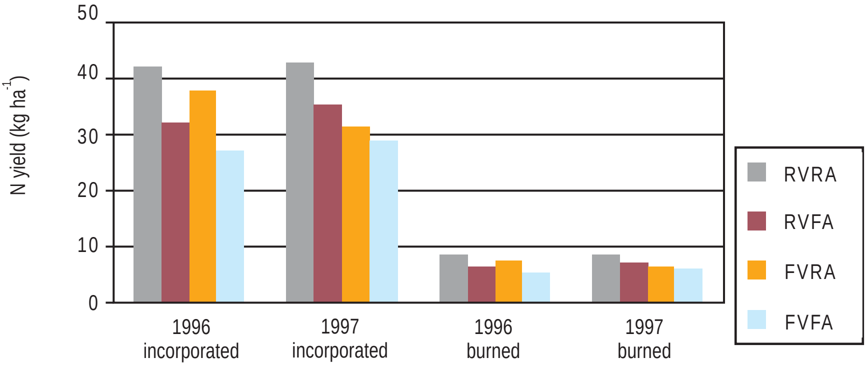
Generally, long-season groundnut and indeterminate soyabean varieties (e.g. Magoye) provide the largest soil fertility benefit to subsequent maize crops, compared to other grain legumes such as short-season groundnut, common bean or determinate soyabean varieties. Good cultural practices such as timely weeding will increase legume yields; and a good crop will provide more residues (Chiyembekeza et. al. 1998). The residues, when incorporated, improve the availability of nutrients for crops grown in rotation. Residues should be incorporated as soon as practical. It is crucial that farmers not burn legume residues, as burning reduces nitrogen by about 70% (Figs. 5 and 6).

"Doubled-up legumes" – maize rotation

The doubled-up legume system is important for farmers who have scarce labor or land, as it allows them to grow more legumes with the same investment in land and weeding. Farmers consistently ranked doubled-up legumes high among organic soil fertility options (Fig. 7 and Kanyama-Phiri et al. 2000).

Examples of a doubled-up legume system include groundnut + pigeonpea intercrop or soyabean + pigeonpea intercrop in rotation with maize. See Table 3 for a full description of these systems. Doubled-up legumes provide soil cover for a long period, extensive root plowing action,

Figure 5. Effect of variety, agronomy, and residue management on nitrogen contribution from groundnut residues.



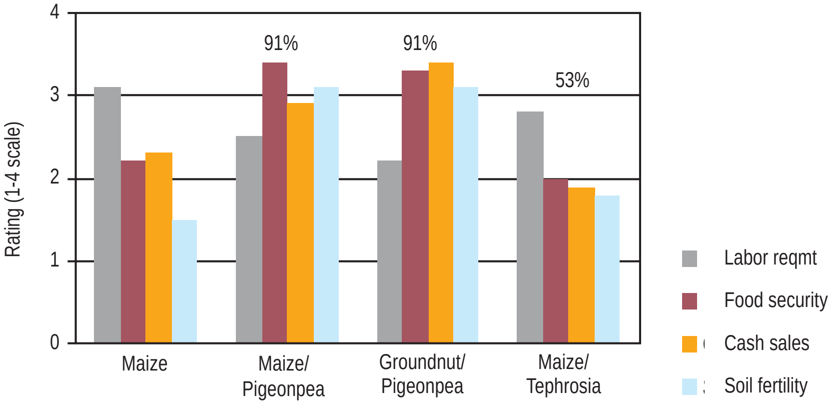
RVRA = Researcher variety researcher agronomy, RVFA = Researcher variety farmer agronomy, FVRA = Farmer variety researcher agronomy etc.

Varieties: improved variety CG 7, local variety Chalimbana. Agronomic practices: number of weedings, plant population density.

The biggest factor in N benefit in both years was not variety or agronomy, but residue management, i.e. whether residues were burned or incorporated.

Figure 6. Farmers near Kasungu burning groundnut residues at harvest. This greatly reduces the nitrogen benefit to subsequent crops grown in rotation with groundnut.

Figure 7. Farmer rating of different crop combinations.



Rating scale 1 = Very low, 2 = Low, 3 = High, 4 = Very high

Figures above the bars (e.g. 91%) show percentage of farmers who plan to try this technology on their own next year with seed provided by researchers. Data from farmer-participatory research at Mangochi, Chitala and Lilongwe.

and enhance N fixation. The residues improve soil fertility by providing organic inputs and phosphate contributions (Natarajan and Mafongoya 1992, Snapp et al.1998b).

Yields of maize grown after a doubled-up groundnut + pigeonpea intercrop generally increase by about 0.5 to 1 t ha^{-1}, compared to maize grown after maize. These results suggest that groundnut + pigeonpea residues are contributing the fertilizer equivalent of about 40 kg ha^{-1} of N, under on-farm conditions.

Mucuna – maize rotation

The potential N contribution of green manures to maize production can be substantial. Table 3 describes the rotation system with maize grown after mucuna (*Mucuna pruriens*), also known as Kalongonda or velvet bean. Mucuna is grown as a sole crop in the first year. Plant along the ridge at 15 cm spacing, one seed per planting station. Ridges are spaced at 90 cm intervals, for a spacing of 15 x 90 cm. The mucuna can be used in two ways: (i) slashed green and the fresh material incorporated at flowering to obtain the maximum nitrogen benefits, or (ii) harvested for grain and the dry residues incorporated. In the second year, maize should be planted using normal farmer practice. When mucuna is planted as a sole crop it produces a huge amount of biomass, often over 10 t ha^{-1} of plant litter. This is much higher than other annual green legume species.

The large amount of biomass incorporated produces a good maize crop in year 2, often double the yield compared to unfertilized maize grown year after year.

The mucuna can also yield about 2 t ha^{-1} of seed. The seed can be eaten but must be soaked overnight before it is cooked. Soaking is necessary to get rid of tannins that are not digestible. One problem is that mucuna seeds can be poisonous if not processed correctly (Lorenzetti et al. 1998). Mucuna-maize rotation is well suited for Southern Malawi, where farmers are familiar with how to prepare the seeds for consumption. Utilization classes should be conducted for farmers who are unfamiliar with mucuna.

Legume Intercrop Systems

Maize-pigeonpea intercrop

Maize-pigeonpea intercropping is a good option for farmers with very small farms, less than 1 ha. Pigeonpea at the recommended plant population and spacing (Table 3), sown within the maize row, alternating with maize planting stations, will not compete with maize or reduce maize yields. The soil fertility benefits are generally 10-25 kg ha^{-1} of N. Pigeonpea intercropping may provide a smaller N contribution to the maize crop than a legume rotation, but it is one of the best ways to gradually improve soil fertility while planting the same amount of land to maize each year. Thus, it is a low-risk method for resource-poor farmers, allowing them to meet their minimum maize requirement each year. Pigeonpea can be called a bonus crop since it provides a small amount of edible grain (about 400 kg ha^{-1}), as well as high quality residues (leaves and pods) with excellent fertility-enhancing properties. The residues contain about 2.5% N and 0.4% P, which is superior to residues of groundnut, soyabean or Tephrosia. In addition, the deep rooting system of pigeonpea “biologically ploughs” the soil, and the woody stems and branches provide some fuel wood. Table 5 summarizes the advantages and disadvantages of planting a maize-pigeonpea intercrop.

Note that if goats and cattle are not controlled after the maize harvest, they will eat the pigeonpea and no grain will be harvested.

Maize-Tephrosia relay intercrop

The potential soil fertility benefits of a maize – *Tephrosia vogelii* (fish bean) relay intercrop system are promising. Tephrosia grown as an intercrop with maize across a wide range of environmental conditions in Malawi, consistently produced about 40 kg ha^{-1} of N (R. Gilbert, unpublished data, 1999). Like pigeonpea, Tephrosia grows slowly at first and thus does not compete much with maize in an intercropping system. However, Tephrosia has one important drawback. It is susceptible to root-knot nematodes (which also attack tobacco, tomato, eggplant, paprika and green pepper), so it should not be planted in a field where these crops have been grown recently or will be grown the following season.

To intercrop maize with Tephrosia, plant maize using normal farmer practice at the start of the season. Just before the first weeding, about 3 weeks after maize emergence, broadcast Tephrosia seed along the side of the ridge at 20 kg ha^{-1}, and weed immediately (Table 3). The weeding practice (banking) will cover the Tephrosia seed with soil and thus it can be planted with very little extra labor. If Tephrosia seed is scarce, another method can be used: plant at 22 cm spacing along the maize row, between maize stations.

This requires more labor than broadcasting, but it is an effective way to establish a maize-Tephrosia relay intercrop.

Tephrosia grows slowly until the maize is mature, then continues to grow in the dry season. Tephrosia should be cut and residues incorporated just before ridging is done for the next planting season, in Sept, Oct or Nov. Areas with Chiperoni rains (winter rainfall) in Southern Malawi will produce the best Tephrosia.

Another Tephrosia system has been developed with the aim of rehabilitating highly degraded soils. In this system, Tephrosia is intercropped with maize in the first year and is then allowed to grow for a second year as a

Figure 8. Normally a 2-way intercrop is recommended, for easy management. However, some participants in a farmer-designed, farmer-implemented trial in Southern Malawi preferred a 3-way intercrop: Tephrosia in foreground, maize-pigeonpea in background.

sole crop. This is an improved fallow system (Fig. 9). It produces more Tephrosia biomass and an extensive root system, to regenerate a field that is very low in soil fertility or degraded and can no longer support maize production. In the second year Tephrosia cannot be intercropped with maize as it will form a stand of bushes. However, this stand can supply fuel wood as well as build up soil fertility. The residues from this improved fallow system will greatly improve yields of a crop grown in the third year, after incorporating the Tephrosia residues. For more information about Tephrosia, see MAEP (1998).

Figure 9. Flowering plants of Tephrosia vogelii in an improved fallow system.

Residue Management

Maize versus legume residues

In terms of fertility benefits from incorporation, legume residues are far superior to maize residues, for two reasons. Firstly, nutrients from residues become available to crop plants only after decomposition. Legume residues decompose quickly, while maize residues may take months to decompose, and therefore do not provide crops with additional nutrients during the critical early growth stages. Secondly, decomposition occurs through the action of bacteria, which require nitrogen and other nutrients to survive. The bacteria obtain these nutrients initially from the soil and later, as decomposition occurs, from the residues. With legume residues, decomposition takes only a few days and does not affect plant growth. But maize residues decompose slowly and usually take up extra nitrogen, reducing what is available in the soil. In many cases farmers will be better off using maize residues for other purposes, rather than incorporating them into the soil.

Alternative uses for maize residues include:

- Fodder for livestock, whose manure can then be applied to fields
- Incorporate with manure to make compost
- Leave on the soil surface as a mulch to increase water infiltration (note that mulching must be done at least two months before maize is planted, to prevent attracting termites which may harm young maize seedlings)
- Lay the stalks across gullies to reduce runoff and erosion.

In contrast to maize residues, legume residues can contribute substantially to soil fertility in the first year of incorporation. As discussed earlier, high-quality legume residues should never be burned. If the residues are burned, nitrogen benefits are almost nil (Fig. 5). It is important to spread the message that the incorporation of legume residues enhances soil fertility (Fig. 10). An alternative to incorporation is to feed good quality residues to livestock. Soil fertility benefits will still be obtained if manure from the livestock is applied to the field.


Figure 10. Pigeonpea residues ready for incorporation on a smallholder farm near Zomba, Southern Malawi.

To maximize soil fertility benefits legume residues should be incorporated when they are still green, such as the green manure rotation system where mucuna is slashed and incorporated at flowering (i.e. in April or May). This method yields the highest quality residues, providing the maximum soil fertility benefits. However, it is not possible to harvest any grain in this system. If a grain legume is grown as a dual benefit system, for grain and for the N contribution, then residues should still be incorporated as early as possible.

Farmers in Southern Malawi currently incorporate low-quality residues, including maize stover and weeds. This is effective in areas where winter rains occur, accelerating the decomposition process, and reducing N and P immobilization at planting time. In areas without winter rains, maize residues will not decompose and can reduce nitrogen available to plants. To get enough nitrogen for future crops the maize residues should not be incorporated directly unless other sources of nutrients are applied at the same time.

Cost-Effective Soil Fertility Management: Opportunities and Challenges

Improving seed availability of legumes

Lack of seed is often the main reason why farmers do not use legume rotations and intercrops. Legumes have low seed-to-seed ratios, which means it takes several seasons to grow enough seed for sale or distribution of new varieties. The problem is particularly serious with groundnut, which has large seeds and limited storage life. When a new legume crop (e.g. mucuna, pigeonpea, soyabean or Tephrosia) is introduced to an area, seed may not be available locally, at least initially.

Legume seed is not widely available from private seed companies in Malawi. Smallholders currently multiply their own seed, buy grain to use as seed, or exchange seed through community networks. New initiatives have been launched to increase seed availability of improved varieties for small-scale farmers in Malawi.

Legume grain utilization

Smallholder farmers in Malawi grow and consume a wide range of grain legumes, but not all farmers in the country are familiar with the legume species highlighted in this brochure. Mucuna and pigeonpea are used by smallholders for both home consumption and sale, but primarily in the Southern region. Soyabean has been introduced in Malawi only recently, though educational efforts have been undertaken on soyabean production and utilization in some localities.

There are severe health hazards associated with eating mucuna and farmers must be educated on the processing steps to make it safe to eat. There is some indigenous knowledge of safe processing methods for mucuna in Southern Malawi, but mucuna should not be promoted without accompanying information on the toxicity hazard and how to safely prepare the seed for consumption (Lorenzetti et al. 1998).

Soyabean also requires an educational campaign on preparation and utilization methods. Soyabean seed contains anti-quality factors that must be neutralized by proper processing, to obtain nutritional benefits and make it easier to digest. Processing technologies such as toasting, soaking and grinding are also required to facilitate the use of soyabean in local foods (Javaheri 1998).

Pigeonpea can be eaten as a green vegetable or as a grain. Knowledge of use as a green vegetable exists in many parts of Malawi, but the grain is not always acceptable in local foods. Simple technologies are available (and widely used in other countries) to reduce cooking time and improve taste by removing the seed coat (Silim et al. 1994). These technologies, if adequately promoted, can greatly improve farmer preference for pigeonpea.

References

Benson, T.D. 1997. Spatial and temporal variation in fertilizer recommendations for maize grown by smallholders in Malawi. Pages 135-144 *in* Maize Commodity Team Annual Report, 1995-96. Chitedze Research Station, Lilongwe, Malawi: Ministry of Agriculture, Department of Agricultural Research.

Chiyembekeza, A., Subrahmanyam, P., Kisyombe, C.T., and Nyirenda, N.E. 1998. Groundnut: a package of recommendations for production in Malawi. Lilongwe, Malawi: Ministry of Agriculture and Irrigation. 20 pp.

Javaheri, F. 1998. Soyabean combating malnutrition in Zambia. Lusaka, Zambia: Department of Agriculture. 50 pp.

Kanyama-Phiri, G., Snapp, S.S., Kamanga, B., and Wellard, K. 2000. Towards integrated soil fertility management in Malawi: incorporating participatory approaches in agricultural research. Managing Africa's Soils no. 11. Edinburgh, UK: IIED-Drylands Programme. 27 pp.

Kumwenda, J.D.T., Waddington, S.R., Snapp, S.S., Jones, R.B., and Blackie, M.J. 1997. Soil fertility management in Southern Africa. Pages 153-172 *in* Africa's emerging maize revolution (Byerlee, D. and Eicher, C.K., eds). Boulder, Colorado, USA: Lynne Publishers.

Lorenzetti, F., MacIsaac, S., Arnoson, J.T., Awong, D.V.C., and Buckles, D. 1998. The phytochemistry, toxicology and food potential of velvetbean (*Mucuna adans*, Fabaceae). Pages 67-84 *in* Cover crops in West Africa: contributing to sustainable agriculture (Buckles, D., Eteka, A., Osiname, O., Galiba, M., and Galioo, G., eds). Ottawa, Canada: IDRC/IITA/Global 2000.

MAEP (Malawi Agroforestry Extension Project). 1998. Undersowing *Tephrosia vogelii* with crops in Malawi. Agroforestry Leaflet Series no. 1, April 1998. Lilongwe, Malawi: MAEP, Ministry of Agriculture and Irrigation.

MOA (Ministry of Agriculture). 1991. Malawi guide to agriculture production. Lilongwe, Malawi: Ministry of Agriculture, Government of Malawi. 120 pp.

Natarajan, M. and Mafongoya, P.L. 1992. A study on intercropping of pigeonpea (*Cajanus cajan* L Millsp.) with maize, sunflower and groundnut in Zimbabwe. Zimbabwe Journal of Agricultural Research 30:163-171.

Silim, S.N., Tuwafe, S., and Laxman Singh (eds). 1994. Pigeonpea improvement in Eastern and Southern Africa: annual research planning meeting 1993. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 152 pp.

Snapp, S.S., Aggarwal, V.D., and Chirwa, R.M. 1998a. Note on phosphorus and genotype enhancement of biological nitrogen fixation and productivity of maize/bean intercrops in Malawi. Field Crops Research 58:205-212.

Snapp, S.S., Mafongoya, P.L., and Waddington, S. 1998b. Organic matter technologies to improve nutrient cycling in smallholder cropping systems of Southern Africa. Agriculture, Ecosystems and Environment 71:187-202.

Table 1. Costs and benefits from maize cultivation with fertilizer and/or residue incorporation

	Total variable costs (MK)	Benefits (MK)	Benefits/ TVC
Lilongwe			
No fertility treatment	1360	3100	2.3
N fertilizer	2134	6570	3.1
Pigeonpea residues	1468	6300	4.3
Residues + N fertilizer	2242	10,224	4.6
Malosa			
No fertility treatment	1312	2081	1.6
N fertilizer	2377	4799	2.0
Pigeonpea residues	1356	3051	2.3
Residues + N fertilizer	2436	6998	2.9

On-farm data from areas with high soil fertility. Nitrogen added was 45 kg ha^{-1} of N.
All figures in Malawi Kwacha (MK).
Source: Kanyama-Phiri et al. 2000

Table 2. Advantages and disadvantages of integrated nutrient management with manure and fertilizer

Manure from *boma*	Fertilizer	Manure + Fertilizer
Advantages		
Inexpensive source of nutrients, if locally available	Provides nitrogen benefit the same season when applied	Provides nitrogen benefit in same season, also adds organic matter to soil
High quality manure includes goat manure, chicken manure and carefully managed cattle manure (stored in a covered heap)	Does not require much labor to obtain fertility benefits	If farmer has enough manure, can stretch fertilizer to cover larger area
Improves soil, adds nitrogen		Farmer can concentrate weeding and nutrients on best part of farm
Disadvantages		
If added to field before maturing (about 3 months) manure may burn plants, if applied too close to seed	Fertilizer is expensive, farmer must have cash or access to credit	If farmer has only a small amount of manure and fertilizer, some fields will not be treated
Large quantity needed	Fertilizer use is not profitable unless maize yield is high	All the disadvantages listed separately for manure and fertilizer
If manure is low quality, yields will not increase in first year	Fertilizer may not be available at the right time	
Requires lot of labor to gather and transport to field; may need scotch cart and oxen	Urea requires careful application. Prevent burning by applying only after sufficient rain, do not apply close to seed	
Weed seeds in manure may later cause weed problem	Nitrogen from fertilizer can leach if rains are heavy, split applications may be required	

Table 3. 'Best bet' options for improving soil fertility through legumes

Practice	Plant population density (x 1000)	How to do it	Farmer considerations
Sole maize	Maize 37	Maize hybrid MH 18, at 3 seeds per planting station, 90 x 90 cm	Current farmer practice throughout Malawi
Maize+PP intercrop	Maize 37, PP 37	Can be planted at same time since PP grows slowly. PP variety ICP 9145, 3 seeds per planting station spaced halfway between maize stations	PP is a bonus crop, planted at low density to minimize impact on maize yield
GN+PP intercrop in 1st year, rotation with maize in 2nd year	GN 62, PP 37	GN variety CG 7, single row at approx 20 cm spacing, on ridges 90 cm apart. To enhance residue quantity and quality, intercrop PP with the earlier-maturing groundnut	Recommended density based on cost of GN seed and farmer-adoptable seeding rates. PP is a bonus crop
Soya+PP intercrop in 1st year, rotation with maize in 2nd year	Soya 250, PP 37	Same as GN+PP, but a double row of soya along each ridge at a spacing of 10 cm. Indeterminate variety Magoye, does not require inoculum, high yield, high residue	Can double the planting density if farmer can afford cost of soya seed. PP is a bonus crop
Maize+Tephrosia relay intercrop	Maize 37, Tephrosia 20 kg ha^{-1} (broadcast) or 4 kg ha^{-1} (4 seeds per 90 cm)	Plant Tephrosia at first weeding. Tephrosia has initially slow growth, does not compete with maize, widely adapted to Malawi environments	To reduce labor, broadcast Tephrosia seed along ridge and cover with soil during maize weeding. Or, if seed is scarce, plant seeds between maize stations
Sole GN, soya or mucuna in 1st year, rotation with maize in 2nd year	GN 62, soya 250, mucuna 50	Rotate GN, soya or mucuna with maize. GN and soya as described above, mucuna at 25 cm spacing on ridges 90 cm apart. Incorporate legume residues as soon as practical, the earlier the better	Mucuna is toxic. Make sure farmers know how to treat seeds before eating

PP = pigeonpea, GN = groundnut, soya = soyabean

Table 4. Nitrogen calculator to estimate legume benefits

Soil type	N required (kg ha^{-1}) to produce 3 t ha^{-1} maize	N benefit (kg ha^{-1}) from previous grain legume crop – about 1.2 t ha^{-1} yield and at least 2 t ha^{-1} residues	N benefit (kg ha^{-1}) from previous green manure – about 2.5 t ha^{-1} residues incorporated
Light textured sandy (<1% organic matter)	45 (2 bags)	11 (½ bag)	23 (1 bag)
Medium textured sandy loam (1-3% organic matter)	34 (1½ bags)	23 (1 bag)	45 (2 bags)
Heavy textured sandy clay loam (>3% organic matter)	23 (1 bag)	34 (1½ bags)	55 (2½ bags)

First determine soil type. If soil organic matter content is known, use that information to determine soil type. Otherwise, use soil texture to estimate amount of organic matter.

Second column shows amount of N required to achieve maize grain yield of 3 t ha^{-1}. Note that low organic matter and light textured soils usually require more N supplementation. The supplemental N can come from an organic source, e.g. legume residues, or from fertilizer.

Columns 3 and 4 show approximate N contribution from a grain legume rotation (e.g. groundnut or soyabean) or from a green manure crop (e.g. mucuna). To obtain N benefits, residues must be incorporated early. If legume yields are substantially higher than indicated, then N benefits will also be higher.

Table 5. Advantages and disadvantages of legume/maize crop combinations

Sole maize	Maize/PP intercrop	Maize/Tephrosia intercrop	Rotate maize with GN+PP intercrop	Rotate maize with Soya+PP intercrop
Advantages				
Low labor requirement	PP does not compete much with maize, and may reduce weeds	Provides high soil fertility benefits and may reduce weeds	Two legumes: both are cash crops, high protein for family nutrition, soil fertility benefits in future	Soya is a very nutritious food, especially for weaning babies and sick
Farmer can meet family maize requirement	Multiple benefits from PP: pods can be eaten fresh, seed eaten or sold, branches used for firewood. Leaves and root nodules improve soil fertility. High quality forage	Goats do not eat Tephrosia leaves	Intercrop improves returns from weeding, and may reduce weeds	Improves soil fertility
Relatively early harvest to overcome food deficit		Branches provide firewood.	PP grows in winter, protects soil	Intercrop improves returns from weeding, and may reduce weeds
				PP protects soil
Disadvantages				
Requires expensive fertilizer to maintain yields	PP may be eaten by livestock	Tephrosia sometimes difficult to establish due to nematodes	PP may be eaten by livestock	Soya seeds must be roasted or boiled before eating
Striga (witchweed) problems	PP sometimes difficult to establish due to nematodes or termites	Seed not always available	Seed may be difficult to get or very expensive, especially GN	Soya does not grow well in very dry areas, especially in sandy soil
	Seed not always available	Labor intensive to slash, incorporate residues into soil		

PP = pigeonpea, GN = groundnut, soya = soyabean. All legume resides should be incorporated into soil as soon as practical. The sooner the better to improve soil fertility and yield of subsequent maize crops.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced, sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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