PART TWO – SMALLHOLDER AGRICULTURE

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CHAPTER 2

LEVELLING THE PLAYING FIELD

Removing obstacles: the soil fertility example

Most of us like to know that our next meal will arrive. The better off we are, the smaller amount of our income we actually spend on food and the greater the certainty of a decent meal in the near future; and food becomes relatively less important in our scale of priorities. In Africa, most smallholder farm families are poor and many are at or even below subsistence for much of the year. Unsurprisingly, therefore, their immediate priority is to grow enough food to meet their home consumption needs. Those at subsistence (or below subsistence) focus entirely on food crop production. As farmers enter the market place and become wealthier, they will substitute some of their crop area to produce crops for sale and may choose to buy in a proportion of their food needs. In a highly market orientated agricultural economy, farmers may produce almost entirely for the market. In subSaharan Africa, few farm families are in this last category and most rely heavily on home production for their household food consumption needs. Consequently the dominant smallholder cropping systems are based around the production of the starchy staple food crop to provide energy for work and growth. In southern and eastern Africa, maize predominates; in other regions, where other starchy staples (cassava, bananas, sorghum, or millet) are better suited to the growing conditions, these crops predominate. But in all cases, a reliable household surplus of food year on year is needed to create the opportunity to break out of the poverty of subsistence agriculture and to build a diversified and stable home economy.

Maize in southern and eastern Africa provides an excellent model for understanding the practical difficulties faced by smallholders in trying to make this break. The crop is grown from sea level (the coastal zones of Mozambique, Kenya and Tanzania) to elevations of 2400 metres above sea level. It is a popular crop in areas with less than 400 mm of rainfall (eastern Kenya, southern Zimbabwe) to the well watered highlands. Maize accounts for 60 per cent or more of the cropped area in Malawi, Zimbabwe and Zambia and very nearly as much in Mozambique, Kenya and Tanzania. About 50 per cent of the calories consumed in the region come from maize. In Malawi, with an average population density reaching 215 persons per square kilometre in the southern region, maize is the main crop in nearly 90 per cent of the area and contributes 80 per cent of daily food calories[1]. Thus the food security (and the potential prosperity) of most smallholder households in this region is critically dependent on the productivity and sustainability of maize-based cropping systems.

[1] Carr (S. 1994 "The unique challenge of Malawi's smallholder agricultural sector" mimeo) attributes the increase in popularity of maize in Malawi to its efficiency as a per hectare calorie producer compared to the other available food plants. As land availability declines, so efficiency of calorie production per hectare becomes of greater importance to the farmer.

Soil fertility decline as a key constraint

Farmers are not resistant to change. Improved maize varieties are used in a third to a half of the area planted to maize in Africa, but, at the household level, yields per hectare, even with fertiliser, remain well below potential Weeds reduce yields where there is insufficient labour for timely weeding. Drought is a problem, especially in semi-arid zones. But declining soil fertility has become the dominant limitation on yield improvement, and on the sustainability of the maize-based systems of southern and eastern Africa.[2]

The old and already highly leached soils of humid and subhumid zones in Africa are low in fertility even before they are cropped. Traditional African agricultural systems were largely based around extended fallows and the harvesting of nutrients stored in woody plants. The site to be cultivated was cleared and burned. A hot burn provided a relatively weed free seed bed into which crops could be sown. After a few years, the weed burden increased, fertility decreased, and it was time to open a new piece of land. A productive and reliable system which neatly minimised the labour required for the crucial task of early season weeding. It worked well as long as people were few and land was abundant.

In the traditional c*hitemene* slash-and-burn system in the *miombo* woodland of northern Zambia, land was fallowed for 50-70 years.[3] Today, in most arable areas of Malawi, Zimbabwe and Kenya, fallowing has almost disappeared, and is declining sharply in Zambia, Mozambique and Tanzania. Continuous cropping of maize, with a consequent downward spiral of soil fertility, is now the norm. Smaling[4] calculated the nutrient balance for 10 countries in Africa and found a negative, and growing, imbalance between nutrient inputs and outputs[5]. Figure 1 presents data from available on-farm nutrient response trials in Malawi from 1972 to the present time.[6] The data suggest a continuing decline in unfertilised maize yields over time. Excluding the 1960 data (which were based on unimproved maize varieties) the trend is downward (despite yield potential of the improved maize varieties used in these trials rising).

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[2] J. Kumwenda, V. Kabambe and W. Sakala, (1993) *Maize Agronomy Annual Report for 1992/3* Chitedze Agricultural Research Station, Malawi.

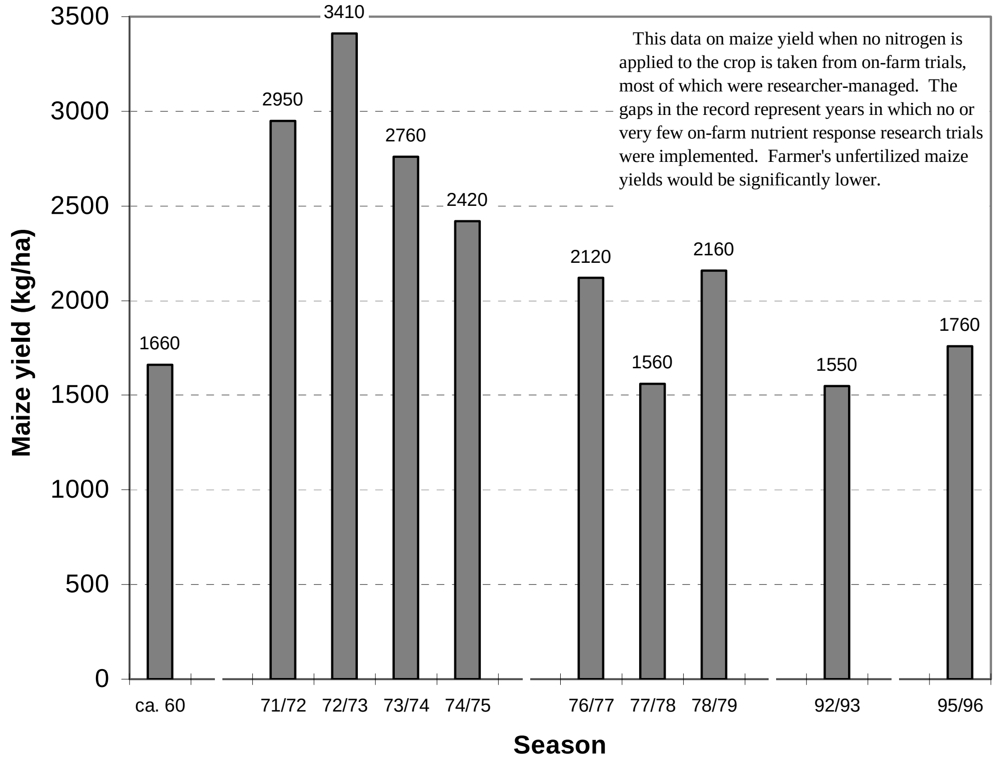
[3] S. Araki (1993)Effect on soil organic matter and soil fertility of the *chitemene* slash-and-burn practice used in northern Zambia. In: K. Mulongoy and R. Merckx (eds.) *Proceedings Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture.* Wiley-Sayce, Chichester, UK. pp367-375

[4] E. Smaling (1993) Soil nutrient depletion in sub-Saharan Africa. In: H. Van Reuler and W. Prins (eds.) *The Role of Plant Nutrients for Sustainable Food Crop Production in sub-Saharan Africa. Leidschendam: VKP*

[5]Estimated rates of net nutrient depletion are high, exceeding 30 kg N and 20 kg K per hectare of arable land per year in Ethiopia, Kenya, Malawi, Nigeria, Rwanda and Zimbabwe (Smaling, 1993).

[6] The data come from a range of sources within Malawi and are not fully consistent in terms of fertiliser source, maize variety, trial design or objectives. Some trials were not replicated, and the data are not disaggregated according to agro-ecological zone, or by rainfall season (although a preliminary analysis did not show obvious differences between good and bad years). No results were available for the 1980s.

Figure 1: Mean maize yields at 0 kg N/ha from nutrient response research trials in Malawi, by year.



There is only one outcome from farming where more is consistently taken out of the soil than is returned to it - crop yields decline and soils erode. Buddenhagen[7]. estimates that nutrients produced from the weathering of minerals and biological nitrogen fixation will enable, at most, the production of 1000 kg of grain per hectare per year on a sustainable basis in the tropics. If soil erosion is taken into account (and soils cultivated with annual crops in the upland tropics are very prone to erosion) yields will be even lower. To feed a family reliably at these low levels of production requires the cultivation of well over a hectare of land. And herein lies the catch. In the short African growing season, managing a hectare if hand hoes are used for cultivation is as much as a family can expect to do. If the family has cattle for draft power, then the area could be as large as two or more hectares. But there is little room for error.

Look more closely at what constitutes a family. A prosperous traditional farm family might comprise parents and working age unmarried children who combine their labour resources to produce sufficient food and items for trade or sale for the family's needs. The family would have cattle for draft power and whose manure would be used to break down tough crop wastes into compost to feed the soil. Too few African farm families today resemble this cheerful picture. Often a woman heads the household, with small children. The older children

[7] I.Buddenhagen (1992) Prospects and challenges for African agricultural systems: an evolutionary approach. Paper presented at the Carter Lecture Series on Sustainability in Africa: Integrating Concepts, University of Florida, Gainsville, USA

may be at school, or have moved to town. If she is fortunate, her husband and children living away will send cash or kind to help support the rural household. If not, she will be attempting to support herself and her children from what she can grow or sell. She will be living on a piece of land that has been cultivated many times before. What inherent fertility was there has long been extracted from the soil. Weeds, including the ubiquitous *Striga*[8], will have established themselves and will compete strongly with whatever she plants for light, water, and nutrients. She may have cattle for ploughing and weeding but, more typically, will rely on hiring from neighbours – and the cattle will only be available after her neighbours have finished their own tasks. In many areas, few, if any, in the neighbourhood may have cattle. Cattle losses through disease or drought, or, increasingly, loss through theft, have reduced herd sizes to tiny numbers. Cultivation and weeding will be done mostly by hand.

We have seen already that if she has access to a hectare or more of land (and to draft power to work it), she may produce enough to feed herself and her family if her health is good and the weather favourable. But the start of the rains brings diarrhoea and malaria. Consequently, her illness or that of her children will result in her planting her crop late. Even a short delay in planting can reduce crop yields markedly. With a poor rainy season (Africa and drought are synonymous) her crop may fail.

The odds are, therefore, that in some, if not many, years, she will find herself unable to produce enough food for her family's needs. She will need to go out to work for neighbouring farmers who will then feed or pay her (and any children that work with her) for the days that she puts in. Typically this work will be planting, weeding, or fertilising the neighbour’s crop - which means that her own is left unplanted, unweeded, and unfertilised until later in the season. Late planting and poor weeding mean a poor harvest and once again she finds herself without food before the crop comes in. Over all this hangs the spectre of AIDS. As much as 25 per cent of the adult population in several countries in southern Africa is infected by the HIV virus. Death amongst the productive young adult population is common; orphans are left in the care of remote or elderly relatives.

The numbers caught in this trap are substantial. At one extreme is Malawi where some 60 per cent of rural households (and 41 per cent of the total population) produce less than they need to feed themselves through the year. On the continent overall, there is growing evidence that many rural families are unable to produce sufficient food for their own annual needs **.** These families face conditions of difficulty and stress for which neither tradition nor science has useful answers. The changes brought about by population growth, disease, and globalisation have destroyed the value of much indigenous knowledge. As noted in the preceding chapter, the rate of change faced by African farmers is greater than any group has dealt with in the past. It is unsurprising that tradition, developed over centuries of slow transition, is overwhelmed by the challenges of today.

Science and soil fertility

[8] *Striga* spp form a family of parasitic weeds on cereal crops. The weed is very difficult to control and can have a devastating effect on crop yields.

New and improved technology should provide a way out. Researchers have earnestly developed what appear to be technically sound solutions to smallholder problems, but which all too often turn out to be financially or managerially unsound. Focus again on soil fertility. There are two fundamental approaches to solving soil fertility problems**.** The best known is simply to add nutrients to the soil by buying in inorganic (or chemical or mineral; choose your nomenclature) fertiliser. This is the central element in most highly productive agricultural systems. The Green Revolution in Latin America and Asia relied heavily on this approach**.** An alternative is what has been called "organic agriculture" in which biology is used to optimise nutrient cycling, and eliminate the need for inorganic fertiliser.

The nutrient most needed in African cropping is nitrogen, which can only come from three sources:

- organic manures from crop wastes or from materials from the surrounding lands,
- biological N-fixation, or,
- mineral (inorganic) nitrogen fertilisers.

Organic agriculture (which includes the first two choices listed above) requires careful consideration. Farmer tradition already includes the use of composts and animal manures as fertilisers. Many farmers grow nitrogen fixing legumes such as beans or groundnuts as part of their farming system. Thus organic agriculture works with the grain of existing farmer practices. Furthermore, inorganic fertilisers are expensive and difficult to obtain. Fertiliser is already the most costly cash input used by the typical smallholder in the maize producing regions of southern and eastern Africa. In Malawi, the cash needed to buy the inorganic fertiliser recommended by scientists as the best practice for successful maize production exceeds most households' total annual cash income[9]**.** Even if they could afford it, the economics are dubious. The Maize Productivity Task Force in Malawi, after analysing the results from 2000 on-farm fertiliser verification trials run over the 1996/97, and 1997/98 seasons, found that for almost all farmers, it did not pay to use fertiliser on maize. In Zimbabwe, of the 32 per cent of farmers applying the recommended package of fertiliser to their maize crop in the 1990/91 season (which was a good growing year), 48 per cent failed to recover the value of the fertiliser**.** It is simply not profitable to use inorganic fertiliser on maize in southern Africa in many instances.[10]

Organic agriculture, unfortunately, has problems of its own. As noted above, organic agriculture involves the efficient recycling of nutrients from within the farming system, or the use of nitrogen fixing legumes to bring fresh nitrogen in from the atmosphere. Recall that African soils are of low fertility to start, and that the fertility of many soils has been run down over decades. Recycling nutrients is inherently a good thing to do but recycling nutrients in already nutrient poor situations at best sustains an already unsatisfactory status quo. Farmers can, and do, harvest nutrients from outside their cropping area. Cattle graze widely and bring in nutrients in their dung. Farmers will dig termite mounds and use the rich soil as fertiliser. But as land pressure grows, so these options become less feasible. Cattle are squeezed out as arable land encroaches on common grazing. Agricultural intensification can be associated

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[9] HIID (1994) Fertiliser policy study: market structure, prices and fertilizer use by smallholder farmers. Harvard Institute for International Development and Economic Planning and Development Department, Office of the President and Cabinet, Government of Malawi, Lilongwe, Malawi. Mimeo.

[10] A.C. Conroy and J.D.T. Kumwenda (1995) Risks associated with the adoption of hybrid seed and fertilizer by smallholder farmers in Malawi. In: D. Jewell, S.R. Waddington, J.K. Ransom and K.V. Pixley (eds.) *Maize Research for Stress Environments*, CIMMYT, Harare, Zimbabwe.

with a decline in the availability of animal manures as livestock are squeezed out[11]. For example, manure from cattle and other animals is very important for most farmers in Zimbabwe, less so in Zambia, but is rarely available in Malawi. Even in the best areas, its supply (and, as importantly, its quality) is inadequate to maintain soil fertility on its own.

Where animals are scarce, farmers have turned to other sources of organic fertility. Leaf litter from trees can make significant contributions in areas close to woodlands - but deforestation associated with the demand for arable land and for building and firewood work against this option as population rises. Composted crop residues are used in wetter areas and where crop biomass production is relatively high - but composts are rarely sufficient for more than a modest part of the cultivated area[12]. These technologies require a substantial labour commitment on the part of farmers. Problems of quality and availability mean that organic manures alone will only rarely provide the productivity boost needed by smallholders.

Legumes are grown throughout the world in no small part because of their ability to fix nitrogen from the atmosphere. The crop which follows the legume can benefit from the nitrogen added to the soil by decaying legume residues. Legumes, therefore, provide a source of new nitrogen and offer a unique opportunity to build up soil nitrogen using biological means. Legume-based agriculture has been the focus of well meaning efforts to transform smallholder African agriculture since the turn of the century. Green manures were heavily researched in the 1920s-1940s and widely used by large commercial farmers in Zimbabwe until a decline in the real price of inorganic fertilisers in the 1950s made the practice uneconomic.

But all legumes are not alike. Not all legumes fix significant amounts of nitrogen, and not all produce sufficient cash or calories to compensate for the cereal crop displaced. Grain legumes[13] potentially have the advantage of both adding nitrogen to the soil, and providing the farmer with an alternative food or cash crop to starchy staple (maize in much of southern and eastern Africa). The data show that the nitrogen contribution from a grain legume crop had been very unpredictable. Brown[14] compared several rotations involving maize and groundnuts in Malawi. Maize yields following groundnuts were 8 to 78 percent higher than continuous maize. MacColl[15] examined residual nitrogen left for maize following legume crops of groundnuts, soyabean, lab-lab and pigeonpea near Bunda in central Malawi. The nitrogen left for the maize varied from 0 to 52 kg N ha^{-1} depending on the legume used, the soil type and the rainfall.

The general rule is that the better a grain legume is at yielding grain, the poorer contribution it will make to soil fertility. Another is that a poor legume crop will fix very little nitrogen. Many farmers in Zimbabwe and parts of Malawi grow groundnuts (*Arches*

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[11] This is more of a problem in the monomodal rainfall areas of southern Africa - where the long dry season makes zero grazing techniques difficult or impossible for smallholders - than in the bimodal rainfall areas of eastern Africa.

[12] And, like manures, quality is often poor.

[13] Common African grain legumes include soyabean, groundnut, pigeonpea, cowpea, and bambara groundnut.

[14] P. Brown (1958). The results of some short-term rotation experiments in Nyasaland. *Rhodesian Agricultural Journal.* 54: 626-633

[15] D. MacColl (1988). Studies on maize at Bunda, Malawi. II. Yield in short rotations with legumes. *Experimental Agriculture* 25: 367-374

hypogaea) in rotation with maize. But yields are poor (0.2-0.5 t/ha) due to a combination of poor seed quality and varieties, low population densities and a failure to use the needed basal fertiliser. The poor groundnut yields and the heavy labour needed to plant, weed, and harvest groundnuts make groundnut-maize rotations unattractive to many smallholders when compared to continuous maize cultivation.. Substantial increases in maize yields consequent on residual nitrogen from a preceding groundnut crop on poor soils have been demonstrated by researchers under research station conditions. Under smallholder farm conditions, maize yields are much more modest since a poor groundnut crop fixes only a little nitrogen. Recent work shows a yield response on the maize crop of some 300 kgs per hectare with the groundnut crop contributing an unexceptional 20 kgN per hectare..

The common bean (*Phaseolus vulgaris*) is widely grown by smallholders in southern Africa, especially the wetter parts of Malawi and Zambia – but the residual contribution of nitrogen from a bean crop is usually very modest[16]. Cowpea (*Vigna unguiculata*) is a good nitrogen fixer but is commonly only grown in small plots by farmers. Insect attack sharply limits yields and the seed stores poorly. Farmers are simply unable to invest sufficient resources into cowpeas for the crop to be grown on a sufficient scale to influence overall farm cereal yields.[17]

Giller *et al*,, have reviewed comprehensively the available options for building soil nitrogen in African soils. Their conclusion is uncompromisingly pessimistic:

> "The most striking conclusion is inevitably that there are no *quick-fix* solutions to the maintenance of all forms of N capital, or SOM [soil organic matter]…. The conundrum is that all restorative technologies for improvement of soil fertility without the use of mineral fertilisers involve either import of organic materials from surrounding land or allocation of land to produce organic materials. In the most densely populated areas, land scarcity prohibits the devotion of land to restoration of soil fertility. In such regions methods for replenishment of the short-term capital N store in soils will be hard to find without either some other form of income generation or short-term assistance to buy fertilisers or direct assistance to compensate for loss of agricultural production, at least in the short term (p.153)."

In short, the evident and serious decline in the productivity of smallholder maize-based cropping systems cannot be reversed by an organic strategy alone. For most smallholders, a totally organic system is too difficult to adopt, or the yield effects are too unreliable or too modest.

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[16] In Malawi, new varieties have been specifically bred for poor soil fertility conditions found on smallholder farms. These yield up to 1.5 t/ha whereas local varieties generally yield less than 0.5 t/ha due to a combination of better disease resistance and improved environmental adaptation (R. Chirwa, pers. comm.). Amounts of N_2-fixation in these new bean varieties have not been determined but are certain to be a component of the improved yield potential

[17] K.G. Giller, C. Cadish, E. Ehaliotis, W. Adams, Sakala and P. Mafongoya (1997). Building soil capital in Africa. In: R. Buresh, P. Sanchez and F. Calhoun (eds.) *Replenishing soil fertility in Africa.* SSSA special pub.no.51. Soil Schience Society of America, Madison, Wisconsin.

The solution should be straightforward. The science of inorganic fertiliser management is well established. Inorganic fertilisers have played a major role in maintaining or increasing soil fertility elsewhere on the planet and there is no reason to suppose Africa should be different. In Africa, the application of the science is too often faulty. Fertiliser recommendations typically ignore soil and climatic variation found in smallholder farming areas, are incompatible with farmer resources, or are inefficient. The farmer ends up using more fertiliser than is necessary, and fails to extract the full benefit from its use. For example, the Zimbabwe recommendation for basal fertiliser on maize is to apply it in the planting hole at planting. Yet farmers almost always apply it just after crop emergence. Their experience is that, under their conditions, the yield loss from this practice is negligible .[18] Doing this allows them, on a given rain, to plant more area more quickly (important on a drying sandy soil), get better crop emergence and have more labour available for other operations.

Farmers are forced into buying nutrients that they do not need, and not having those that they do. There is rarely a response to potassium on the predominant granite soils in smallholder areas of Zimbabwe, yet the compound fertiliser recommended (and which is the most readily available) contains potassium. Both nitrogen and phosphorous are included in many compounds. There is good evidence to show that, for major groups of farmers, it is better to use straight nitrogen (which is cheaper than nitrogen available in a compound fertiliser) just after planting and cheaper forms of phosphorous at other times. In the 1950s, 60s and 70s several nutrient deficiencies were detected for maize on sandy soils in Zimbabwe, including sulphur and magnesium, and less commonly zinc and boron. Although fertilisers with some of these elements are readily available in Zimbabwe, they are rarely promoted for smallholder cereal production. Recent Malawi experience provides a striking example of how fertiliser efficiency can be dramatically improved if the fertiliser provided to farmers has suitable micronutrients added and this fertiliser is supplied specifically to those areas which need it.

Fertiliser recommendations are too often based simply on soil chemical analyses. The concept of regular maintenance dressings (for potassium and phosphate) has resulted in unrealistically high recommendations for smallholder farms, especially those in semi-arid areas[19]. The outcome is recommendations that are of little practical value to many farmers.

Farmer practice in Zimbabwe highlights the inadequacy of much existing fertiliser advice. Farmers have learned to adjust fertiliser use according to rainfall patterns and planting times, despite an absence of official recommendations to do so. Almost all smallholder farmers apply some inorganic fertiliser to maize in the wetter areas (Natural Regions II and III). In a survey of 10 communal lands in such wetter areas, Waddington, *et al*[20] found that farmers applied an average of 65 kilograms of N per hectare to their earlier plantings of maize. Later plantings (which have significantly lower yield potential) received only some 60 per cent of those for earlier plantings. In semi-arid areas (where the reliability of fertiliser technology is much less[21]), few farmers use inorganic fertiliser. In Chivi communal area (which is

[18] E. Shumba (1989) Maize technology research in Mangwende, a high potential communal area environment in Zimbabwe. Part 2: The on-farm experimental program. *Farming Systems Bulletin* 1, 1-13

[19] M. Piha (1993) "Optimising Fertiliser Use" *Experimental Agriculture* Vol 29 405-415 and other researchers note the problems associated with unrealistic fertilizer recommendations.

[20] S.R. Waddington, M. Mudhara, M. Hlatshwayo and P. Kunjeku (1991) Extent and causes of low yield in maize planted late by smallholder farmers in sub-humid areas of Zimbabwe. *Farming Systems Bulletin* 9, 15-31

[21] Such as Natural Regions IV and V - where most smallholders in Zimbabwe actually live and where the likelihood of a poor yield response due to drought is high.

representative of these conditions), less than 10 per cent of farmers regularly applied fertiliser, and then only low rates of nitrogen as topdressing[22].

Fertiliser will remain a high cost item for African farmers for the foreseeable future. It is critical, therefore, that farmers are able to get the most out of whatever fertiliser they are able to purchase. The rapid re-introduction of organic materials to smallholder agriculture is needed - through a focused combination of new science and traditional agricultural wisdom. Despite many years of effort, legumes remain marginal in many of the maize-based systems of the region. In southern and eastern Africa, low phosphorus levels in the soils inhibit legume growth. Much of the work underlying legume-based technologies has been done on research stations. Insufficient account has been taken of the need to tailor legume-based technologies to farming circumstances where labour is short. The necessary fertiliser to "kick start" the system may be too costly or unavailable, and there are often difficulties in obtaining legume seeds. Finally, but not least, the family may not be able to release land from food crops. Sustainable cropping, and the food security of many farming households and of the continent as a whole, requires a reliable supply of adequate soil nutrients, preferably from the careful use of modest amounts of the most appropriate inorganic fertiliser for local conditions combined with nutrients derived from organic sources. Kumwenda *et al*,[23] have reviewed comprehensively the soil fertility technology options from intercropping to agroforestry. In the following chapter will be reviewed several of the most promising of these. The criteria for their selection include that they are actually being taken up by significant numbers of farmers in southern Africa and that they use the best of existing African scientific knowledge.

One story will focus on improved fertiliser use. Flexible soil fertility recommendations that better address actual nutrient deficiencies, take advantage of cropping system opportunities, are efficient in the highly variable rainfall regime faced by most smallholders and are compatible with farmer socio-economic circumstances are required. Moisture and soil fertility work both with and against each other. The climate of southern and eastern Africa means that moisture is a frequent constraint to maize yield and to yield response to fertiliser. The efficiency (measured through grain production) of both water use and N use is raised when both are in adequate supply. But the high risk of poor response to fertiliser in dry years is a major reason why most farmers in semi-arid areas use little or no fertiliser. A partial solution to this can be found in "response farming" techniques that use early rainfall events to decide on the amounts of fertiliser to apply.

Piha has explored the interaction between nutrient use and rainfall. His data show how, by adjusting fertiliser use to the evolving rainfall pattern in any one season, the profitability of fertiliser use can be significantly increased. His results, from trials over 5 years and on farmers' fields, show that his approach gave 25 - 42 per cent more yield and 21 - 41 per cent

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[22] Zimbabwe data from the 1991-4 seasons in Gutu (Natural Region IV) communal area show 80 per cent of farmers using an average of 19 kg N ha^{-1} on fields that were monitored. In Chivi (Natural Region IV-V), only 23 per cent of farmers applied fertiliser at an average rate of 8 kg N ha^{-1} (DR&SS/CIMMYT unpublished). In intermediate areas such as Shurugwi-Chiwundura and Wedza most farmers (79-91 per cent) use topdress N but less than half applied basal fertiliser (see Huchu and Sithole, 1994).

[23] J.D.T. Kumwenda, S.R. Waddington, S.S. Snapp, R.B. Jones and M.J. Blackie (1997). Soil fertility management in southern Africa. In: D. Byerlee and C. Eicher (eds.). *Africa's Emerging Maize Revolution.* Lynne Rienner, London

more profit than did existing fertiliser recommendations. He also showed that existing recommendations were too risky for lower rainfall areas and needed to be adjusted downwards if fertiliser use was to be profitable in those areas. The significance of the recent work by Piha and other similar efforts is that productive and profitable agriculture is reliably possible on poor soils, and in semi-arid conditions, with the judicious use of inorganic fertilisers. Many of Africa's smallholders live in exactly these environments.

The next story will involve organic agriculture, and legumes. Legumes, as we have seen, are the only long term way of adding, as opposed to mainly recycling, nitrogen. The most suitable legumes, from the soil fertility perspective, are often the hardest for the farmer to adopt. Broadly speaking, the larger the likely soil fertility benefit from a legume technology, the larger the initial investment required in labour and land, and the fewer short-term food benefits it has. There is often a direct conflict between the short term requirement to meet today's food supply and building up the long term fertility of the soil to meet tomorrow's food needs. Grain legumes have the fewest adoption problems; and are widely grown by farmers in southern and eastern Africa, mainly for home consumption of the seed and sometimes leaves. But the more productive high harvest index grain legumes offer relatively little organic matter and N to the soil since most of the above-ground dry matter and almost all the N is removed from the field in the grain. Species that combine some grain with high root biomass and shoot-leaf biomass (such as pigeonpea (*Cajanus cajan)* and dolichos bean (*Dolichos lablab*)) offer a useful compromise of promoting farmer adoption and improving soil fertility.

Carr[24] reports that, on severely depleted soils in Malawi, soyabeans (*Glycine max*) will produce more calories per unit of land than unfertilised maize, in addition to fixing nitrogen from the atmosphere. Also in Malawi, Kumwenda reported average soyabean yields of 2200 and 860 kg ha^{-1}, respectively, in monoculture and intercropping from a self-nodulating (promiscuous) variety "Magoye" grown in pure stand. Promiscuous soyabeans are attractive to smallholders because not only do they produce a valued grain but they also have good root and above ground biomass. "Magoye" soyabean is grown very widely in Zambia and is being grown by thousands of smallholders in Malawi, but Malawi has not yet approved recommendations for its use. Zimbabwe researchers have seized the opportunity provided by the promiscuous soyabean technology and moved quickly to put in place an active programme to promote the production, sale, and home consumption of this powerful legume.

[24] S. Carr (1994) The unique challenge of Malawi’s smallholder agricultural sector. Mimeo.