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No. 2008-001

Synthesis of Soil Management Options for Better Targeting of Technologies and Ecological Resilience under Variable Environmental Conditions

By

Moses Mwale

Zambia Agriculture Research Institute

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Vulnerability and Resilience of Social-Ecological Systems

RIHN Research Project 1-3FR

Research Institute for Humanity and Nature (RIHN)
Inter-University Research Institute Corporation, National Institutes for the Humanities

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ABSTRACT

Lack of access to food and its availability is of central concern in Africa and a fundamental challenge for human welfare and economic growth. Low agricultural production results in low incomes, poor nutrition, vulnerability to risks and lack of empowerment. The New Partnership for Africa's Development (NEPAD) targets an average annual increase of 6% in agricultural productivity to ensure food security and sustained national economies. Land degradation and soil fertility or nutrient depletion are considered as the major threats to food security and natural resource conservation in the semi arid tropics (SAT). What is needed is to break the cycle between poverty and land degradation in Africa by employing strategies that empower farmers economically and promoting sustainable agricultural intensification using efficient, effective and affordable agricultural technologies. Such affordable management systems should be accessible to the poor, small-scale producers and the approach should be holistic and dynamic in order to foster both technical and institutional change. This paper aims to increase the dissemination of our knowledge base on soils and its management in Zambia. This includes issues of soil conservation and conservation farming. The main activities being to: inventories available technologies for alleviating land degradation and how to demonstrate and adapt the best-bets in farmers' circumstances using farmer participatory approaches; scale up best bet technologies for sustainable land management and marketing options through the use of appropriate tools, methods and strategies; and to study the resulting ecological resilience under variable environmental conditions.

要旨

食料へのアクセスの不足と食料供給量の不足はアフリカでの主要な問題であり、人間の福祉と経済成長のための基本的な課題である。低農業生産は、低所得、栄養不足、リスクへの脆弱性、エンパワーメントの欠如をもたらす。アフリカ開発のための新パートナーシップ(NEPAD)は、食糧安全保障と持続的国家経済を確保するために年間平均６％の農業生産性の増加が目標である。土地荒廃と土壌肥沃度の枯渇、すなわち土壌養分の枯渇が、半乾燥熱帯(SAT)での食糧安全保障と自然資源保全に対する大きな脅威であるとかんがえられている。アフリカでは、農民に経済力を与えること、効率的で、有効な、手頃な農業技術を用いて持続的な農業集約化を推進することによって、貧困と土地荒廃の間にあるサイクルを壊すことが必要である。そのような手頃な管理システムは貧しく、小規模な生産者にとって利用しやすく、そのアプローチは技術的、制度的な変化を促進するために全体論的でありダイナミックでなければならない。　本論文は、ザンビアでの土壌とその管理に基づく知識を普及することが目標である。土壌保全と保全型農業の問題を含んでいる。主な取り組みは、１．土地荒廃を軽減するのに利用可能な技術を棚卸しすること、そして農民参加型アプローチから農民の事情を踏まえた最善の策をどのように示し、適用するかということ、２．適切なツール、方法、戦略の利用を通じて持続的な土地管理やマーケティングオプションのための最善の策を拡大すること、３．環境変動下で結果として生じる生態レジリアンスを研究することである。

Synthesis of soil management options for better targeting of technologies and ecological resilience under variable environmental conditions

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1.0. Introduction

Zambia's Agriculture is predominantly rainfed. Of the total land area of 75 million hectares, 42 million hectares, or 56%, is available for agriculture (Agricultural Statistics Bulletin, 1996). Of this, 85% is suitable for crop production. Currently, cleared land is about 14 million hectares. Land utilised for agriculture averages 1.4 million hectares per year. In terms of total agricultural land, just over 3% is currently being utilised.

Zambia is divided into three agro-ecological zones based mainly on rainfall (Veldkamp *et al*., 1984). Region I is in the southern areas of Southern and Western Provinces and the Luangwa valley of Eastern Province. It receives less than 800 mm of rainfall annually. Region II with the highest agricultural activity, is the central plateau of Eastern, Lusaka, Central and part of Southern and Western Provinces, with an annual rainfall of 800 to 1000 mm. Region III, mostly occupied by acid soils, covers large areas of Northern, Luapula, North-western and Copperbelt Provinces. It receives above 1000 mm of rainfall per annum. This zone has great potential in rainfed and irrigated agriculture due to reliable rainfall and its large number of water bodies (lakes, rivers and perennial streams).

There are approximately 850,000 farmers in Zambia. These can be grouped into three main categories. Seventy-five percent are smallholders with an average farm size of up to 5 hectares. Seventeen percent are emerging commercial farmers or emergent farmers with farm sizes between 5 and 20 hectares. Eight percent are large commercial farmers with farm sizes exceeding 20 hectares.

The major crops grown in the country are maize *(Zea mays*), sunflower (*Helianthus annus*), soybeans (*Glycine max*), groundnuts (*Arachis hypogeae*), sorghum *(Sorghum bicolor*), cotton (*Gossypium hirsutum*), common beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*) sugarcane (*Saccharum officinarum*), millets (finger and bulrush), rice (*Oryza sativa*) sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), tobacco (*Nicotiana tabacum*) and wheat (*Triticum aestivum*). The cultivation methods are mainly hand-hoe. Animal draft power is used mostly in the Southern, Eastern, Western and parts of Central Provinces where animals are traditionally part of the farming systems. Use of tractors is predominantly by commercial farmers.

Maize, being the main staple food, is the single most grown crop in Zambia covering an area of 800,000 hectares. This scenario is a result of the agricultural policies of the past which over-emphasised maize production to the exclusion of other crops.

The fertilizer subsidies of the 1980's and government fixing of agricultural prices in favour of maize led to maize monoculture and the marginalization of other crops such

[1] Final Report as an invited Research Fellow in the "Vulnerability and Resilience of Socio Ecological Systems" Project at the Research Institute for Humanity and Nature, Kyoto, Japan, April 1 – June 30, 2007.

as food legumes (Sichinga, 1996). Maize monoculture resulted in an increase in ‘soil mining’ causing severe soil acidification and eventual soil fertility decline (Mwale *et al*., 1999). The traditional concept of conservation farming and sustainable agriculture was sidelined. There was over dependence on maize as a single agricultural commodity. However, other crops such as legumes are important as they are major sources of dietary proteins among smallholder farmers all over Zambia because animal proteins are expensive.

2.0. Problem Statement

The major problems causing low food production in Zambia and other countries in sub-Saharan countries are: declining soil fertility, low use of external inputs, loss of soil organic matter and soil structural damage due to poor land husbandry practices. Other constraints are natural disasters (severe drought), limited access to capital, poor information on appropriate technologies and poor marketing arrangements. These problems affect over 90% of the farmers and are getting worse due to land pressure, caused by a growing population and increasing cash demands on the farmers and the demand of agricultural support services in recent years. These problems have resulted in overall household food insecurity and widespread malnutrition. Currently the scientific community is faced with the challenge of developing new technologies or modifying and adapting already developed technologies in order to achieve increased and sustained farm level production. This paper is a synthesis of soil management options for better targeting of technologies and ecological resilience under variable environmental conditions. It is imperative to institute a multidisciplinary, multifaceted approach to combating soil fertility decline in different farming systems for the purposes of achieving increased and sustained crop production under variable environmental conditions. The technologies highlighted are those identified as key technologies with high potential to improve soil fertility, productivity and sustainability of agricultural lands, thereby enhancing the socio-economic well being of the small-holder resource-poor farmers of Zambia. Ultimately, this will lead to a more resilient healthy rural population who can increase their contributions to the national economy through their farming enterprises.

The technologies to be synthesised are further highlighted below:

3.0. Technology Synthesis

3.1. Liming

Soil pH refers to the concentration of hydrogen ions in the soil solution and is a measure of soil acidity. An acidic soil is one whose pH is below 7.0. In the tropics, acidification is rapid due to excessive leaching of bases and accumulation of Fe and Al ions. For most crops, production is negatively affected when pH falls below 5.5. Even in a situation where the initial soil pH is above 5.5, the continuous use of inorganic fertilizers eventually causes the soil pH to drop and if lime is not applied, this may render the soil become permanently barren. Acidification of agricultural lands due to inorganic fertilization is exacerbated by poor land husbandry practices of smallholder farmers characterised by mono cropping, residue burning, plough pans and declining organic matter, all of which lead to high top soil losses and yield decline over time. Research has demonstrated that regular liming results in stabilization of yields due to its ability to counteract the effects of acidification. Periodic soil testing and liming should therefore be part of the farming systems if productivity has to be maintained or enhanced.

In Zambia, soil acidity could be due to parental material, excessive inorganic fertilizer application, leaching of bases and accumulation of Fe, H and Al ions (in region III) or a combination of these factors. Excessive rains causes leaching of most of the nutrients leaving the aluminium and hydrogen ions.

In Zambia, lime is usually in the form of calcium carbonate, $CaCO_3$, commonly called calcitic lime. There are also some dolomitic limestone, or calcium magnesium carbonate ($CaMg(CO_3)_2$), deposits. Cattle manure and crop residues have been used as liming materials but with little impact.

Correction of soil acidity improves fertilizer use efficiency by crops. Liming reduces problems of aluminium toxicity, increasing the effective rooting depth. A bigger soil volume is explored for nutrients and water by the crops. Liming also improves the availability of phosphorus and some micronutrients. Liming is good for most crops, including maize but also provides the nutrient Ca for legumes such as groundnuts, cowpeas and soyabeans.

In the tropics the amount of lime to apply is normally based on the amount to neutralize Al ions in soil solution as basing on the difference between the existing soil pH and the desired pH, will normally lead to over liming resulting in micronutrient deficiencies. Sandy soils that are commonly found in most places are weakly buffered and hence have a lower lime requirement when compared with heavier clay soils.

Because some crops are more sensitive to soil acidity than others, the amount of lime to apply depends on the crops to be grown. It is also a function of organic matter content of the soil, the cost of liming and the rate at which soils become acidic. For maize-based cropping systems, the target value is between pH 4.5 and 5.5 for the humid tropics since local crops are somewhat tolerant to acidity. For most crops grown in Zambia a target soil pH value of 5.0 is a good compromise.

The soil needs to be tested to work out the amount of lime to apply per unit area. If improved agricultural systems are to be developed, the input of mineral fertilizers must be matched by an input of lime so as to alleviate Al toxicities and avoid a decline in pH and the problems it causes. There are clearly demonstrated crop responses to lime applications, which improves pH and calcium supply. Lime is recommended to be applied at 1.0 and 1.5 to 2.0 t ha^{-1} on sandy and clayey soils, respectively every fourth year. With these rates, over liming is avoided and nutrient disorders are absent. Soils with low pH and low in magnesium can be limed with dolomitic limestone.

The economic analysis made by Mapiki, et. al (1995) can be used taking into account the current prices and revised coefficients and production responses made. Key among these measures is Value Cost Ratios and Discounted Cash Flows to measure both short term and long term economic effects of lime. Economic analysis is necessitated by farmers expecting acceptable returns on their invested resources. Since lime has both short and long term effects, this has an implication on the way economic benefits are assessed. Short term benefits are measured by the value cost ratio (VCR).

$$VCR = \frac{Marginal\,Value\,Product\,(\mathrm{MVP})}{\mathrm{Marginal\,Cost\,Input\,(MCI)}}$$

Marginal value product is the value of the additional product or yield resulting from one additional unit of the input; Marginal cost input is the value of each additional unit of input. While a VCR value greater than 1 indicates profitability, VCR values greater than 2 (or 200% return) are generally considered as minimum to induce adoption of high cost soil fertility enhancing technology (Qygard, 1987).

3.2. Legume/Green Manure Based Rotation Systems

Crop rotations are important for optimum soil cover, improvement of soil fertility, reduction of pests and diseases and improved fertilizer use efficiency. Crops explore different volumes of soil due to different rooting patterns thereby increasing the uptake of soil nutrients and moisture subsequently reducing soil degradation. Rotating a cereal after a legume has beneficial effects to the cereal crop, which would utilize the residual nitrogen fixed by the legume crop the previous season. Residual inorganic fertilizers from a well fertilized cereal, such as maize, benefit greatly the succeeding legume. It is a recommended practice to rotate cowpea, soybean or common bean after a well fertilized maize crop. Expected yields following this practice are good. Crop rotations help control weeds (striga), pests (bean–stem maggot) and diseases (Helminthosporium), however, qualitative and quantitative benefits of crop rotations have not been fully carried out for all legumes of economic importance in Zambia.

In Zambian agriculture, crop production is largely dependent on inorganic fertilizer inputs. This has been exacerbated by farmer's monocropping maize (heavy user of fertilizers) year after year. This makes the use of fertiliser a prerequisite to crop production, particularly in maize and cotton. But the use of fertilizer is not sustainable due to cost and of actual availability. Therefore to boost crop production, there is need to incorporate into the system other cost-effective soil fertility improvement techniques. This is where the use of green-manure based technologies enters the agricultural picture.

Therefore, in order to demonstrate the benefits of green manure based technologies to farmers, the legume plant in the crop rotation system should alternate between a leguminous crop (e.g. beans) and a leguminous green manure plant (e.g. sunhemp). The use of legumes in enhancing soil quality has long been recognized. "Green manuring" involves the soil incorporation of any field or forage crop while green or soon after flowering, for the purpose of soil improvement. Green manures can be annual, biannual, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year.

3.3. Cover Crop

Farmers identify low soil quality as a major problem affecting crop production in most parts of Zambia. Erratic rainfall, its poor distribution and frequent occurrence of drought have taken its toll on crop production too. In order to combat these phenomena, conservation farming through use of cover crop based technologies is being promoted among small scale farmers. In Zambia, both the development and use of cover crop based technologies is in its infant stages. In South America, Brazil in particular, this technology has proved its worth and is being used with great success. To push conservation farming forward, promotion and research in cover crops must be encouraged.

A cover crop is defined as a crop grown primarily for the purpose of adding organic matter to soil and or soil protection against erosion by water or wind usually between periods of regular crop production (Arthur et. al.1979). Cover crops, which are usually leguminous, are close growing crops that are inter–planted in young growing crops. Apart from protecting the soil from the pounding effect of raindrops, soil wash and undesirable effects of sunshine, cover crops have other advantages. By deposition of leaf litter and death of their roots, they build up soil organic matter, which improves the physical condition of soil and raises its base-exchange capacity. As the organic matter decomposes, it gradually releases plant nutrients. They also reduce leaching and roots of deeper rooting species bring up nutrients that would otherwise be lost from the subsoil which become available for the crop. In some cases cover crops also act as biological rippers. In sunny dry weather, the shedding effect of the cover crops helps to maintain soil moisture.

Cover crops must easily be propagated by seed, should grow rapidly without competing with the crop and be tolerant to some shade and cutting back from around the crop. It should also be resistant to pests and disease and should not act as an alternate host to pests or diseases attacking the crop. It should also have the capacity to suppress weed growth.

Some of the conditions which would encourage the use of cover crops by small-scale farmers are: when they are grown on land that has low opportunity costs (for example, intercropped with food or commercial crops, on land left fallow, under tree crops, or during periods of expected drought); their use requires very little additional labour (or, as in some cases, saves labour by controlling weeds especially by communities affected by HIV/AIDS); seed is readily available at no out-of-pocket cost to the farmer; and their biomass (seeds, leaves, vines) provides benefits over and above improvements to soil fertility.

Cover crops which have shown good promise to be used either in intercrops or sole crops as improved fallows or in rotation are: velvet beans (*Mucuna* spp.); Lablab bean (*Dolichos lablab*), Jack bean (*Canavalia ensiformis*), Sunhemp (*Crotalaria* spp), Pigeon Peas (*Cajanus cajan*) and Cowpeas (*Vigna unguiculata*). Cowpeas can be used as food (both leaves and grain) while Jackbean can be used as grain. Velvet beans can be intercropped with maize, cotton or sorghum to suppress the weeds and it has the potential to be used as a food rich in protein as long as farmers are able to get rid of the toxic substance called L-Dopa. Velvet bean seed can also be used as a feed. Lablab bean can also be used both as a feed and food. Sunhemp has the potential to be pelleted into chicken feed.

3.4. Conservation Agriculture (CA)

Conservation agriculture involves adopting a number of crop husbandry practices that together comprise a complete farming system. If these practices are followed correctly, a number of important benefits arise. Figure 1 illustrates the main elements of CA while the benefits are shown in Table 1.

Table 1. *Benefits of conservation agriculture*

Planting system	♦ Increases opportunity for early planting due to early preparation of basins or ripping
Soil fertility management	♦ Reduces soil erosion due to minimum soil disturbance ♦ Increases soil biological activity due to adequate soil organic matter input ♦ Traps soil moisture / improves water harvesting and storage ♦ Increases soil organic matter
Environment friendly	♦ Improves air and water quality
Working environment	♦ Reduces and saves on labour ♦ Reduces machinery wear and tear

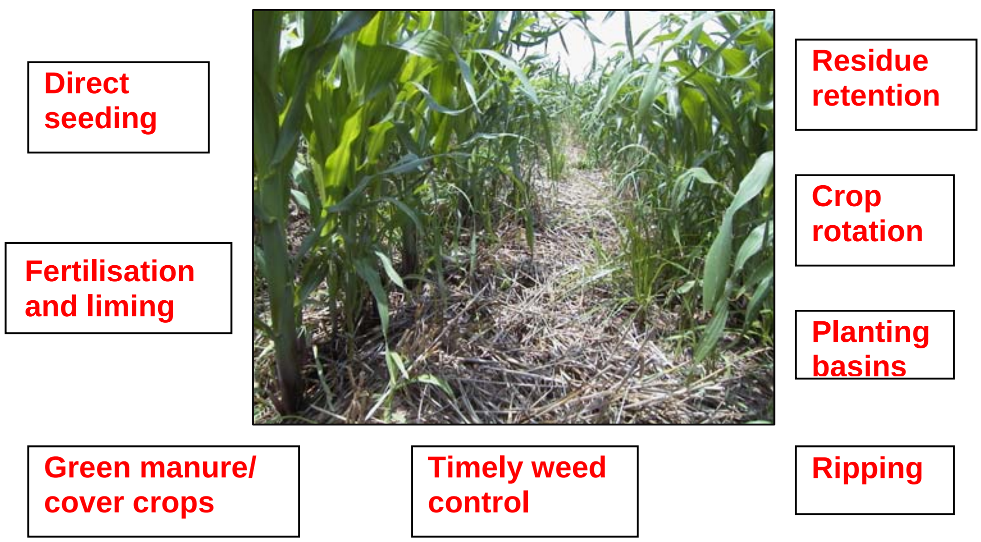

Figure 1. Main elements and benefits of Conservation Agriculture

3.5. Agroforestry and Improved Fallows

Trees play a crucial role in most farming systems and provide a range of products and services to rural and urban people. As natural vegetation is cleared for agriculture and other types of development, the benefits that trees provide are best sustained by integrating trees into agriculturally productive landscapes; a practice known as agroforestry. Farmers have practised agroforestry for many years in various forms. Agroforestry focuses on the wide range of useful trees grown on farms and in rural landscapes. Among these are fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition and food security; fodder trees that improve smallholder livestock production; timber and fuel wood trees for shelter and energy; medicinal trees to combat disease; and trees that produce gums, resins or latex products. Many of these trees are multipurpose, providing a range of benefits.

A fallow period is a period of time when a farmer decides to let his land rest in order for it to regain fertility. In an improved fallow system, fast-growing nitrogen fixing trees or shrubs are grown for 1 to 3 years in order to raise the fertility of the soil in a short period of time. The trees are of two types; those that are able to grow again when cut (coppicing trees) and those that die out when cut (Non coppicing). Some of the most important agroforestry tree species widely used for soil fertility improvement are: *Cajanus cajan, Gliricidia sepium, Tephrosia vogelii, Sesbania sesban* and *Caliandra Calothersus.* The proven legume tree species should be utilised in the areas where they perform best.

3.5.1. Proven impact of agroforestry

- ✓ Reducing poverty through increased production of agroforestry products for home consumption and sale.
- ✓ Contributing to food security by restoring farm soil fertility for food crops including production of fruits, nuts and edible oils.
- ✓ Reducing deforestation and pressure on woodlands by providing fuelwood grown on farms.
- ✓ Increasing diversity of on-farm tree crops and tree cover to cushion farmers against the effects of global climate change.
- ✓ Improving nutrition to lessen the impacts of hunger and chronic illness associated with diseases such as HIV/AIDS.
- ✓ Augmenting accessibility to medicinal trees, the main source of medication for 80% of Africa's population.
- ✓ Control and avoid soil erosion
- ✓ Cost effective or reduction on the use of inorganic fertilizers
- ✓ Used as fodder for livestock.
- ✓ Protection of crops through the use of a live fence e.g. sisal around a garden.

3.5.2. Farmer concerns

Some of the concerns that farmers have in adopting improved fallows include: Long waiting period before deriving benefits, extra labour associated with cutting and removal of plants from the field., threat of bush fires, disturbance by domestic animals which are left to graze freely especially during the period after harvest.

Table 2: Summary of soil fertility management practices in Zambia

Technology category		Practices	Advantages
Cultural practices	Crop rotation	Legumes after cereals	Reduction in fertilizer use, improved soil fertility, pest and disease control, weed control (e.g. striga)
	Agroforestry improved fallow	2-3 year fallow phase with tree species like *Gliricidia*, *Acacia, Leucaena*, *Sesbania, Tephrosia*, etc	Improve soil fertility, control and avoid soil erosion, cost effective or reduce the use of chemical fertilizer, improve soil structure, provide a fodder bank, to have source of timber, firewood, medicine, bee forge, fibber and natural remedies.
	Green manure crop fallows	Velvet beans and Sunhemp either incorporated or left on the surface	Improve soil structure and fertility, leading to vigorous growth of the following crop and reduce erosion
Compost manure practices	Mixed plant residues, animal dung, earth / soil materials, wood ash, water		Improves soil structure, reduce erosion and improves water and nutrient holding capacity of the soil.
Erosion control practices	Conservation tillage	Ripping, basins and minimum tillage	Erosion control and rain water infiltration
	Contour conservation	Vertiver grass	
Liming	Dolomitic (more magnesium than calcium) or calcitic (more calcium than magnesium) lime		Reduces soil acidity, make nutrients readily available for crop uptake and eliminates aluminium toxicity
Inoculum	*Rhizobia* inoculum		Enhances biological nitrogen fixation in legumes and increases yields
Fertilizers*	Basal and top dressing fertilizers		Supply the nutrients needed for enhanced crop production

**Wherever possible, it is recommended that farmers should combine organic and inorganic nutrient sources for sustainable crop production*

4.0. Integrated Approach

It is well appreciated that most households diversify their agricultural enterprises to try and reduce vulnerability in case one enterprise fails. A good combination of agricultural enterprises will result in positive interdependence among them to the advantage of a farmer. Figure 2 illustrates how the input cost can be minimised at a farm that practices recycling and diversification and thereby increasing resilience.

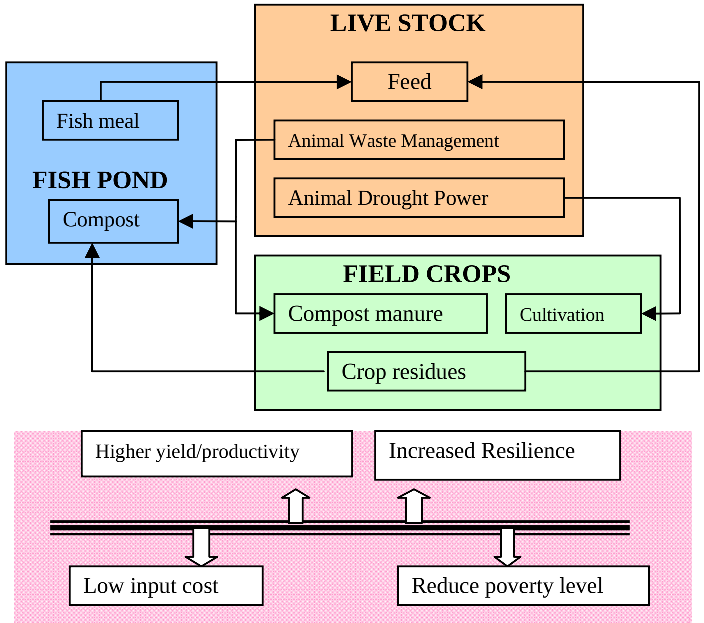

Figure 2: A form of integrated farming approach

An integrated and diversified farm does not only facilitate input cost reduction as seen in Figure 2 but also allows for a wider source of income for a small-scale farmer as shown in Figure 3:

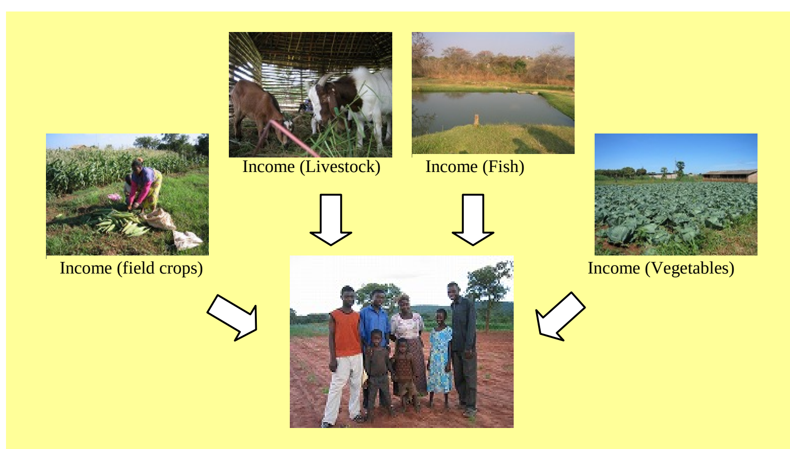

Figure 3: Integrated and diversified farm productivity gives more income

5.0. Link to the Resilience Project

Proposed Work plan for ZARI into the Resilience Project

The Zambia Agriculture Research Institute will be involved in the "Vulnerability and Resilience of Social-Ecological System" Project through activities in Theme 1. This will be specifically focusing on the "Ecological Resilience and Human Activities under Variable Environment" with Dr. Hitoshi Shinjo as the Theme Leader.

Field work will be conducted in Petauke District as from the 2007/08 season. Gliricidia sepium and Cajanus cajan improved fallows will be established. These will be grown for a period of three years before being sown to maize. Gliricidia sepium has the ability to coppice (re-grow after cutting) while cajanus cajan does not. Fertilized and unfertilized continuous maize will also be planted as control treatments. Two more fallow plots will be set up; traditional and natural fallow. The traditional fallow is the plot which had been cropped before and then left to rest while the natural fallow is an area which had never been cropped before. All plots will be 25 x 25 m. All treatments will be replicated three times in a randomized complete block design (See the diagram). The experiment will be conducted for a total of five years.

In order to establish the ecological resilience of the soil in these treatments, some measurements will be carried out; through the Automatic weather station set up at the site, wind speed and direction, soil temperature and moisture, air temperature and humidity, solar radiation, barometric pressure and rainfall will be recorded. In all treatments, soil respiration which is a good indicator of soil resilience will be monitored every two weeks. Soil sampling and soil hardness measurements will also be conducted on a regular basis. In all the fallow treatments, it is important to establish the vegetation types. Crop yields will also be estimated.

Plot lay out for the Agroforestry demonstration at Mwelwa Village, Petauke

5m F I RE B R E A K 5 m F I RE B R E A K

F I R E B R E A K 5m F I R E B R E A K	I	II	III	F I R E B R E A K 5m F I R E B R E A K
	5 TF	6 CC	1 GS	
	2 MCF	3 NF	4 MoF	
	3 NF	5 TF	6 CC	
	1 GS	4 MoF	3 NF	
	4 MoF	2 MCF	5 TF	
	6 CC	1 GS	2 MCF	

5m F I RE B R E A K 5m F I RE B R E A K

KEY TO TREATMENTS.

Replicates, I, II and III

1 = Gliricidia Sepium (GS)
2. = Maize Continuous Fertiliser (MCF)
3 = Natural Fallow (NF)
4 = Maize without Fertiliser (MoF)
5 = Traditional Fallow (TF)
6 = Cajanus Cajan (CC)

6.0. Knowledge gaps needing further research

1. There is need to establish site specific fertilizer recommendations. The current blanket recommendations are outdated and inefficient.

2. There is need to recommend appropriate combinations of organic and inorganic fertilizers for optimum utilization of scarce nutrient resources

3. There is need to quantify the amount of nitrogen fixed by legumes (green manures, cover crops and grain legumes) on farm. This has implications on the subsequent crop grown on the same piece of land and fertilization regimes that could be instituted.

4. There is need to establish the biophysical and social economic boundary conditions of legumes for better targeting of such technologies

5. Conservation farming is a promising technology but it should be promoted in areas where it has comparative advantage

6. There is need to constantly monitor soil changes (chemical, physical and biological) in long term experiments to see the impacts of such technologies on the environment

7. There is need to integrate the Geographical Information System (GIS) in soil fertility research. This would help refine the targeting of such technologies.

7.0. Conclusions and Discussion points

- ✓ The various programme working with farmers should encourage farmer to farmer extension by way of Training Farmer Trainers. This enhances farmer participation.
- ✓ Encourage exchange visits for farmers to broaden their understanding of technologies and exchange views and experiences.
- ✓ Work with the community to control bush fires and livestock in the dry season. Involvement of local leadership is necessary.
- ✓ Strengthen and encourage community seed multiplication at farm level in order to promote increase in the use of the technologies
- ✓ The demonstrations plots being promoted should be larger than 20 x 20m in order to maximize on benefits
- ✓ Legumes should not be treated as a single package for addressing soil fertility, but as an input into the whole package.
- ✓ Information on best-bets should be disseminated through field manuals, brochures, posters and technical publications
- ✓ Farmer-market linkage framework for output markets should be developed and tested with the private sector

8.0. Acknowledgements

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