Integrated Soil Fertility Management – a concept that could boost soil productivity

Soils are naturally poor in sub-Saharan Africa, and poor management has further reduced their productive capacity. The author argues that more fertiliser use is required to reverse further nutrient mining and productivity decline and that this agro-input is best used in combination with other measures to ensure that most of its nutrients are taken up by the crop.

The need for sustainable intensification of agriculture in sub-Saharan Africa (SSA) has gained support, in part because of the growing recognition that farm productivity is a major entry point to break the vicious cycle underlying rural poverty. Fertiliser use is extremely low in much of the sub-Saharan Africa region (8 kg/ha on average), and this is one of the main factors explaining lagging agricultural productivity growth. Most of the soils in Africa are inherently infertile, and poor agricultural management practices during the past decades have led to a severe decline in their productive capacity. Given the low levels of fertiliser use and poor soils in SSA, fertiliser use must increase if the region is to reverse the current trends of low crop productivity and land degradation. There are renewed efforts to raise fertiliser use in SSA from the current 8 kg to 50 kg nutrients per ha by improving the marketing, policy and socio-economic environment to increase fertiliser availability at prices affordable to smallholder farmers. Since fertiliser is very expensive for most smallholder farmers in SSA, the Alliance for a Green Revolution in Africa (AGRA) has adapted Integrated Soil Fertility Management (ISFM) as a framework for boosting crop productivity through combining fertiliser use with other soil fertility management technologies, based on site conditions.

Bernard Vanlauwe
International Institute of Tropical Agriculture (IITA)
Nairobi, Kenya
B.Vanlauwe@cgiar.org

■ Taking smallholder farming conditions into account

Before proposing a definition for ISFM, it is important to sketch the context under which the smallholder farmer in SSA operates. At the regional scale, overall agro-ecological and soil conditions have led to diverse population and livestock densities across SSA and to a wide range of farming systems. Each of these systems has different crops, cropping patterns, soil management considerations, and access to inputs and commodity markets. At the national scale, smallholder agriculture is strongly influenced by governance, policy, infrastructure, and security levels. Within farming communities, a wide diversity of farmer wealth classes, inequality, and production activities may be distinguished. Analysis of farmer wealth classes in north-east Zimbabwe illustrates the variability that is typical of farmer communities in maize-based farming systems. Use of cattle manure and more fertiliser by the wealthier farmers results in higher farm-level productivity than on poorer farms. At the individual farm level, it is important to consider the variability between the soil fertility status of individual fields (Figure 1), which arises due to farmers preferring to apply limited fertilisers and organic nutrient resources to small areas of the farms. Any definition of ISFM must consider these attributes.

■ What is Integrated Soil Fertility Management?

We define ISFM as *'A set of soil fertility management practices that necessarily include the use of fertiliser, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximising agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles.'* A conceptual presentation of the definition is shown in Figure 2. The definition includes a number of concepts that are described below.

1. Focus on agronomic use efficiency. Fertiliser and organic inputs are both scarce resources in the areas where agricultural intensification is needed. This is why the definition focuses on maximising their use efficiency. Agronomic efficiency (AE) is defined as the extra

*Figure 1: Photographs of a 3-week old maize crop in two different plots within the same farm (about 200 m apart) in Western Kenya. Both maize crops were planted at the same time. The left photograph shows a responsive plot near the homestead while the right photograph shows a less-responsive plot with high densities of 'couch grass' (*Elymus repens *(L.) Gould ssp.* repens*), an obnoxious weed (see insert in the centre). Adapted from Vanlauwe et. al, 2010.*

produce generated (in kg) per unit of nutrients applied (in kg).

2. Fertiliser and improved germplasm. In terms of response to management, two general classes of soils are distinguished: (i) soils that show acceptable responses to fertiliser (Step A – blue line, Figure 2) and (ii) soils that show minimal or no response to fertiliser due to other constraints besides the nutrients contained in the fertiliser (Step B – green line, Figure 2). We have classified above soils as 'responsive soils' and 'poor, less-responsive soils' respectively. In some cases, where land is newly opened, or where fields are close to homesteads and receive large amounts of organic inputs each year, a third category of soil exists where crops respond little to fertiliser as the soils are fertile. These soils need only maintenance fertilisation and are termed 'fertile, less responsive soils'. The ISFM definition proposes that application of fertiliser to improved germplasm on responsive soils will boost crop yield and improve the agronomic efficiency relative to current farmer practice, characterised by traditional varieties receiving too little and insufficiently managed nutrient inputs (Step A – blue line, Figure 2). Major requirements for achieving production gains on 'responsive fields' within Step A include (i) the use of disease-resistant and improved germplasm, (ii) the use of the correct fertiliser sources, and rates, (iii) appropriate fertiliser use in terms of placement and timing, and (iv) crop and water management practices.

3. Combined application of organic and mineral inputs. Organic inputs contain nutrients that are released at a rate determined in part by their chemical characteristics or organic resource quality. However, organic inputs applied at low rates commonly used by smallholder farmers in Africa seldom release sufficient nutrients for optimum crop yield. Combining organic and mineral inputs has been advocated as a sound management principle for smallholder farming in the tropics because neither of the two inputs is usually available in sufficient quantities and because both inputs are needed in the long run to sustain soil fertility and crop production.

4. Adaptation to local conditions. As previously stated, soil fertility status within and between farms is highly variable and a challenge before the African Green Revolution is adjusting recom-

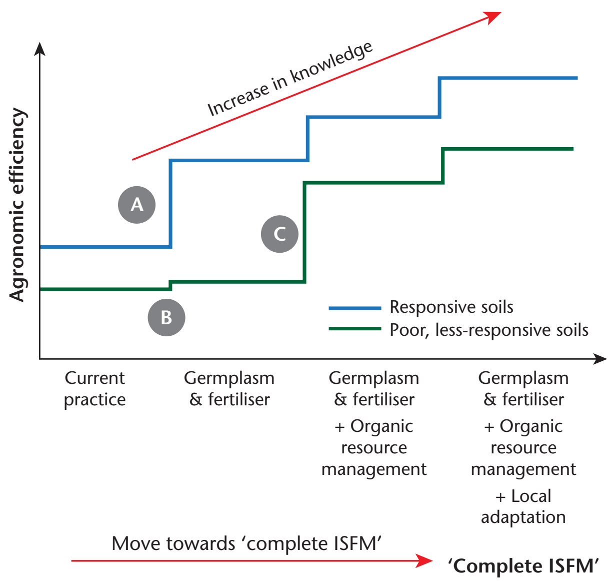

Figure 2: Conceptual relationship between the agronomic efficiency (AE) of fertilisers and organic resource and the implementation of various components of ISFM, culminating in complete ISFM towards the right side of the graph. Soils that are responsive to NPK-based fertiliser and those that are poor and less-responsive are distinguished. The 'current practice' step assumes the use of the current average fertiliser application rate in SSA of 8 kg fertiliser nutrients per ha. The meaning of the various steps is explained in detail in the text. Adapted from Vanlauwe et. al, 2010.

Figure 3: Application of phosphor fertiliser to a dual purpose soybean variety that produces substantial amounts of leafy biomass and leaves a net amount of fixed N in the soil and rotation of this soybean with a N-efficient and disease-resistant maize variety that receives a minimal amount of N fertiliser is a good example of an ISFM strategy. Adapting fertiliser rates to prevailing soil fertility conditions would qualify such intervention as 'complete ISFM'.

mendations to include such variability in soil fertility status. Firstly, soil fertility status can vary considerably within short distances. Often, the soil organic matter (SOM) content is a good proxy for soil fertility status, provided that this parameter is not over-extrapolated across dissimilar soils. Soil organic matter contributes positively to specific soil properties or processes fostering crop growth, such as cation exchange capacity, soil moisture and aeration, or nutrient stocks. On land where these constraints limit crop growth, a higher SOM content may enhance the demand by the crop for N and consequently increase fertiliser N use efficiency.

5. A move towards 'complete ISFM'. Several intermediary phases are identified that assist the practitioner's move towards complete ISFM from the current 8 kg ha^{-1} fertiliser nutrient application with local varieties. Each step is expected to provide the management skills that result in yield and improvements in agronomic efficiency (Figure 2). Complete ISFM comprises the use of improved germplasm, fertiliser, appropriate organic resource management and local adaptation. Figure 2 is not necessarily intended to prioritise interventions but rather suggests a need for sequencing towards complete ISFM. It does however depict key components that lead to better soil fertility management. For less-responsive soils, investment in soil fertility rehabilitation will be required before fertiliser AE will be enhanced.

Integration of ISFM principles in farming systems

Principles embedded within the definition of ISFM need to be applied within existing farming systems. Two examples clearly illustrate the integration of ISFM principles in existing cropping systems: (i) dual purpose grain legume – maize rotations with P fertiliser targeted at the legume phase and N fertiliser at rates below those recommended that are targeted at the cereal phase in the moist savanna agro-ecozone (Sanginga et al., 2003) (Figure 3) and (ii) micro-dose fertiliser applications in legume-sorghum or legume-millet rotations with retention of crop residues and combined with water harvesting techniques in the semi-arid agro-ecozone (Bationo et al., 1998). As for the grain legume-maize rotations, application of appropriate amounts of mainly P to the legume phase ensures good grain and biomass production, with the latter in turn benefiting a subsequent maize crop and thus reducing the need for external N fertiliser (Sanginga et al., 2003). As for the micro-dose technology, spot application of appropriate amounts of fertiliser to widely spaced crops such as sorghum or millet substantially enhances its use efficiency, with further enhancements obtained when combined with physical soil management practices aiming at water harvesting.

Dissemination of ISFM

The gradual increase in complexity of knowledge as one moves towards complete Integrated Soil Fertility Management (Figure 2) has implications on the strategies to adapt for widespread dissemination of ISFM. Furthermore, a set of enabling conditions can favour the uptake of ISFM. The operations of every farm are strongly influenced by the larger rural community, policies, supporting institutions and markets. Not only are farms closely linked to the off-farm economy through commodity and labour markets, but the rural and urban economies are also strongly interdependent. Farming households are also linked to rural communities and social and information networks, and these factors provide feedback that influences farmer decision-making. Because ISFM is a set of principles and practices to intensify land use in a sustainable way, uptake of ISFM is facilitated in areas with greater pressure on land resources.

The first step towards ISFM acknowledges the need for fertiliser and improved varieties. An essential condition for its early adoption is access to farm inputs, produce markets and financial resources. To a large extent, adoption is market-driven as commodity sales provide incentives and cash to invest in soil fertility management technologies, offering opportunities for community-based savings and credit schemes. Policies towards sustainable land use intensification and the necessary institutions and mechanisms to implement and evaluate these are also a factor that facilitates the uptake of ISFM. Policies favouring the importation of fertiliser, its blending and packaging, or smart subsidies are needed to stimulate the supply of fertiliser as well. Specific policies addressing the rehabilitation of degraded, non-responsive soils may also be required since investments to achieve this may be too large to be supported by farm families alone.

While dissemination and adoption of complete ISFM is the ultimate goal, substantial improvements in production can be made by promoting the greater use of farm inputs and germplasm within market-oriented farm enterprises. Such dissemination strategies should include ways to facilitate access to the required inputs, simple information fliers, spread through extension networks and knowledge on how to avoid less-responsive soils. A good example where the 'seeds and fertiliser' strategy has made substantial impact is the Malawi fertiliser subsidy programme. Malawi became a net food exporter through the widespread deployment of seeds and fertiliser, although the aggregated agronomic efficiency was only 14 kg grain per kg nutrient applied (Chinsinga, 2008). Such AE is low, and ISFM could increase this to at least double its value with all consequent economic benefits to farmers. As efforts to promote the 'seed and fertiliser' strategy are under way, activities such as farmer field schools or development of site-specific decision guides that enable the tackling of more complex issues can be initiated to guide farming communities towards complete ISFM, including aspects of appropriate organic matter management or local adaptation of technologies. The latter will obviously require more intense interactions between farmers and extension services and will take a longer time to achieve its goals.

References and further reading:
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In brief

■ 'Carbon farming': Jatropha plantations could mitigate climate change

New biomass plantations in desert regions could slow climate change, according to scientists at Hohenheim University in Germany. In a joint study with the management consultancy Atmosphere Protect GmbH, scientists conclude that each hectare of Jatropha curcas could bind up to 25 tons of atmospheric carbon dioxide annually for over 20 years. The researchers call this approach ‚carbon farming'. Jatropha grows on barren, dry soils which cannot be used to grow food. As the plant cannot survive entirely without irrigation despite its high tolerance to drought, coastal regions where seawater can be desalinated would be particularly suitable for cultivation. Bioenergy from the plantation's fruits and pruning can be used to cover part of the energy for irrigation. According to the scientists, an area over around one billion hectares is suitable for ‚carbon farming' worldwide. The costs are around EUR 42–63 for each ton of carbon dioxide bound. Based on this, the scientists regard the method as economically promising and competitive with other approaches, such as subterranean storage of carbon dioxide. *(Hohenheim University, ile)*

■ Early prediction of crop failures possible

Climate models can help predict some crop failures several months before harvest, according to a new study. The research showed that in about one-third of global cropland, temperature and soil moisture have a strong relationship to the yield of wheat and rice at harvest. And, for those two key crops, the model could predict crop failures three months in advance for about 20 per cent of global cropland. The impact of climate extremes – the kind of events that have a large impact on global production – is more predictable than smaller variations in climate, but even variations of 5 per cent in yield were correctly simulated in the study for many parts of the globe, the authors said. In the study, the scientists created and tested a new crop model, incorporating temperature and precipitation forecasts and satellite observations from 1983 to 2006. They then examined how well the data predicted the crop yield or crop failure that actually occurred at the end of each season. The ultimate yields can be estimated according to the climatic condition several months before. According to the scientists, the pattern is set by the pre-existing conditions experienced in spring. The team studied four crops – maize, soybeans, wheat and rice – but the model proved most useful for wheat and rice. Crop failures in regions of some major wheat and rice exporters, such as Australia and Uruguay, could be predicted several months in advance, according to the study. *(University of Leeds/ile)*

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