Integrated soil fertility management

Operational definition and consequences for implementation and dissemination

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Abstract: *Traditional farming systems in Sub-Saharan Africa depend primarily on mining soil nutrients. The African green revolution aims to intensify agriculture through the dissemination of integrated soil fertility management (ISFM). This paper develops a robust and operational definition of ISFM based on detailed knowledge of African farming systems and their inherent variability and of the optimal use of nutrients. The authors define ISFM as a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm, combined with the knowledge on how to adapt these practices to local conditions, aimed at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed in accordance with sound agronomic principles. The integration of ISFM practices into farming systems is illustrated with the dual-purpose grain legume–maize rotations in the savannas and fertilizer micro-dosing in the Sahel. Finally, the dissemination of ISFM practices is discussed.*

Keywords*: agronomic use efficiency; fertilizer; micro-dose; organic inputs; soil organic matter; grain legume–maize rotation*

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Earlier versions of a green revolution in South Asia and Latin America boosted crop productivity through the deployment of improved varieties, water and fertilizer. However, efforts to achieve similar results in Sub-Saharan Africa (SSA) have largely failed (Okigbo, 1987). Most of the recent increases in crop production have resulted from expanding crop production areas, at the expense of traditional fallows. This has caused substantial nutrient mining in areas under continuous cultivation and in conversion of marginal areas to agriculture, thus causing further land degradation (Smaling *et al*, 1997).

The need for sustainable intensification of agriculture in SSA has gained support, in part because of the growing recognition that farm productivity is a major entry point to break the vicious circle underlying rural poverty. Recent landmark events include the African Heads of State Fertilizer Summit held in Abuja, Nigeria (Africa Fertilizer Summit, 2006) and the launching of the Alliance for a Green Revolution in Africa (AGRA). Kofi Annan, the Chairman of the Board of AGRA, has repeatedly stressed that the African green revolution should be made uniquely African by recognizing the continent's great diversity of landscapes, soils, climates, cultures and economic status, while also learning lessons from earlier green revolutions in Latin America and Asia (Annan, 2008). Besides the aforementioned uniquely African features, recent global developments in increased fertilizer and commodity prices, the growing competition for land for biofuel production, the continuing HIV/AIDS pandemic, climate change and the increasing scarcity of water must be incorporated in any strategy to achieve the African green revolution.

Since fertilizer is an expensive commodity, AGRA has adapted integrated soil fertility management (ISFM) as a framework for boosting crop productivity through reliance upon soil fertility management technologies, with the emphasis on increased availability and use of mineral fertilizer. Various definitions of ISFM have been proposed, including: 'ISFM is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation – biological, physical, chemical, social, cultural, economic and political' (TSBF-CIAT, 2005) and 'The ISFM package includes the combined use of soil amendments, organic materials, and mineral fertilizers to replenish the soil nutrients and improve the efficiency and cost-effectiveness of external inputs' (IFDC, 2002).

Both these definitions and others are incomplete in the sense that they fall short of defining principles that are unique to ISFM.

The objectives of this paper are: (i) to develop a robust definition of ISFM that can be used as a practical means for objectively evaluating its implementation; (ii) to apply the definition to relevant technologies with great potential for dissemination to smallholder farmers; and (iii) to highlight factors that will facilitate the adoption of ISFM practices. In the current paper, the term 'fertilizer' is used for processed agro-minerals and manufactured fertilizer, while organic inputs include crop residues, manures, composts and other locally available organic resources.

Before proposing a definition for ISFM, it is important to sketch the context in which the smallholder farmer in SSA operates, thereby recognizing the wide diversity of farming systems and the environments in which these occur.

Attributes of smallholder farming systems in SSA

In the 1970s, Sanchez (1976) concluded that African soils were as variable as (if not more so than) soils in other regions. Such variability strongly impacts upon soil fertility and its management. At the regional scale, overall agroecological and soil conditions have led to diverse population and livestock densities across SSA and to a wide range of farming systems (FAO and World Bank, 2001). Each of these systems has different crops, cropping patterns, soil management practices and access to inputs and commodity markets.

At the national level, smallholder agriculture is strongly influenced by governance, policy, infrastructure and security levels. For instance, fertilizer is subsidized in Rwanda, but taxed in the neighbouring Democratic Republic of Congo (DRC). Roads also play a major role in fostering agricultural intensification through access to farm inputs and commodity markets. Such issues related to infrastructure can drastically change upon crossing a national border, as illustrated above. Some countries seek to control farmer associations and produce markets, while others provide incentives for rural collective actions and free markets. The *filière coton* in Burkina Faso provides a positive example of services to members through improved access to farm technologies and product marketing (Kherallah *et al*, 2002).

Within farming communities, a wide diversity of farmer wealth classes, inequality and production activities may be distinguished (Chianu *et al*, 2008). Traditionally, local indicators of wealth have been identified that can then be used to classify farming households against a set of thresholds (Defoer, 2002). Tittonell *et al* (2005a) developed farmer typologies based upon production objectives of individual households, as related to their access to production factors. The application of this knowledge to the process of technology adoption has been demonstrated by Shepherd and Soule (1998), who noted that farmers with a larger quantity and wider diversity of resources were able to assume greater risks and venture more readily into new technologies and farm enterprises.

At the individual farm level, it is important to consider the variability between the soil fertility status of individual fields, which may be as large as differences between different agroecological zones (Table 1). This variability has obvious consequences for crop productivity, resulting in yield ranges between 900 and 2,400 kg maize grain ha^{-1} for different fields within the same farm, as documented in western Kenya by Tittonell *et al* (2005b). These within-farm soil fertility gradients (SFGs) most often exist in areas with large population densities – resulting in intensive use of land – and where amounts of farmyard manure are insufficient (Figure 1). SFGs are created by the position of specific fields within a soilscape (Deckers *et al*, 2002), by the selective allocation

Table 1. Soil fertility status for different agroecological zones (Windmeijer and Andriesse, 1993) and for various fields within a farm in Burkina Faso (Prudencio *et al*, 1993). Home gardens are near the homestead, bush fields furthest away from the homestead and village fields are at intermediate distances.

Area	Organic C (g kg^{-1})	Total N (g kg^{-1})	Available P (mg kg^{-1})	Exchangeable K (mmol kg^{-1})
Agroecozones (0–20 cm):				
Equatorial forest	24.5	1.6	NA	NA
Guinea savanna	11.7	1.4	NA	NA
Sudan savanna	3.3	0.5	NA	NA
Fields within a village:				
Home garden	11–22	0.9–1.8	20–220	4.0–24
Village field	5–10	0.5–0.9	13–16	4.1–11
Bush field	2–5	0.2–0.5	5–16	0.6–1

NA = not applicable.

Figure 1. A four-week-old maize crop in two different plots on the same farm (about 200 m apart) in western Kenya. Both crops were planted at the same time and managed in exactly the same way. On the left is a responsive plot near the homestead, while on the right is a less responsive plot with high densities of couch grass (*Elymus repens* [L.] Gould subsp. *repens*), a noxious weed (see insert).

of available nutrient inputs to specific crops and fields, and by improved management (for example, time of planting, weeding, etc) of plots with higher fertility (Tittonell *et al*, 2005b).

The above section sketches a summary of the farming conditions in SSA and the variability that exists at different scales. Any definition of ISFM must consider these attributes.

Operational definition of ISFM

We define ISFM as *a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm, combined with the knowledge of how to adapt these practices to local conditions, aimed at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles*. The goal of ISFM is optimized crop productivity through maximizing interactions that occur when fertilizers, organic inputs and improved germplasm, along with the required associated knowledge, are integrated by farmers. The proposed definition is unique in the sense that it allows for objective evaluation of the occurrence of ISFM in a specific field.

A conceptual presentation of the definition is shown in Figure 2. The definition includes a number of concepts that are described below.

Focus on agronomic use efficiency

The definition focuses on maximizing the use efficiency of fertilizer and organic inputs, since these are both scarce resources in the areas where agricultural intensification is needed. Agronomic efficiency (*AE*) is defined as incremental return to applied inputs, or:

$$AE\ (\text{kg ha}^{-1}) = (YF - YC)/(F_{appl}) \qquad (1)$$

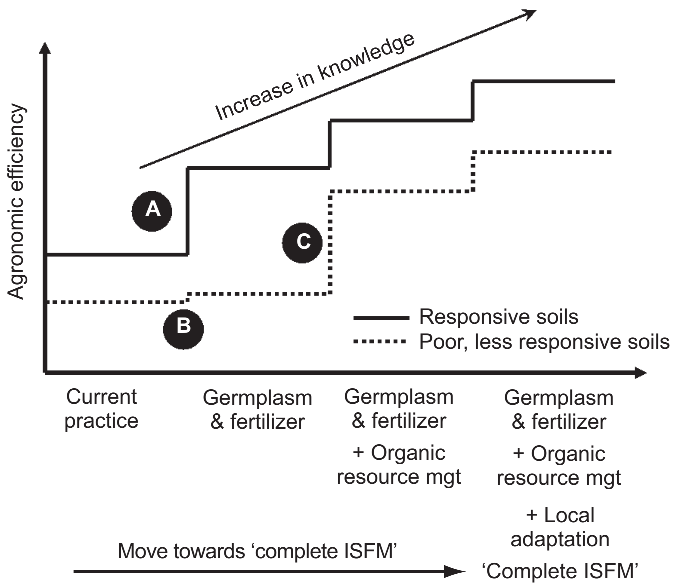

Figure 2. The conceptual relationship between the agronomic efficiency (*AE*) of fertilizers and organic resource and the implementation of various components of ISFM, culminating in complete ISFM towards the right side of the graph. Soils that are responsive to NPK-based fertilizer and those that are poor and less responsive are distinguished. The 'current practice' step assumes the use of the current average fertilizer application rate in SSA of 8 kg fertilizer nutrients ha^{-1}. The meaning of the various steps is explained in detail in the text. At constant fertilizer application rates, yield is linearly related to *AE*.

where *YF* and *YC* refer to yields (kg ha^{-1}) in the treatment where nutrients have been applied and in the control plot respectively, and F_{appl} is the amount of fertilizer and/or organic nutrients applied (kg ha^{-1}). Agronomic efficiency is composed of 'capture efficiency' or the proportion of nutrients taken up and 'conversion efficiency' or yield produced per amount of nutrients taken up. Capture efficiency is in part regulated by a sufficient supply of otherwise non-limiting nutrients and plant requirements for soil moisture, aeration and physical support. Conversion efficiency is in part regulated by genotypic properties, including those determining biomass accumulation and harvest indices, etc. Together, these result in favourable *AE*s (Giller *et al*, 2006).

Returns are greatest during the first increments of fertilizer response where the slope is steepest. As excess nutrients are applied, the response curve attenuates and *AE* decreases. With the current low overall fertilizer application rates in SSA (about 8 kg/ha) and even with the 50 kg ha^{-1} target set by the Africa Fertilizer Summit (2006), aiming at maximizing *AE* remains a sensible goal. In many African farming systems, the production of cereal straw for livestock feed, building materials, etc, is important, so that the economic yield is not just the cereal grain, but includes the straw. Note also that maximal *AE* leads to maximal economic returns to inputs used, since both indicators are linearly related to specific input and output prices.

Fertilizer and improved germplasm

In terms of response to management, two general classes of soils are distinguished: (i) soils that show acceptable responses to fertilizer (Path A, Figure 2) and (ii) soils that show minimal or no response to fertilizer due to other constraints besides the nutrients contained in the fertilizer (Path B, Figure 2). We have classified the above soils as 'responsive soils' and 'poor, less responsive soils' respectively. For instance, on sandy granitic soils, N use efficiency by maize varied from >50 kg grain kg^{-1} N on the more fertile fields close to homesteads, to less than 5 kg grain kg^{-1} N in degraded outfields (Zingore *et al*, 2007). 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 class of soil exists where crops respond little to fertilizer as the soils are already fertile. These soils need only maintenance fertilization and are termed 'fertile, less responsive soils'. The ISFM definition proposes that application of fertilizer to improved germplasm on responsive soils will boost crop yield and improve the *AE* relative to current farmer practice, characterized by traditional varieties receiving too little and suboptimally managed nutrient inputs (Path A, Figure 2). Numerous studies have looked at the responses of various crops to applied fertilizer in Africa. Results from the FAO Fertilizer Program, for instance, have shown an average increase in yield of 64% after application of NPK as 45–15–10 across SSA (FAO, 1989). Recent experiences with the Millennium Villages project showed an average threefold increase in maize yield with fertilizer application (Sanchez *et al*, 2007).

Major requirements for achieving production gains on 'responsive fields' within Path A (Figure 2) include (i) the use of disease-resistant and improved germplasm, (ii) the use of the correct fertilizer formulation and rates, and (iii) appropriate fertilizer, crop and water management practices. Use of improved germplasm in areas where constraints other than the nutrients applied through the fertilizer limit plant growth will certainly not boost the *AE* of fertilizer. Such constraints include pests, diseases or drought. When one or more of these constraints is removed, benefits from fertilizer use are obtained. For instance, in areas affected by *Striga*, a parasitic weed affecting cereal growth throughout SSA, application of fertilizer to herbicide-resistant maize will result in higher yields compared with local maize varieties (Kanampiu *et al*, 2003). In SSA, most soils are deficient in N and P, with some areas low in K, S or micronutrients. The relative importance of these limitations varies with soil type and past management. Moreover, different crops have different requirements for specific nutrients. Soil nutrient status and crop requirements must be considered when formulating fertilizers for maximal *AE*. Lastly, fertilizer management practices can substantially affect crop responses. For instance, incorporating rather than broadcasting urea reduces volatilization losses, banding P fertilizer on strongly P-adsorbing soils enhances its uptake, and point-placement of fertilizer with cereals results in higher uptake (Aune and Bationo, 2008). Adjusting N applications to seasonal rainfall patterns is one means of reducing nutrient losses and improving fertilizer use in semi-arid areas (Piha, 1993). Better agronomic management may, however, conflict with other demands for labour at critical phases of the cropping season, or may become confounded by lack of experience in its site-specific application.

Combined application of organic and mineral inputs

Organic inputs contain nutrients that are released at a rate determined in part by their biochemical characteristics or organic resource quality. However, organic inputs applied at realistic levels 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, because positive interactions between both inputs have often been observed (Vanlauwe *et al*, 2001) and because both inputs are needed in the long term to sustain soil fertility and crop production. Two other issues arise within the context of ISFM: (i) does fertilizer application generate the required crop residues that are needed to optimize the *AE* of fertilizer for a specific situation, and (ii) can organic resources be used to rehabilitate 'less responsive soils' and make these responsive to fertilizer (Path C in Figure 2)? The first issue is supported by data obtained in Niger by Bationo *et al* (1998). Where fertilizer was applied to millet, sufficient residue was produced to meet both farm household demands for feed and food and the management needs of the soil in terms of organic inputs and surface protection of the soil from wind erosion. Evidence also supports the second rehabilitation issue. In Zimbabwe, applying farmyard manure for three years to sandy soils at relatively high rates enabled a clear response to fertilizer where such a response was not visible before rehabilitation (Zingore *et al*, 2007). In south-western Nigeria, integration of *Senna siamea* residues reduced topsoil acidification resulting from repeated application of urea fertilizer (Vanlauwe *et al*, 2005). Applying the above principles to maximize *AE* will require adaptation to the prevailing soil fertility status (SFGs) and other site-specific modifiers of crop growth.

Adaptation to local conditions

As previously stated, farming systems are highly variable at different scales and one challenge for the African green revolution involves adjusting for site-specific soil conditions. First, soil fertility status can vary considerably within short distances, resulting in three general soil fertility classes, as explained above and demonstrated in Figure 3. A good proxy for soil fertility status is often the soil organic matter (SOM) content, provided that this parameter is not overextrapolated 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 the fertilizer N use efficiency. On the other hand, SOM also releases available N that may be better synchronized with the demand for N by the plant than fertilizer N. Consequently, a larger SOM pool may result in lower N fertilizer *AE*s. Evidence from western Kenya shows that for fertile soils, *AE* for plant nutrients is less than that for less intensively managed outfields (Vanlauwe *et al*, 2006).

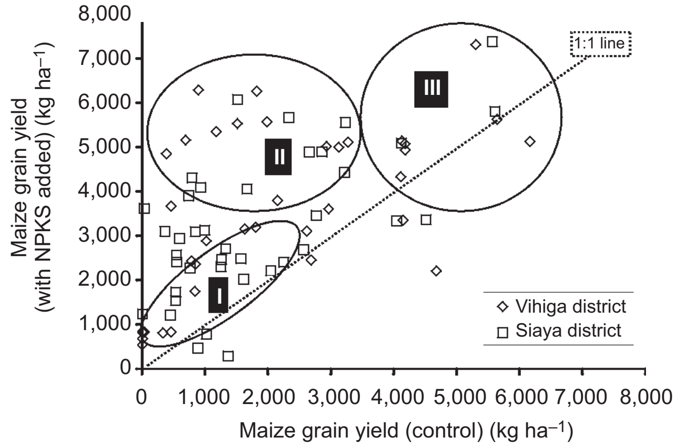

Figure 3. Variability in response to applied fertilizer (NPKS) in Vihiga and Siaya districts of western Kenya during the long rainy season of 2004. Three classes of soils can be identified: Class I fields have relatively low yields without fertilizer and respond little to applied NPKS (referred to as 'poor, less responsive fields'); Class II fields have relatively low yields without fertilizer, but respond well to fertilizer application (referred to as 'responsive fields'); and Class III fields have relatively high yields without fertilizer and respond little to fertilizer application because of this (referred to as 'rich, less responsive fields').

Adaptation to local conditions also includes accompanying measures that are needed to address constraints that are unlikely to be resolved by fertilizer and organic inputs. These adjustments include application of lime on acid soils, water harvesting techniques on soils susceptible to crusting under semi-arid conditions, or soil erosion control on hillsides. For ISFM to remain a practical approach to better soil management for farmers, it must become readily integrated into field practices that are dictated by these local conditions.

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} fertilizer nutrient application with local varieties. Each step is expected to provide the management skills that result in yield and improvements in *AE* (Figure 2). Complete ISFM comprises the use of improved germplasm, fertilizer, appropriate organic resource management and local adaptation. Figure 2 is not necessarily intended to prioritize 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 instance, in areas where farmyard manure is targeted towards specific fields within a farm, local adaptation is already taking place, even if no fertilizer is used, as is the case in much of Central Africa. For less responsive soils, investment in soil fertility rehabilitation will be required before fertilizer *AE* will be enhanced. It is important to note that the different steps are part of ISFM, but only when all steps are taken can one expect maximal *AE* or 'complete' ISFM. For instance, a farmer adopting good agronomic practices for applied fertilizer is going to improve the *AE* of those inputs and is thus implementing one component of ISFM. However, land managers can only be considered complete ISFM practitioners when they also recycle organic inputs, plant improved germplasm and use the required accompanying measures. Lastly, the above evidence for the different 'steps' is fragmented and derived from different cropping systems and agroecozones, and a concerted effort with a standardized multilocational design, encompassing the existing variability in soil fertility, is needed to determine which circumstances are most crucial in the stepwise improvement of fertilizer and organic input *AE*.

ISFM and environmental issues

ISFM interacts with environmental quality by minimizing nutrient losses to the environment and maximizing crop productivity per unit of nutrient applied. In this way, agricultural production is intensified and pressure to convert additional lands to agriculture is reduced. While soil fertility is most often defined as the capacity of a soil to grow crops, soil health is usually defined in broader terms, and encompasses the potential of soils to provide a full range of ecosystems services. The Millennium Ecosystem Assessment (2005) defined healthy soils as those soils that were capable of delivering essential provisioning, regulating and supporting ecosystem services on a sustained basis. Examples of the latter are nutrient cycling, water flow regulation or maintenance of soil biological diversity. Many of these services are directly or indirectly related to the soil organic matter pool, although knowledge of how much SOM and of which quality is required to retain specific service functions is currently limited. ISFM is a viable entry point for improved soil health, and more so when ISFM practices increase the soil organic matter pool over time. Recycling of organic inputs is likely to result in increased SOM and restoration of degraded soils. Whether the 'seed and fertilizer' strategy is able to produce sufficient crop residues to impact positively upon the SOM pool is uncertain and ultimately regulated by soil microclimate, texture and structure, organic input strategies and soil tillage regime.

Principles embedded within the definition of ISFM need to be applied within existing farming systems (Figure 4). Two examples clearly illustrated the integration of ISFM principles in existing cropping systems: (i) dual-purpose grain legume–maize rotations with P fertilizer targeted at the legume phase and N fertilizer at rates below the recommended rates targeted at the cereal phase in the moist savanna agroecozone (Sanginga *et al*, 2003) and (ii) micro-dose fertilizer applications in legume–sorghum or legume–millet rotations with retention of crop residues and combined with water harvesting techniques in the semi-arid agroecozone (Bationo *et al*, 1998; Tabo *et al*, 2007).

As for the grain legume–maize rotations, application of appropriate amounts of mainly P to the legume phase ensures good grain and biomass production, the latter in turn benefiting a subsequent maize crop and thus reducing the need for external N fertilizer (Sanginga *et al*, 2003). Choosing an appropriate legume germplasm with a

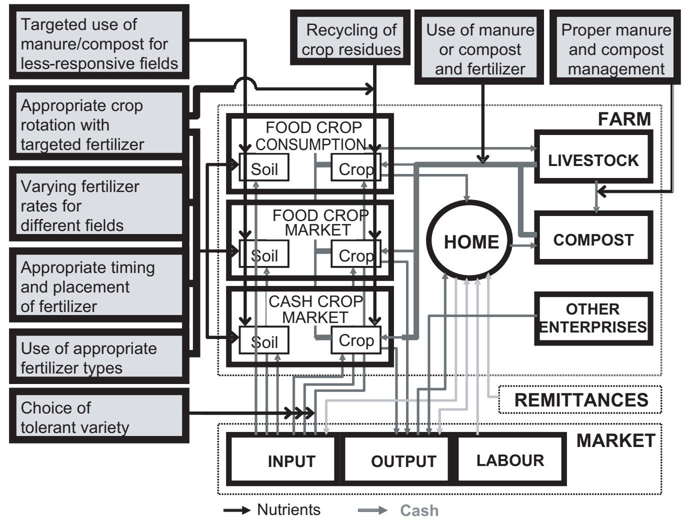

Figure 4. Components of a typical farming system, indicating flows of nutrients and cash (adapted from Tittonell *et al*, 2005a). The boxes with grey tints give examples of specific ISFM interventions.

low harvest index will favour accumulation of organic matter and N in the non-harvested plant parts, and choosing adapted maize germplasm will favour a matching demand for nutrients by the maize. Application of a sufficient amount of legume crop residues can also improve other soil conditions, thus leading to improved use efficiency of the applied N fertilizer (Sanginga *et al*, 2003). Selection of fertilizer application rates based on local knowledge of the initial soil fertility status within these systems would qualify the soil management practices as complete ISFM.

As for the micro-dose technology, spot application of appropriate amounts of fertilizer 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 aimed at water harvesting. Recycling crop residues can reduce wind and water erosion (Bationo *et al*, 1998) and thus further benefit growth and nutrient demand of a following cereal. Rotating a legume, such as cowpea, with sorghum or millet has been shown to increase cereal yields further (Aune and Bationo, 2008). Although both systems are good examples of complete ISFM, the selection of management priorities is in line with the overall economic conditions (for example, the presence of a market for the grain legumes produced) and the resource endowment of the farm family (for example, sufficient financial resources to purchase the required inputs). Certain conditions enable the dissemination and retention of ISFM practices.

Dissemination of ISFM

The gradual increase in complexity of knowledge as one moves towards complete ISFM (Figure 2) has implications for the strategies in adapting 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, plus 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. For example, as noted above, it is quite common for small farm households to derive a significant part of their income – often 40% or more – from off-farm activities. Farming households are also linked to rural communities and social and information networks, and these factors provide feedback that influences farmer decision making; for example, the negative impact of the structural adjustment programmes of the 1980s and early 1990s on the formal agricultural extension institutions. 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. In areas with substantial fallow land, such fallow periods can continue to regenerate the soil fertility status, as was the case in most of SSA until recently, and still is the case in many humid forest environments, with incentives for adoption of ISFM being reduced.

The first step towards ISFM acknowledges the need for fertilizer 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, providing 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 what facilitates the uptake of ISFM. Policies favouring the importation of fertilizer, its blending and packaging, or smart subsidies, are needed to stimulate the supply of fertilizer 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. Another factor that may facilitate the dissemination of ISFM involves the promotion of improved nutrition, for example, through incorporation of legume-based products in local diets.

While dissemination and adoption of complete ISFM is the ultimate goal, substantial improvements in production can be made by promoting 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. The latter can be based on earlier experiences of the farmer, since most local indicators of soil fertility status are linked to the production history of specific fields (Mairura *et al*, 2008). A good example of where the ‘seeds and fertilizer’ strategy has made substantial impact is the Malawi fertilizer subsidy programme. Malawi became a net food exporter through the widespread deployment of seeds and fertilizer, although the aggregated *AE* was only 14 kg of grain per kg of nutrient applied (Chinsinga, 2008). Such *AE* is low and ISFM could increase this to at least double its value, with all the consequent economic benefits to farmers.

As efforts to promote the ‘seed and fertilizer’ strategy are under way, activities such as farmer field schools or development of site-specific decision guides that enable tackling 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 longer to achieve its goals. Farmer adoption of ISFM may further be accelerated through the implementation of balanced rural campaigns that combine all of these considerations by offering farmers information, technology demonstrations, product samples, financial incentives and opportunities to develop their skills within their own farms.

Conclusions

The African green revolution aims at intensifying agriculture through large-scale dissemination of ISFM practices. An operational definition of ISFM is proposed as *a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm, combined with the knowledge on how to adapt these practices to local conditions, aimed at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles.* This definition acknowledges the need for integration of improved germplasm, organic inputs, plus variability in production factors for maximum fertilizer *AE*. ISFM practices are also best integrated in farming systems shown to have great potential for dissemination. Although complete ISFM is knowledge-intensive, much can be achieved through the promotion of the ‘seed and fertilizer’ strategy while simultaneously setting up structures and institutions to address the complexity of complete ISFM. Various accompanying measures can facilitate the adoption of ISFM practices in priority farming systems. Widespread adoption of ISFM has the potential not only to improve farm productivity and farmers’ welfare but also to bring about environmental benefits.

Acknowledgments

The authors gratefully acknowledge the Bill & Melinda Gates Foundation for supporting various workshops and discussion sessions during which the main ideas presented in this paper were developed.

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