Closing yield gaps in sub-Saharan Africa through Integrated Soil Fertility Management

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In many parts of SSA, cereal crop yields are estimated at < 1.5 ton ha^{-1} while the actual potential is more than 5 tons/ha. For grain legumes average crop yields have stagnated at about 0.7 ton ha^{-1} against a potential of up to 3 ton ha^{-1}. This represents a yield gap of more than 300% for both cereal and legume crops. The low yields are largely attributed to low use of organic and mineral nutrient resources resulting in negative nutrient balances (Jager et al., 2001). These low crop yields have led to increased food insecurity, poverty and malnutrition in most parts of SSA, which are likely to worsen as the population continues to grow.

There is potential for reducing the yield gap of most common cereal and legume crops through use of integrated soil fertility management (ISFM) technologies. ISFM is defined 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, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe et al., 2010). ISFM technologies can potentially produce better results when used in the context of 4R nutrient management stewardship which require implementation of best management practices (BMPs) that optimize the efficiency of nutrient use based on the right source, rate, time and place of application. In the African context, successful implementation of such technologies require involvement of all the key stakeholders in the food production value chain (farmer, extension agents, policy makers and market actors).

Closing yield gaps with ISFM

Performance of different ISFM technologies are location specific with significant and sustainable adoption of appropriate technologies being a function of farmers' access to appropriate inputs (fertilizer and seeds), information and availability of favorable output markets. This implies that successful promotion of ISFM should factor in the entire production value chain. Cases of how this strategy has succeeded in boosting crop yields and household incomes have been reported from AGRA supported projects implemented by various National Agricultural Research Systems (NARS) in the different sub-Saharan Africa countries. As a result, farmers uptake of demonstrated ISFM technologies increased by over 100%, while yields of maize, sorghum, pigeon peas and other crops under demonstration increased by between 100 and 300%. Similar approaches and success stories have been reported by a wide range of other organizations and partners in eastern, western and southern Africa.

Caption: ISFM performance on maize and legume in central Kenya

Impact of ISFM intervention

Case 1: ***Impact of cereal-legume intercropping on maize and grain legume yield in western Kenya***

In maize-legume intercrop demos established by KARI in 2010 through support of AGRA, improved cereal-legume intercrop technologies increased maize yield by between 2.8 and 3.3 tons/ha (300%) (Fig 1).

Additionally, the legume yields were in the range of 1.0 and 1.3 tons/ha in comparison to the baseline of 0.7 tons/ha. The maize and legume grain produced were sufficient to meet annual food requirements of farming households and leave a marketable surplus valued at >1,200 US$ per year.

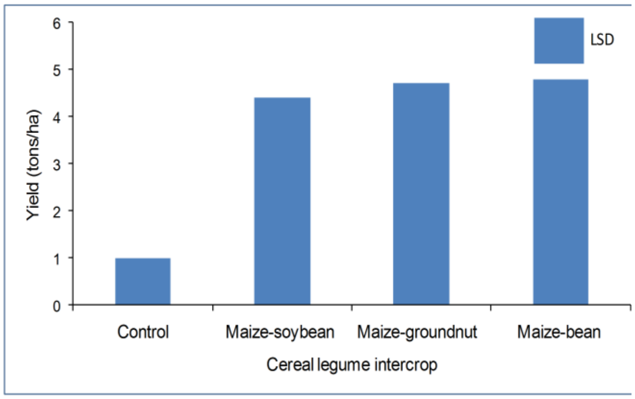

Fig 1: Effect of maize-legume intercropping on maize yield over three consecutive seasons in western Kenya

Case 2: ***Impact of nutrient combination on yields of maize and soybean in western Uganda***

A total of 200 mother demos of maize-soybean rotations were established by the Millenium Village Project (MVP) in 2010 show-casing good agronomic practices with various levels of manure and fertilizer combinations. Maize crop yields for plots with organic and inorganic fertilizers ranged between 1.9 and 4.0 tons/ha which was between 50 and 200% higher than yields from farmer practice. Across the two soybean cropping seasons, average soybean yields from the improved technology plots ranged between 1.2 and 1.8 tons/ha; this was between 50% - 100% higher than yields from the farmer practice.

Case 3: ***ISFM in the context of soil fertility gradient in Zimbabwe***

In simulation exercise carried out by teams from Wageningen and CIAT to assess the impact of ISFM at village scale (Rufino et al., 2010), information from ISFM experiments, soil types, livestock feeding and manure management was combined and used to design a strategy to restore the fertility of unproductive soils and boost crop yields in north-east Zimbabwe. In a baseline scenario which represented current management with small amounts of NP fertilizers (between 5–50 kg N ha^{-1} y^{-1} and 2–17 kg P ha-^{1} y^{-1}), the village reached food self-sufficiency for its 66 household only in years of good rainfall. In an alternative scenario using principles of ISFM, small rates of fertilizers (30 kg N and 15 kg P ha^{-1} y^{-1}) were applied to the home fields and crop residues were incorporated. Mid- and outfields received a full NP fertilizer rate (60 kg N and 30 kg P ha^{-1} y^{-1}), and all of the available manure (2–4 t ha^{-1} y^{-1}).

This continuous addition of small amounts of manure (2–4 t ha^{-1} y^{-1}) and fertilizers increased maize yields in the mid- and outfields from 0–0.5 to 1–3 t ha^{-1}. At the village scale, this represented more than double the amount of grain needed for food self-sufficiency plus extra feed for the livestock.

Case 4: ***Effect of fertilization and inoculation on soybean yields***

Soybean trials were conducted in Kenya, Uganda, Tanzania, Rwanda and Malawi for 3 consecutive years between 2009 and 2012 evaluating the effect of basal P application and inoculation on soybean yields. Results suggested that planting soybeans with P fertilizer without inoculation could increase soybean yields by approximately 100% but by inclusion of seed inoculation in the package yields increased by 170% relative to the farmer practice. Other studies have shown that legume yields can be boosted further by supplying limited doses of N at the establishment stage. This is crucial in meeting N demand prior to nodule development. Following full nodulation, the effect of externally supplied N on the performance of N fixing legume is limited.

Economic impact of ISFM

Economic analysis carried out on data from 10 projects across eastern, southern and western Africa yielded benefit-cost ratio values of more than 2 (Table 1). Benefit-cost ratio is a good indicator of financial attractiveness of an intervention (Kaizzi et al., 2012). Opportunity cost for resource poor people with little access to money is often 100% of the actual value due to other high priority uses of available funds and other investment opportunities (CIMMYT, 1988). Therefore, in SSA the benefit-cost ratio of more than 2 is required for an investment to be attractive (CIMMYT, 1988; Kaizzi et al., 2012).

Table 1: Effect of ISFM on performance of different crops and financial attractiveness

Country	ISFM intervention	Crop	Yield Change (tons/ha)	*BCR
Kenya (Western)	Maize-Legume Intercrop	Maize	+4 (300%)	1.8-2.2
Uganda (Isingiro)	Improved seeds +fertilizer + crop rotation	Soy bean	+1 (100%)	2.0-2.3
Tanzania (SHT)	Improved seeds+ fertilizer+Maize-legume rotation	Maize	+4.5 (300%)	2.1-2.5
Ghana	Maize -legume rotations + improved seeds + fertilizer	Soy bean	+1.5 (150%)	2.3-2.7

Integrating of ISFM principles in farming systems

Comprehensive work on how ISFM technologies can be integrated into the African farming systems has been done over the last two decades by groups of scientists from CIAT, IITA, ICRISAT, IPNI, IFDC, ICRAF and NARS. The results show that the ISFM principles should be applied within the existing farming systems (Vanlauwe and Zingore, 2011). Two examples clearly illustrate the integration of ISFM principles in existing cropping systems in SSA: (i) dual purpose grain legumes-maize rotations with P fertilizer targeted at legume phase and N fertilizer targeted at the cereal phase in moist savannah agro-ecozones (Sanginga et al 2003) and in Western Kenya (AGRA, 2012), and (ii) micro-dose fertilizer applications in legume-sorghum or legume-millet rotations with retention of crop residues and water harvesting techniques in semi-arid agro-ecozones (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, the latter in turn benefiting a subsequent maize crop and thus reducing the need for external N fertilizer. As for the micro-dose technology, spot application of appropriate amounts of fertilizer to widely spaced crops like sorghum or millet substantially enhances its use efficiency with further enhancements obtained when combined with physical soil management practices aimed at water harvesting

Challenges and policy requirements for increased adoption of ISFM

Although a lot of evidence exist in regards to the potential of ISFM to boost crop yields, the uptake of ISFM technologies has remained low. To a large extent, ISFM adoption is driven by availability and access to appropriate inputs. In SSA, sustained input availability has worked well in parts of Kenya, Uganda, Tanzania and Malawi especially when there are workable policies to support private-public partnership relationships through public support to establishment and management of private agro-dealer networks. Access cannot work under extreme poverty that characterizes most of farmers in SSA unless input financing is made available to stabilize the input supply and demand. There is a need for intervention by states through mechanisms for lowering input costs. Further, policies that can boost availability of affordable financing will improve farmer access of inputs and use of ISFM.

In addition to issues related to inputs, most farmers lack technical capacity to implement ISFM technologies independently. They therefore require effective extension services to understand which technologies work where. At present, in most African countries the ratio of extension staff to farmers is about 1:1000 against the recommended ratio of 1:400. But even the ability of available extension staff to offer quality extension services is often constrained by various capacity challenges. Policies that could boost the capacity and quality of extension services through improved recruitment rates, in service training and provision of tools for extension are crucial.

Finally, often good markets for surplus produce in SSA are not accessible by farmers. As a result, it is estimated that approximately 30% of food produced in SSA is wasted before reaching the market (Lynd and Wood, 2011). To boost crop yield with ISFM, there is a need for public investment in the areas of access to market through provision of information on availability of remunerative markets, market research, promotion of value addition and reduction of market barriers.

Conclusions

Integrated soil fertility management technologies are capable of closing or at least reducing the yield gaps for most crops that are grown in SSA. The challenges that need to be dealt with for these technologies to work include: ensuring access to information on what works where and improving access to input and output markets.

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