Improving soil health in Africa: challenges and promising solutions

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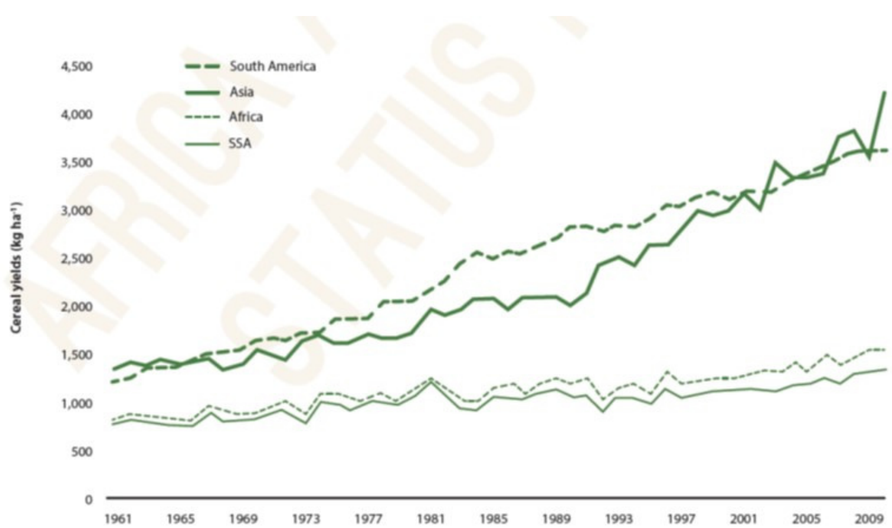
1.0 Introduction

Soil health is critical to sustainable agricultural productivity and environmental well-being. The term soil health refers to the capacity of soil to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Soil-health improvement that includes maintaining its three key properties (physical, chemical, and biological) is essential for food security at a time when many countries in Africa are faced with the global volatility of food prices. It is also essential for intensifying agricultural production because of high population pressure on land in many regions of Africa. Declining soil health is, indeed, a major cause of stagnant agricultural productivity growth in Africa. This is attributed to the depletion of nutrients by crops harvested and to soil erosion. Fallowing land that traditionally helped restore soil fertility is no longer feasible in many areas due to population pressure.

Soil nutrient losses are estimated to be about 8 million metric tons and are valued at more than US$4 billion (Toenniessen, Adesina, & Devries, 2008). These losses combined with soil erosion have led to soil degradation, with more than 80% of Africa's soils having chemical or physical limitations that impede crop production (Lal, 2010). This is, indeed, the case with many smallholder fields in Africa, where application of fertilizer and manure inputs have been too low for too long.

The impact has been a declining trend of per capita food production in Africa over the past 40 years, although there has been positive growth in the past 5–6 years (*Figure 1*). This in turn, has led to severe food and nutritional insecurity and reduced on-farm incomes (Hazell & Haggblade, 2009) and contributed to farmers expanding production to less suitable lands, thus further extending the frontiers of degradation. The cost of this can be enormous (Nkonya *et al.*, 2011).

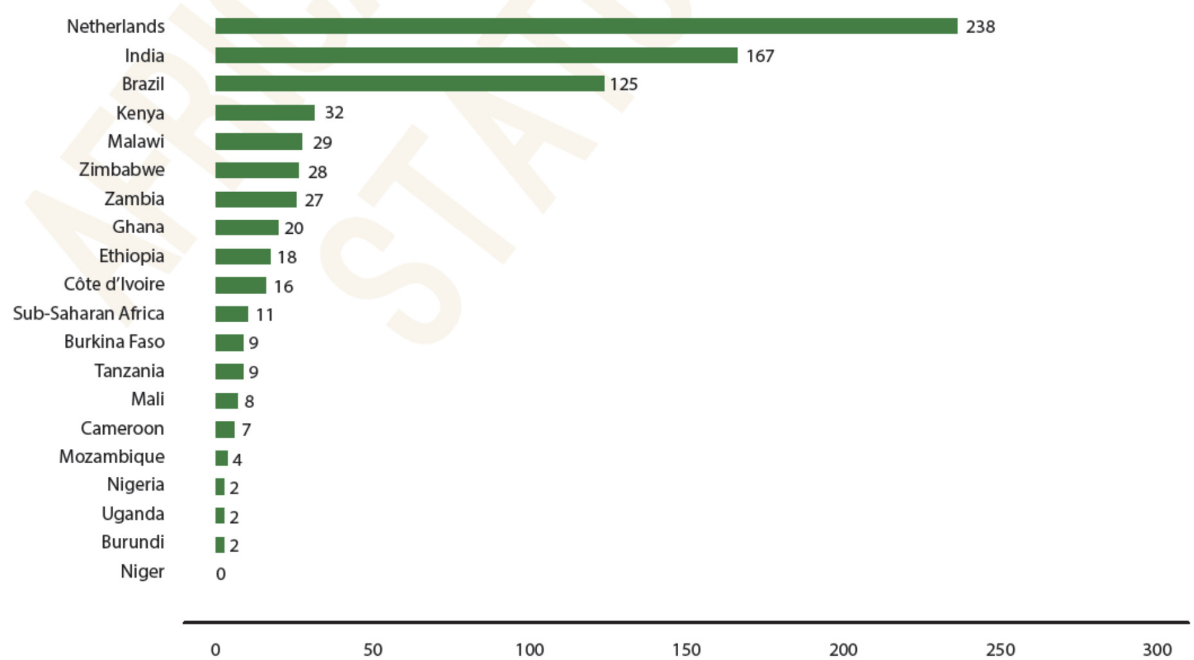
Figure 1: Cereal yield trends, 1961 – 2009



2.0 Increasing fertilizer use and accessibility

There is consensus among the R&D community that increasing fertilizer use by smallholder farmers is essential to reverse the declining trend of food production in Africa (Hazell & Haggblade, 2009; Sanchez, Denning, & Nzighubea, 2009). Inorganic (mineral) fertilizer usage in Africa currently stands at 9–10 kg/ha^{-1} of nutrients compared to greater than 150 kg/ha in Asia (*Figure 2*). At the minimum, mineral fertilizer use should be increased to at least 50 kg of nutrients per hectare by 2015 as per recommendations of the Abuja Summit on fertilizer use in Africa (International Fertilizer Development Center [IFDC], 2006). Key to this is reducing the high costs of fertilizer, which are often in the range of US$800–US$1,000 per ton at farm gate and the most expensive in the world.

Figure 2: Fertiliser usage (in kg/ha) on arable land



Source: FAO (2009)

In general, the high prices are due to fertilizer markets that are weak, underdeveloped, and characterized by high transaction costs. Consequently, these markets sell at prices that are beyond the reach of the majority of small-scale and subsistence farmers. The high transaction costs are exacerbated by supply-side and demand-side constraints, which severely hinder the development of efficient and effective private sector-led fertilizer markets in Africa. These constraints manifest themselves in the form of irregular and costly supply of inputs and weak demand. A key constraint to both the supply and demand sides is lack of access to finance for the fertilizer value chain actors. Fertilizer is a capital-intensive business; therefore, manufacturers, importers, distributors, and agro-dealers require access to finance to manufacture, procure, and distribute fertilizer.

With regard to access to finance by importers and agro-dealers, banks tend to view the fertilizer business as risky and therefore charge high interest rates and impose strict collateral requirements on potential borrowers from the fertilizer business sector. For their part, the importers and distributors find the collateral and lending terms unattractive, given the seasonality of agriculture, the relatively low returns from the inputs business, and the high level of risk caused by climatic variations. As a result, banks in Africa typically have a low percentage of loans to the fertilizer importing and distribution businesses. Although microfinance facilities are widely available in many countries, the size of the loans is typically too small to support the development of a fertilizer business. Consequently, importers, and even more so agro-dealers and stockists, have limited access to finance to invest in the fertilizer business. The majority resort to using their own savings or income from other business ventures to finance part or all of their businesses. This limits the size of their orders, increases transport and other transaction costs, and restricts the scale of business operations. It also reduces the funds available to invest in market development activities, such as extending credit to farmers and providing technical support and fertilizer delivery services.

Weak demand for fertilizers is due to a number of factors, including low purchasing power of farmers and the low input/output price ratio. Fertilizer is costly and often out of the reach of smallholder and subsistence farmers. In 2007–2008, fertilizer prices reached historically high levels, and although prices have since declined to pre-2007–2008 levels they still remain high, particularly in relation to output prices. Even when farmers can afford to purchase fertilizers, the poor performance of output markets (lack of storage, poor roads, and low output prices) results in low returns. In light of the low economic incentive to use fertilizers, governments, donor agencies, and NGOs have adopted strategies to reduce the economic burden on farmers by increasing their financial access to fertilizers. These strategies include direct subsidies on fertilizer prices, distribution of vouchers that can be redeemed for fertilizer, distribution of starter packs to get farmers to experiment with fertilizer, and fertilizer-for-work programs. While many of these approaches have achieved some short-term successes, they often have collapsed once the external funding ended, making them unsustainable over the longer term.

Notwithstanding this, there is definitely something positive to say about fertilizer subsidy programs that many countries have reintroduced since 2005 in Eastern Africa (Kenya, Malawi, Rwanda, Tanzania, and Zambia) and West Africa (Burkina Faso, Senegal, Mali, Nigeria, and Ghana). The subsidy programs take into consideration lessons learned and bring innovations to their design (e.g., targeting vouchers) to support both the most constrained farmers and encourage the development of input markets. Despite their high costs and management problems, the subsidy programs have resulted in growth in supply volumes and increasing impact on agricultural productivity in several countries, with Malawi being a good example (Denning *et al.*, 2009). This is corroborated by a more recent study (Druilhe & Barreiro-Hurlé, 2012) that, albeit available evidence being limited, indicates the subsidy programs have been effective in raising fertilizer use, average yields, and agricultural production but that their success is highly dependent on implementation.

On the financing side, several instruments are being piloted, including credit guarantees with banks. Some of these instruments are now being deployed by the African Fertilizer Agribusiness Partnership (AFAP) that was established in 2011 with some starter funding from the Alliance for a Green Revolution in Africa (AGRA). Specifically, AFAP focuses on addressing the supply-side constraints through agribusiness partnership contracts that involve matching grants with fertilizer suppliers and distributors. Initial focal countries are Mozambique, Tanzania, and Ghana.

Among the various options deployed by AFAP and others, the most sustainable and scalable is probably the value chain financing approach through the private sector that provides inputs (seeds and fertilizers) and output markets for produce. Some promising examples of this approach are emerging in several countries (Malawi, Zambia, and Ghana) for both cereals and grain legumes. At the same time, availability has been improved significantly through the expansion of the agro-dealers. For instance, AGRA has trained more than 14,000 agro-dealers in 13 focal countries over the past 5–6 years. This has, in some regions, reduced the distance for farmers to access fertilizers to less than 2 km.

3.0 Closing the yield gap

There is consensus among the agricultural scientific community that jumpstarting smallholder participation in agriculture in Africa requires the combination of organic and inorganic fertilizers, not either or none. This approach is that commonly referred to as integrated soil fertility management (ISFM). ISFM is a set of soil fertility management practices that includes the use of fertilizer, organic inputs, and improved germplasm, combined with the knowledge of how to adapt these practices to local conditions. The aim is to maximize agronomic use efficiency of the applied nutrients and improve crop productivity (Vanlauwe *et al.*, 2011). In acidic soils, the application of agricultural lime would be essential for enhancing the efficiency and benefits of fertilizers applied. For example, two projects supported by AGRA in western Kenya and Rwanda in 2009 showed that the use of lime improved soil fertility and increased crop production (see Text Box A).

TEXT BOX A: IMPROVED SOIL FERTILITY INCREASES CROP PRODUCTION

Effect of Lime and Fertilizer on Maize Crop Yield in Western Kenya and Wheat in Rwanda

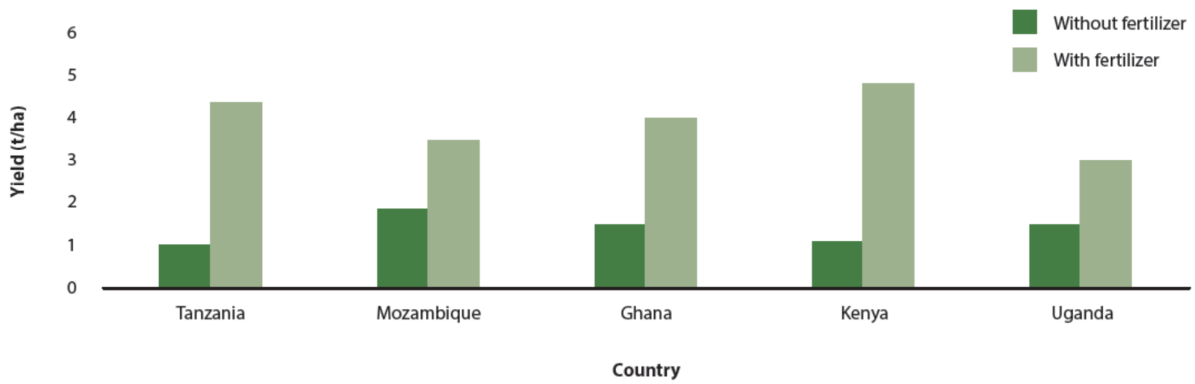
Recommended fertilizer rates in western Kenya (i.e., 60 kg N/ha^{-1} and 50 kg P/ha^{-1} applied either as DAP or Mavuno (10-26-10; 4% sulfur, 8% calcium, and 4% magnesium) increased maize yield more than threefold. Although maize crop responses to lime were small (200–300 kg/ha^{-1}), farmers were nevertheless excited by this effect, especially in plots that previously yielded almost nothing. Part of this excitement has been associated with observed reduction in striga in limed plots.

Effect of Lime and Fertilizers Application on Wheat Yields in Kibeho and Cyahinda Sites of Nyaruguru District, Rwanda, during February–June 2012 Rain Season

Results from the field indicated that high yields (1.7–3.4 metric tons/ha) were obtained from lime in combination with farmyard manure and DAP. Therefore, combining lime with fertilizer increased crop yields through enhanced soil health and reduced effects of noxious weeds.

The entry point for ISFM in many areas is likely to be fertilizers because of the limited availability and poor quality of organic fertilizers such as farmyard manure. Under such conditions, the applications of small amounts of fertilizers can jumpstart smallholder crop yields (*Figure 3*), resulting in three to four times more production of maize (a staple food crop in many countries) when improved seeds are also used compared with no fertilizer application. The yields of cassava, another staple food, can also be raised similarly, up from the typical less than 12 metric tons/ha under smallholder production with application of small amounts of fertilizer, especially those containing potassium (Vanlauwe, 2012). Crop yields can also be increased through the integration of fertilizers with the leafy biomass of *Tithonia diversifolia*, a shrub commonly found in many regions of Africa that is high in potassium and other nutrients (Jama *et al.*, 2000).

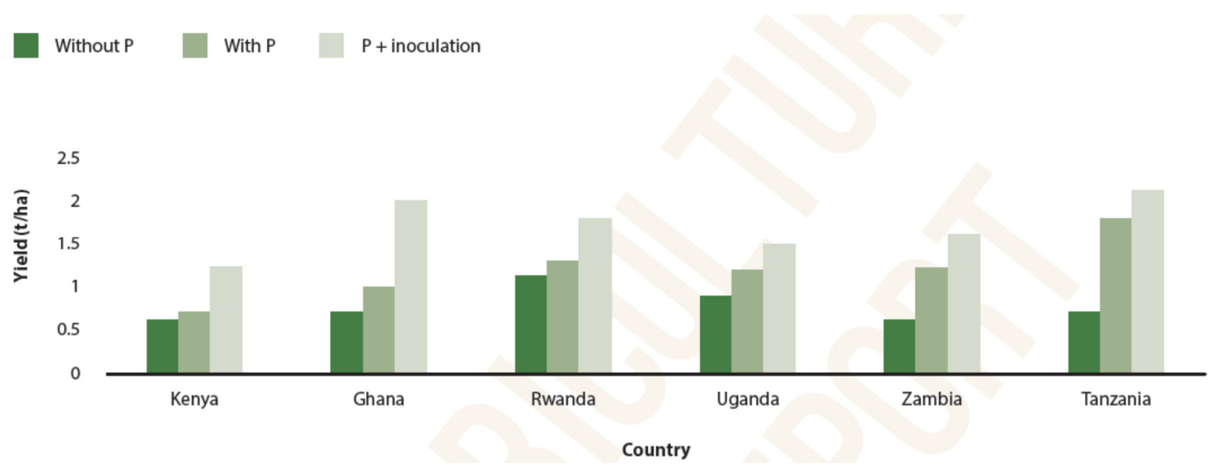
Figure 3: Maize yields, with and without fertilizer application, in 5 African countries under on-farm conditions



The integration of legumes into the production system is another key feature of ISFM. Legumes require appropriate Rhizobium bacteria to fix nitrogen (N) from the air. Because of the importance of grain legumes in African farming systems and their potential benefits to soil health, there is renewed interest in the identification and supply of appropriate (infective, effective, and competitive) Rhizobium strains to optimize biological N fixation. Rhizobia inoculants cost only a fraction of the N equivalent of fertilizer supplied through regular chemical fertilizer. There is scope for increasing the benefits of N fixation through growth of fodder legumes, including agroforestry species, especially in areas where no grazing systems for livestock are practiced.

Currently, the yields of grain legumes are low (typically less than 1 ton ha^{-1}) in much of Africa, as is their likely contribution to soil fertility improvement. This can, however, be changed through the use of improved seeds along with the application of small amount of phosphorus (P) fertilizers and Rhizobium inoculum (*Figure 4*).

Figure 4: Soybean yields with phosphorus and rhizobium inoculum application in 6 African countries



Such high yields generate additional crop residues that can be used to produce compost manure or used as livestock feed that in turn gives quality manure. Because of this recognition of the importance of grain legumes in the farming of Africa, many R&D organizations are scaling up the production and commercialization of grain legumes. They are also addressing challenges associated with supply of improved seeds and inoculum through public–private initiatives. The N2Africa and the Tropical Legumes projects are among the many stakeholders addressing these challenges, the former on the production and distribution of quality inoculum and the latter on the supply of improved legume seeds.

4.0 Entrance to sustainable agriculture through ISFM

Yield improvement normally is greater when organic inputs and inorganic fertilizers are applied together, and especially when farmers apply the right fertilizer source at the right rate, right time, in the right place, and using the right method. Such improvement in realized yields provides a good entry point for developing sustainable agriculture. High yields result in the production of more crop residues that can be used to supplement farmyard manure production through compositing. The biomass can also be fed to livestock to supplement much-needed feed and produce high-quality manure at the same time.

While it is possible to increase yields in similar ways with organics such as high-quality manure in the absence of fertilizers, the amounts of organics needed would often not be available on smallholder farms to cover large production areas. Over time, as the production of crops residues and other organic materials increases on the farms, fertilizer use could be reduced.

The practice of ISFM also lends itself to the gradual introduction of conservation agriculture principles, starting with the rotation of cereals with legumes. Depending on the species and site, the rotations could have minimum tillage benefits. This practice can result in significant soil fertility benefits and yield gains over conventional tillage systems, as demonstrated by 4-year-long multilocational studies in Zambia involving maize and cotton in rotation with a Crotalaria species, a non-grain-bearing, fast-growing leguminous shrub (Thierfelder & Wall, 2010).

Such interventions that integrate conservation agriculture, especially with trees, can be a good entry point for highly degraded soil. This is important because of the poor and variable response to fertilizers in such soils (Vanlauwe *et al*., 2011). Under such conditions, small fertilizer applications, such as the microdosing practice promoted in the Sahelian countries of Mali, Burkina Faso, and Niger, are recommended. When these applications are combined with livestock manure, the yields of sorghum increase by three to four times over the no-input system (AGRA, 2012). The amount of fertilizer applied is about one-third of what is typically recommended for broadcast application; about 60 and 25 kg of N and P per hectare, respectively. The yields can be further enhanced by practices that conserve water such as the zai pits (i.e., small planting pits) that are widely practiced in the Sahelian countries, especially Burkina Faso. This technology can also enhance crop yields in wetter regions that have degraded soils, such as the Ethiopian highlands (Amede, Menza, & Awlachew, 2011).

Sound, integrated use of fertilizers in ISFM requires developing and disseminating appropriate recommendations that are soil and crop specific and that take advantage of the nutrients supplied by organic fertilizers. Unfortunately, this is lacking in many countries, partly due to the absence of rapid methods of soil analysis. Fortunately, diagnostic methods that use infrared spectroscopy and remote sensing have emerged recently. This technology has been pioneered by the Africa Soil Information Service (AfSIS) in several countries. Ethiopia is now using the AfSIS approach to rapidly map its soils ahead of a national effort to refine and improve upon the existing fertilizer recommendations nationwide.

The benefits of improved fertilizer recommendations cannot, however, be realized by farmers unless the agricultural extension systems are improved and resourced well. This is particularly essential for ISFM technologies that are knowledge intensive. The public extension services in many countries are too few to deliver this knowledge well. This service could, however, be strengthened through public–private investments and in ways that take advantage of the opportunities offered by Africa's rapidly growing ICT.

5.0 Sustaining the gains made through crop-livestock-agroforestry interventions

The journey toward sustainable agriculture that is based on ISFM can be hastened by the integration of livestock and agroforestry interventions in the production system. Smallholder farmers in Africa mostly practice mixed farming, and its benefits are greater when livestock are incorporated, partly through sustained crop productivity with manure that complements inorganic fertilizer use. Indeed, farmers know the economic value of manure and are among the many reasons why they raise livestock (Steinfeld *et al.*, 2006). Use of manure, although not often enough, plays a crucial role in sustaining smallholder crop– livestock production systems. This is achieved through the cycling of nutrients within the systems through interventions such as use of fodder trees.

There are many niches where trees can be grown on smallholder farms to provide services such as soil and water conservation. This includes terraces on sloping lands where hedges that are continuously cut back for fodder are planted (Mugwe *et al.*, 2008). Such examples of livestock-mediated agroforestry interventions provide unique opportunities for the sustainable intensification of smallholder agriculture, with good examples practiced at scale on the densely populated eastern slopes of Mount Kenya and Mount Kilimanjaro. Many such agroforestry technologies are available and need to be scaled up as part of integrated soil fertility management (ISFM).

5.1 Implications for policy

Improving African soil health and enhancing fertilizer use are interlinked with the need to adopt a long-term perspective instead of a narrow focus on short-term yield gains. Public policy interventions should be geared toward strengthening smallholder farmers' demand for fertilizers through investments in agricultural research and extension.

The yield improvement realized with the use of various options that improve soil fertility (e.g., the use of small amounts of fertilizers, good agronomic practices and technology packages [ISFM], and crop–livestock integration) represent low-hanging fruit for reversing the current stagnation of Africa's agriculture. Doing so will provide opportunity for sustainable intensification of their agriculture and longer-term prosperity, which hinges on generating surpluses that could be sold into competitive markets. This, however, has the following important implications for policy and investments:

• Skills in soil fertility diagnosis are essential for developing appropriate fertilizer recommendation that farmers can adapt to their circumstances

• The application of ICT for extension and advisory services for soil health must take into consideration the fact that ISFM dissemination is complex and knowledge intensive

• Innovations in financing that can improve access to affordable credit required to procure inputs, especially expensive fertilizers

• Agricultural water management can help reduce risks associated with frequent droughts, some within the cropping season after farmers have invested in fertilizers and improved seeds and that are likely to discourage farmers from their investment unless they could count on water for their crops

• Improved access to remunerative markets can drive farmers' investments in improving their soils and raising their productivity

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