BACKGROUND PAPER

Sustainable Agricultural Resources Management: Unlocking Land Potential for Productivity and Resilience

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EXECUTIVE SUMMARY

While it is generally that agricultural productivity in Africa has to increase through appropriate intensification it is often forgotten that a fertile soil is the basis for valorizing other technology improvements such as improved varieties. Moreover, enhanced crop productivity is the key towards competing in agricultural value chains. Traditionally farming communities have been managing natural resources to provide sufficient food through fallow-based systems, which are sustainable under low population densities. With growing population densities, however, soil fertility-regenerating fallow periods are shortened or absent and farming has continued with replenishing nutrients removed by crops. Nutrient mining thus triggers a whole set of degradation processes, including erosion due to lack of sufficient soil cover and acidification due to removal of crops and crop residues. With degradation becoming more complex and severe, rehabilitation measures equally become more complex and expensive. Tackling soil and land degradation right now avoids tackling increasingly harder problems to solve later on.

This paper aims at (i) highlighting the challenges faced by African farmers to unlock the productivity potential of their farms, (ii) identifying opportunities to reverse the current farming conditions African farmers face, and (iii) suggesting actions that will realize these opportunities. Throughout the document, lessons learnt from earlier initiatives are integrated into the opportunities and recommendations, as well as on-going initiatives to which the African Transformation Agenda could add value. It is noted that this document should not be considered in isolation of other strategic documents focusing on crop-specific value chains, rural infrastructure, agro-input supply, capacity development, amongst others.

Most African soils are old and have not undergone rejuvenation processes through for example glacial action, sedimentation, or volcanic activity. On-going degradation processes are further aggravated by climate change and variability and growing rural populations while young people are leaving agriculture. On the positive side, access to ICT tools and networks has substantially increased over the past decade. Various initiatives are engaged in addressing above issues, in Africa with a growing commitment from governments and other actors over the past decade. Some examples include (i) the CAADP process which contains soil and land management dimensions, (ii) AGRA, set up after the Abuja Fertilizer Summit, (iii) successful subsidy programs in various countries, including Malawi, Nigeria, or Ethiopia, (iv) regional policy blocks such as ECOWAS, (v) the international research community, including the CGIAR centers, and (vi) numerous donor organizations, including the Bill and Melinda Gates Foundation or USAID.

The Integrated Soil Fertility Management paradigm was conceptualized in the context of the Soil Health Program of AGRA, and focusses on increasing crop productivity through the deployment of appropriate fertilizer in combination with improved varieties, organic inputs, and other implements. The latter could include application of lime where soil acidity is an issue, investing in water harvesting techniques where drought can limit productivity, or controlling soil erosion where there is a risk for the topsoil to be lost. Legumes, and especially dual purpose legumes, have particular attributes that can address various soil fertility constraints, including carbon and nitrogen accumulation and positive impacts on phosphorous deficiency. Besides these attributes, multipurpose legumes provide immediate benefits to farming communities. Implements aiming at water harvesting or small-scale irrigation systems can enhance the supply to water to growing crops and thus increase nutrient use efficiencies. Water and nutrients in combination usually produce the largest increases in crop productivity. Investing in soil conservation structures is a critical component of managing soil fertility in particular on
soils with significant slopes. Technically, functional options exist but due to the lack of direct, short-term benefits from such investments, this is a major component which market forces by themselves are unlikely to be able to sustain.

Based on the many challenges and identified opportunities, seven investment opportunities are identified that will require investment in the short to medium (first 5-year period) and in the longer term (second 5-year period). These include: (1) Establishment of a soil and land quality monitoring and evaluation framework; (2) Facilitation of access to crop- and site-specific fertilizer blends and application rates; (3) Promotion of multipurpose legumes in farming systems; (4) Valorization of locally available sources of rock phosphates to address phosphorus deficiencies; (5) Facilitation of access to crop- and site-specific sources of lime and application strategies; (6) Establishment of small to medium water harvesting practices and infrastructure; and (7) Facilitation of the establishment of appropriate soil conservation structures.

Each of the above investment is decomposed in its essential components and for estimating investment costs, two nested criteria are use: firstly, at the highest level, all agricultural land having specific constraints is calculated based on soil, weather, and elevation information. For nutrient-related constrains, FAO soil types are used to differentiate between N, P, and acidity-related limitations. For erosion-related constraints, land with a slope above 5% is considered while for drought-prone areas, agricultural land in semi-arid conditions is considered. Secondly, within above areas, it is envisaged that some prioritization will take place. While this prioritization strategy is not clear yet, the calculations below are based on the assumption that such priority areas will cover 10% of the total agricultural area with specific constraints.

Based on above proposed interventions, a total investment of US$1.1 billion will be required for the first 5 years. The individual interventions vary between US$70 and $273 million for a 5-year period. A total investment of US$451 million will be required for the second 5-year period. The individual interventions vary between US$25 and 191 million for a 5-year period. The only investment that’s not substantially less during the second 5-year period is the continued construction of soil conservation structures which will require continued incentives. Obviously, investment costs alone cannot be the major criterion to prioritize since returns on investment can also vary substantially. Moreover, co-investment of different actions create extra benefits beyond those created by individual investments. For instance, co-application of rock phosphate-derived products and legume inoculants is likely going to result in added benefits, superseding those created by the individual application of rock phosphate products and inoculants.

Unlocking the potential of land for productivity and resilience will require medium-to-long term commitment to ensure that the longer-term benefits can be appreciated by farming communities. Intensifying land use and ensuring a continuously supply of produce even under suboptimal growth conditions will require investments in land, water, and soil fertility management by farming communities and such investments will only be sustained if the greater and more stable production will yield the financial means to re-invest. While subsidies and other incentive mechanisms are essential in the short term, in the longer term, returns-on-investment should be generated through the agricultural value chains themselves, requiring engagement of the private sector (e.g., agro-input supply, logistics, processing and value addition), the financial sector (e.g., credit provision, insurance), and government (e.g., extension services, credit guarantee, rural and market infrastructure).
1. BACKGROUND

The vast majority of hungry people, 827 million, live in developing countries, with the highest prevalence in sub-Saharan Africa (SSA) (24.8 percent of population) (FAO, 2013). Eradicating hunger and extreme poverty is the first and foremost objective of the eight Millennium Development Goals, which were to be achieved by the year 2015 (UNMDGs 2012). The above goals are also included in the new seventeen UN Sustainable Development Goals (SDGs) post-2015 and to be achieved by 2030, in particular its Goal 1 (End poverty in all its forms everywhere) and Goal 2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture) (UNSD Knowledge Platform 2015). The SDGs were discussed at the recent UN Sustainable Development Summit 2015 (25-27 September 2015) of the General Assembly. However, despite numerous successful achievements over the last few decades, the various challenges to overcoming food and nutrition security, in Africa in particular, remains sorely wanting. Solutions to address the rising threat of food insecurity and deliver the predicted increased demand of ~75% of global food production by 2050 to feed over 9 billion people worldwide are yet to be afforded (World Bank, 2008; Keating et al. 2010; Cleland, 2013). As broadly defined by the FAO, “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.” (FAO, 2008). The magnitude and complexity of the challenge to create a food secure Africa will, consequently, require action throughout the food system.

Africa holds probably the greatest potential for expanding food production, where the most undeveloped arable land is available, equivalent to 25% of the world’s fertile land, to unlock a major agro-industry treasure chest and transform itself from its current state. Current crop productivity levels, at the regional level, are the poorest globally, presenting substantial potential gains. Numerous recent studies abound on the topic of the food crisis facing Africa and the numerous strategies necessary to cross this critical juncture. However, efforts to bridge this void remain an unreachable goal, with yet more studies highlighting the ominous situation. Growing populations are engulfing agricultural land, while urban centers demand ever increasing food supplies from an ever dwindling agricultural workforce. Add the omnipresent threat of climate change, land degradation and soil nutrient depletion and the magnitude of the position begin to be realized. A very diverse group of smallholders also dominate African agriculture, with large heterogeneity in socio-technical regimes, farmer typologies, production objectives, and biophysical conditions. This provides for a multitude of pathways from the current low productivity to sustainably increasing productivity (Vanlauwe et al., 2014). Agricultural productivity for most starch staple crops and grains across Africa is static, at best, providing increasingly less per capita, as populations escalate (Hazell and Wood, 2008; FAOstat, 2014).

In order to undertake such a multifaceted and complex agricultural transformation for Africa at scale, undoubtedly requires a ‘business unusual’ approach. Efforts to promote a food secure Africa and also in other parts of the world through agricultural transformation should be undertaken with the aim of protecting and promoting sustainable use of natural ecosystems, as indicated in the new Goal 15 of the UNSDG (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss). Among the various responses, the increase of agricultural productivity through Sustainable Intensification (SI) approach is a key policy goal (Garnett et al., 2013). Vanlauwe et al. (2015), highlighted the intricacies and complications for sustainably intensifying production systems in SSA, and that enhanced productivity goes hand
in hand with the maintenance of other ecosystem services and enhanced resilience to shocks. Increased production must undoubtedly be met through higher yields because increasing the area of land in agriculture carries major environmental costs. Food security therefore require as much attention to increasing environmental sustainability as to raising productivity, while additionally taking both biophysical and social contexts into account (Garnett et al., 2013; Vanlauwe et al., 2015). Achieving a sustainable, health enhancing food system in SSA will require multiple changes in addition to agricultural production, with radical agendas necessary to reduce resource-intensive consumption and waste and to improve governance, efficiency, and resilience (Garnett et al., 2013).

The institutional context needs to be right for delivering the necessary goods and services underlying an agricultural transformation for Africa. Governments must enable and embrace the private sector to support technological improvements and efficient agro-input delivery, access to credit, markets, mainstreaming a perspective of youth empowerment gender equality. It is estimated that if women farmers had the same access to resources as men, the number of hungry in the world could be reduced by up to 150 million (FAO, 2011). The African “green revolution” will however need to first address a dominant ecological factor in SSA, albeit supplemented and reinforced by new germplasm development and agronomy for improved water management (Keatinge et al., 2010) as well as taking into consideration the broader socioeconomic aspects. Not least, policymakers need also consider multiple goals for the food system in multifunctional landscapes (IAASTD, 2009).

There is no doubt about the need to intensify the production systems and elevate output per unit area in SSA. The intensification process however, needs to be eco-efficient encapsulating both the ecological and economic dimensions of sustainable agriculture (Keatinge et al., 2010; Vanlauwe et al., 2015). The challenge however, revolves around how to increase productivity in line with the increasing rising demands for food, and increasingly when juxtaposed against evolving eco-efficient demands for fiber and fuel production: a situation that will need careful consideration when making policy decisions.

The yield and production increases of the last 50 years have been achieved with a significant cost to the natural resource base (degraded soils and ecosystem impacts) and atmosphere, with 31% of global greenhouse gas emissions attributed to agriculture and forestry (IPPC, 2007). It is therefore imperative that any such initiatives consider such ecological and environmental aspects. The intensification process, consequently, should aim to help offset the destruction and preserve ecologically important ecosystems, such as the Congo Basin, the second largest rainforest on the planet, with around 18% of the world’s remaining tropical rainforest found within the region (www.easterncongo.org), or the unique Serengeti-Masai Mara plains in East Africa, home to the annual wildebeest migration spectacle. Initiatives such as REDD now integrate agriculture in their strategies, with intensification of agriculture a key pillar in the strategy to conserve forests (UN-REDD, 2013). Much is reliant on the need for access to and availability of quality inputs and technologies, either through an improved private sector or public-private partnerships. An obstacle here is the limited attraction for investors to take action, certainly at the early stages when outlay will be high and returns low. However, the tide is turning and Syngenta International AG recently demonstrated their interest when they announced a commitment to build a $1 billion business in Africa over the next 10 years, reflecting the company’s belief that Africa has the resources not only to feed its growing population, but also to become a major world food exporter (Syngenta, 2012). Harnessing such interest and investment opportunities provides the inertia for progress, but which cannot stand alone. Physical infrastructures, such as roads, markets and facilitating policies for example,
need rehabilitation, improvement or adaptation. Connecting private sector investment with Governments and initiatives, such as The Global Soil Partnership (FAO), The Green Revolution for Africa (AGRA, CGIAR, GFAR) and similar investments in soil and water management, when combined with advocacy that drives public policy change and increased attention, will make for new opportunities essential for successful progress. Creation of agriculture and agribusiness as attractive investment and career options will ultimately attract actors that can help transform African agriculture towards unlocking that vast human and natural endowment potential. Education is key to reverse the trend in training opportunities and expertise resource base that is sorely deficient across Africa. Towards this about 20 African countries have thrown their weight behind the IITA Youth ‘Agripreneur’ initiative (www.iita.org), a pilot scheme that is engaging youths in agriculture, a strong indication of a path forward.

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2. CHALLENGES

2.1 Major challenges

Old highly weathered soils

Most African soils are extremely old (>100 million years), have undergone severe weathering and leaching, thus are inherently infertile and lack capacity to retain essential nutrients for plant growth. Representatives of 29 major soil groups are found in Africa (Figure 1), with Arenosols (16.7%), Leptosols (14.0%), Ferralsols (11.8%) and Calcisols (11.4%) contributing a total of 54% of the land area (Figure 1). About 10.3% of the land area is not suitable for agriculture. The largest part of the Arenosols and of the Calcisols are in areas of low precipitation and thus not used for agriculture, unless irrigation is provided.
Natural ecosystems, specifically moist savannahs and rain forests create the impression of great fertility, yet this is based on high rain fall and temperatures, combined with tight nutrient cycles between the living and the dead biomass. Once these systems are converted to agriculture, soils degrade rapidly through increased nutrient leaching, erosion, loss of (soil) biodiversity and processes of organic matter and nutrient cycling. The nutrient reserves in such systems are largely stored in the biomass and released rapidly when traditional approaches such as slash & burn are used for land conversion. Soil organic matter decomposition is accelerated and crops are not able to absorb the readily available nutrients. Due to the soils’ low quality of clay minerals, nutrient retention capacity is low, causing high leaching losses after land conversion. The exposure of the soil to rain and wind causes erosion and loss of the valuable topsoil, depending on slope and rain intensity.

**Changes in land use frequency and reduction of fallow length**

In the past, at low population densities, farmers returned land after short cropping phases to long fallow phases during which the soils’ fertility recovered to pre-clearing status. These fallsows ensured full soil recovery and the system’s sustainability. Today population densities are too high to allow fallow length required for full fertility recovery. Farmers have shortened or abandoned fallows depending on population density. The consequence is further soil degradation and declining yields. Most farmers have not changed soil and crop management
compatible with shortened fallow systems thus the fertility recovery remains incomplete, compromising the natural resource base for crop production.

Depending on the local conditions (slope, amount and intensity of rain fall, clay mineralogy, soil texture, and soil profile) different processes contribute to soil degradation. Nutrient mining by crops is a general feature, aggravated by erosion in areas of steep slopes and high rain fall intensity, where fallow has been abandoned due to high population density and where crops are grown that do not leave biomass on the land. Soil degradation by erosion is rapid, while other processes such as biodiversity loss, loss of structural stability and of soil organic matter are slow, often going unnoticed over long periods. Some degrading processes do not immediately cause yield loss, thus are considered ‘normal’.

**Soil and land degradation**

Where major soil loss through erosion is not an issue, soil nutrient depletion through run off, leaching and nutrient uptake by crops are the initial causes of declining yields (green line) and degradation (brown line) (Figure 2). Declining biomass production and yields can be ameliorated by supplying the limiting nutrients (dotted green line, left hand side, figure 2) at this stage. Without nutrient additions biomass production declines, causing reduced organic matter inputs to the soil. Degradation continues and additional degradation processes lead to further fertility and yield declines, aggravating effects of nutrient mining. Once several degradation processes have caused fertility and yield declines to low levels (right hand side, figure 2), the soils become ‘non-responsive’ i.e. fertilizer does not cause yield increases. At this stage simple nutrient addition has no significant effect on crop yields because other soil functions have ceased. First the soil’s capacity to retain water and nutrients, its biological processes and other functions need to be rehabilitated (dotted brown line, right hand side, figure 2) before crop yields will increase and contribute to soil fertility maintenance (dotted green line, right hand side, figure 2). Taking countermeasures at later stages of soil degradation is more costly and labor intensive, has lower impact on crop yields and requires long term investment to attain fertility and yield levels similar to those in early stages of degradation.
Therefore a major challenge is to raise awareness that combating soil degradation needs to start in the early stages when relatively simple measures can prevent further degradation and decline.

The lack of agro-input systems permitting easy and affordable access to fertilizer and other inputs prevents farmers to balance nutrient deficiencies. In Uganda, Fermont et al (2009) determined a 13 ton ha\(^{-1}\) yield gap in cassava which was to >50% due to lack of fertilizer. Given today’s situation in many countries, farmers are inclined to extract the soil’s nutrient reserves as much as possible before resorting to fertilizer, often at stages where fertilizer alone is not sufficient to regain high yields.

When fertilizer is used on degraded soils, or when inappropriate formulations and rates were applied, farmers may have observed problems with crops and partial failure. Such experiences made farmers believe that fertilizer harms the soil. For most of SSA no science based fertilizer recommendations exist for most crops. Thus a major research priority is identifying the major yield limiting nutrients and required rates to ameliorate deficiencies. Due to the variability of agroecosystems, soils across landscapes and within farms (Vanlauwe et al, 2006; Tittonell et al, 2012), differences between crops and cropping systems a ‘one serves all’ type recommendation cannot be expected.

Some soils are of such age and weathering status that they are strongly acidic. On such soils fertilizer alone may not be sufficient to increase crop yields because the soil’s chemistry limits the transfer of nutrient elements to crops or causes imbalances (through antagonistic reactions of the soil with nutrients and prevention of nutrient uptake). Acidic soils are usually high in free aluminum and manganese with toxic effects on plants. Although soil acidity is in many sites a natural phenomenon countermeasures need to be taken before crop production can be intensified successfully. Soil amendments such as lime ameliorate the acidity induced toxicities, yet the effect declines over time requiring repeated applications to maintain soil pH and exclude

Figure 2: Conceptual soil fertility and crop yield decline over time and effects of countermeasures taken at different stages of soil fertility degradation.
toxicities. Soil organic matter positively affects soil acidity and high biomass production by the crops is a key factor in keeping soil acidity and toxicities at tolerable levels. On acidic soils a key challenge are the high initial investment costs into regulating the chemical reaction by liming due to the bulkiness of lime limited by infrastructural shortcomings. Once the soils are responsive to fertilizer application and biomass production is increased, the addition of organic matter (OM) may replace liming. Research will need to determine best combination of liming and OM addition to keep the soil pH at suitable levels with smallest inputs of lime and highest agronomic efficiencies of fertilizer nutrients. Soil acidification can be caused by human interference, such as excessive use of urea fertilizer, tillage to extract a maximum of soil nutrients with crops, aggravated by crops not leaving any considerable amount of OM after harvest, high land use frequency and any soil management that leads to rapid decomposition of SOM. The countermeasures are the same as on naturally acidic soils.

**Lack of appropriate soil information systems**

Detailed information on soil properties is lacking for most of SSA, yet the soils’ properties determine the measures required to ameliorate any form of degradation. Thus another major research priority is the improvement of the soil information systems. Although major efforts are undertaken to obtain soil information at high spatial resolution, these activities are far from covering any sufficient proportion of the agriculturally relevant land area in SSA and often do not look into the areas of potential expansion. Thus a major challenge here is to establish research programs that develop methods permitting the rapid and cost efficient collection of high resolution soil data to facilitate the creation of soil related decision support systems. Today GIS and modeling capacities allow developing site specific decision support tools such as nutrient management systems to be offered to farmers as decision support tools, freely available on mobile phones and through extension services. This type of decision support tool can as well be developed for any other farming operation comprising varietal choice, tillage and crop husbandry regimes, IPM and weed control measures etc. However, the major challenge here is to assemble the data required to develop site specific decision support tools. Providing decision support tools alone will not solve the problems, therefore close public-private partnerships are required to establish essential input supply infrastructure.

**2.2. Emerging trends**

There are some major trends happening in agriculture that need to be taken into consideration when planning and implementing sustainable intensification. These trends are often inter-related and appropriate response to them need a multi-scale, multi-actor approach in order to include them in the sustainable intensification process. Below there is an outline of major trends

**Intensification for conservation**

Studies have shown that the most degraded soils are in the most densely populated areas in Africa (Vanlauwe et al., 2014). Continuous soil degradation leads to a decrease in productivity on smallholder farms and with increasing population, this trend will only get worse. In areas that still allow it, like in the Congo basin, farmers often clear new pieces of land for crop production. Although there is a clear livelihood benefit, clearing forest leads to pressure on valuable ecosystem services. In Africa, the Congo basin is the last biodiversity and carbon hotspot in sub-Saharan Africa so there is an urgent need to preserve it. At the same time, smallholder farmers need to get opportunities to improve their livelihoods through agriculture.
IITA works on the possibility to conserve the forest in the Congo basin by planning and implementing intensification in rural areas close and far from forest margins.

**Aging rural population**

With increasing urbanization and decreasing or stagnating production of cash and food crops in rural areas, the new generation is leaving the agricultural sector, escaping poverty and underemployment or seeking for opportunities and quick returns on investment in the urban areas (White, 2012). This trend results in an aging rural population and a slowly disappearing workforce in agriculture. This threatens the sustainability of the rural livelihoods and the provision of food to the urban areas. IITA does research on how to keep the young generation involved in agriculture by studying opportunities that target youth.

**Climate change**

More and more knowledge is created on the impact of climate change on agriculture in the world. The level of impact of climate change will be different for different areas in Africa (Vermeulen et al., 2013). This will mean that different climate-smart intensification strategies will be needed in different areas at local level. In some areas, transformational adaptation will be required where new crops will have to be introduced because current crops will not be a viable option anymore because they will be too affected by climate change. In other areas where climate change will be smaller, climate-smart intensification strategies on existing farming systems should be developed and implemented in order to sustain the livelihoods of farmers in that area. Understanding the impact of climate change on the climatic suitability of different crops will be needed to plan for sustainable intensification.

**Increased availability of ICT tools**

ICT has high potential to improve agriculture in developing countries. It provides a multitude of affordable and accessible information and communication services to the agricultural sector. It will empower poor farmers with information and communication assets and services that will increase their productivity and incomes as well as protect their livelihoods and food security. Furthermore, it will enable for information to be flowing back from farmers to research, private or public sector. This will enable tracking of farmer adoption behavior but also will be able to monitor pests and diseases and other constraints for production. Accomplishing these tasks requires the implementation of a complex set of policy, investment, innovation, and capacity-building measures, in concert with beneficiaries and other partners, which will encourage the growth of locally appropriate, affordable, and sustainable ICT infrastructure, tools, applications, and services for the rural economies and societies.

**2.3. On-going initiatives**

**Comprehensive Africa Agriculture Development Programme**

The Comprehensive Africa Agriculture Development Programme (CAADP) promotes the investment in the agricultural sector of Africa around four pillars:

- Land and water management
- Rural infrastructure and trade-related capacities to improve market access
- Increasing food supply and reducing hunger
- Agriculture research, technology dissemination and adoption.
Implementation of these pillars require effective policy environment. For instance, an investment of 10% of the national budget into agriculture has been recommended to allow an annual growth rate of 6% for the agricultural sector by 2015. Assessment of the implementation level across is required to determine the rate of success, draw lessons able to inform future policy decisions in order to meet the intended goal. Market access for both inputs and outputs is critical to trigger adoption of proven technical for sustainable land and water management.

**FARA:** Is leading agricultural R4D on the continent through a number of sub-regional organizations (e.g., ASARECA, CORAF) thereby leading the R4D arm of CAADP on the continent.

**Abuja Fertilizer Summit**

In June 2006, the African Union (AU) Special Summit of the Heads of State and Government adopted the 12-Resolution ‘Abuja Declaration on Fertilizer for the African Green Revolution’. At the end of the Summit, the AU Member States resolved to increase fertilizer use from 8 kilograms to 50 kilograms of nutrients per hectare by 2015. As a result of the efforts, fertilizer use has significantly increased. The Figure below shows the progress in 2011 (www.nepad-caadp.net). In 2014, the average fertilizer use in countries like Nigeria and Malawi had exceeded the threshold value set in the Abuja Declaration (Figure 3). However, in other countries such as Uganda and Niger the average in 2014 was still below the continental average of 2006. Efforts to improve the distribution network by engaging the private sector, enhancing the outputs markets and access to credit may be useful.

![Figure 3: Progress towards the Abuja goals for selected countries in Africa.](image)

**Alliance for a Green Revolution in Africa**

Shortly after the Abuja Fertilizer Summit, AGRA was formed. Its Soil Health Program has been quite instrumental in promotion of ISFM practices and building the capacity in this area. One of the most outstanding initiatives is the improvement of recommendations for sustainable intensification including fertilizers recommendations tailored to local conditions. As results of AGRA’s interventions, over 600,000 farmers have adopted ISFM practices and ≥ 18,000 received training on ISFM practices. For instance, over 7.5 metric tons of organic fertilizers have been sold with the support of AGRA. Over 100 PhD and hundreds of MSc students have been supported by AGRA in areas related to soil health including increased soil productivity through proven ISFM practices.
National fertilizer subsidy programs

In Malawi, the most comprehensive subsidy program after the Drought Recovery Inputs Project (1992/93) was the Starter Pack (SP) (1998/99 and 1999/2000). SP was universally targeted to 2.8 million beneficiary farm households, providing free seed and fertilizer sufficient for each beneficiary household to cultivate about 0.1 hectares of maize. Due to cost concerns and donor pressure, SP was replaced by the Targeted Input Program (TIP) in 2000/01 and 2001/02 with similar benefits, but targeted at only half of the SP beneficiaries. This downscaling of TIP was partly blamed for the severe food crisis of 2001/02. Hence, in 2002/03 an “extended” TIP was implemented, once again reaching 2.8 million beneficiaries. By 2003/04, TIP was again scaled back (1.7 million beneficiaries), while a near-universal TIP was implemented in 2004/05, an election year. The Agricultural Input Subsidy Program, later renamed the Farm Input Subsidy Program (FISP) was implemented in 2005/06.

There is much talk about FISP exit strategies and policy alternatives. However, the available evidence is not convincing enough to simply dismiss FISP as an economic failure. In fact, there are many good reasons not to dispose of FISP, the most important of which is the historical evidence of recurring periods of food deficits when subsidy programs were not widely targeted. Already some are blaming current food deficits on the fact that FISP had been downscaled in a time of high fertilizer costs and weak exchange rates. While economically it may at times make sense to import food rather than subsidize its production, currently, it seems not to be the case in Malawi. Moreover, the socioeconomic and humanitarian effects of hunger are far-reaching, while the logistical challenges of providing food aid are immense. However, it is equally important to continue exploring outcomes under policy alternatives, including those that are less prone to weather or price risks. These could be policies within the broader sphere of agricultural policy (e.g., irrigation and rural infrastructure, market linkages and development, credit provisioning and insurance, or research and extension services) or those outside the traditional ambit of agricultural policy (e.g., cash transfers or public works). The Malawian government faces a unique challenge of finding itself in a “public spending trap” where reduced spending on FISP is politically and socially risky. However, as long as FISP crowds out other socioeconomic spending, it could have detrimental consequences for growth and welfare outcomes in the long term. These opportunity costs and outcomes under policy alternatives need to be better understood and quantified.

The results of fertilizer subsidy programs in Nigeria have been variable over time. With the old fertilizer subsidy program less than 30% was reaching the target, while the target outreach was 70% of the intended fertilizer users. Since 2011, with the Agricultural Transformation Agenda (ATA), the direct procurement and distribution by the government was cancelled, and an electronic voucher system installed. The initial plan was two reach out 5 million farmers per year, for a total of 20 million farmers in 4 years. The challenges associated with the new system include but are not limited to:

- Fertilizer quality that could be affected by adulteration (distribution network)
- Delays or rejection of the electronic vouchers, or defect of mobile phones
- Lack of trust of agro-dealers by farmers, compared to the former system where the fertilizer was distributed through the government system
- Given the size of the country, 900 voucher redemption centers (in 2012) were insufficient
- The cost of entry of new agro-dealers is considered relatively high
In Ethiopia, fertilizer subsidies were removed in 1997-1998, in context of liberalizing fertilizer pricing. While the private sector was quite enthusiastic in the beginning, it quickly vanished almost a year later mainly because of the import conditions. The holding companies with strong ties to the government dominated the market thereafter and fertilizer import was dominated by the Agricultural Inputs Supply Entreprise (AISE). In 2008, Cooperative Unions played a major role in fertilizer import (80%), while the remaining 20% was still covered by AISE. It is worth mentioning that farmers have access to credit guarantee to facilitate procurement of seeds and fertilizers.

In Rwanda, as part of Vision 2020, the government applies a subsidy program to ensure that farmers have access to production inputs for food security. However, it has been recommended to the government to develop an exit strategy from fertilizers subsidies. However, it has also been recommended to maintain a subsidy equivalent to transport cost from the nearest sea port until the railroad reaches Kigali. By then, the fertilizer subsidy will be redirected to support farmers to overcome other limitations to achieve profitable agricultural production. The fertilizer subsidy is applicable for staple crops such as maize, wheat, rice, and potatoes. For instance, the subsidies provided by the Government include (1) a transportation and import tax subsidy amounting to approximately $155 per metric ton for all imported fertilizers, and (2) a 50% subsidy for wheat and maize producers to purchase DAP and Urea. Reduction of fertilizer subsidies will be gradually done through monitoring its impact on fertilizer uptake by farmers.

**International organizations and research programs**

Most of the 15 centers of the CGIAR have activities in Africa and aim at improving food security and reduce rural poverty. The research programs include: (1) genebanks, (2) dryland cereals, (3) grain legumes, (4) livestock and fish, (5) maize, (6) rice, (7) roots, tubers, and bananas, (8) wheat, (9) aquatic agricultural systems, (10) dry land systems, (11) integrated systems for the humid tropics, (12) water, land and ecosystems, (13) climate change, agriculture and food security, forests, trees and agroforestry, (14) agriculture for food nutrition and health, and (15) policy institutions, and markets. Given the similarity of the overall goal for all the Centers, there is a lot of collaboration across Centers. IITA, for instance, is involved in 9 CG programs i.e. 1, 3, 5, 7, 11, 12, 13, 14, and 15. In addition to CGIAR centers, other organizations involved in research in Africa include (but are not limited to): ICIPE, IFDC, IPNI, and CABI, with a goal similar to that of CGIAR Centers. All these international research organizations generally collaborate with national agricultural research organizations to facilitate local operations. Examples of ongoing initiatives by some if these organizations to improve crop productivity for food security and wealth generation are listed below.

- **IITA**: Putting nitrogen fixation to work for smallholder farmers in Africa (N2Africa) and institutionalization of quality assurance mechanism and dissemination of top quality commercial products to increase crop yields and improve food security of smallholder farmers in sub-Saharan Africa (COMPRO-II)
- **IFDC**: Balanced crop nutrition to reduce yield gaps: fertilizer recommendations tailored to initial soil fertility (soil fertility mapping in East Africa)
- **IPNI**: Plant nutrition research and development activities to support sustainable crop production intensification in more than 10 countries in West, East and Southern Africa
- **CABI**: In collaboration with AGRA, optimization of fertilizer recommendations in AFRICA (OFRA) to improve efficiency and profitability of fertilizer use in 13 SSA countries within the framework of ISFM
It is worth mentioning that most of these organizations have significant invested in integrated soil fertility management (ISFM) as one of the viable option to improve soil and crop productivity in sustainable manner and even restore moderately degraded lands. In fact, yield gaps in SSA are due to several factors including soil acidification, nutrient deficiencies, climatic conditions such as rainfall, and crop management among others. Adequate diagnostic of limiting factors is critical for sustainable intensification.

Regional economic blocks

Regional economic blocks play a crucial role to develop agricultural policies intended to facilitate farmers’ access to innovative technologies and increase the profitability and competitiveness of the agricultural sector. In SSA such blocks include (1) the Common Market for Eastern and Southern Africa (COMESA), (2) the Economic Community of West Africa States (ECOWAS), (3) the Southern Africa Development Community (SADC), and (4) the Economic Community of Central African States (ECCAS). Examples of recent initiatives include:

- **COMESA & ECOWAS**: In collaboration with partners such as AFAP or USAID, harmonization of agricultural input policies (e.g. seeds & fertilizers) at the regional economic block level
- **SADC**: Support to Member States’ measures designed to improve farmers’ access to and participation in regional input and output markets
- **ECCAS**: In collaboration with the European Union is working on a regional agricultural policy to facilitate regional access to agricultural inputs

Donor community

Given that agricultural research is not significantly funded by the national systems, both national and international research organizations mainly count on donor organizations. Such donors include FAO, USAID, EU, BMGF, DIFD, IFAD, DFATD-IDRC, and UNEP/GEF among others. Examples of initiatives recently supported by selected donors include:

- **USAID**: West Africa Fertilizer Programme - Building an enabling environment for fertilizer sector growth
- **FAO**: Collaboration with AFAP to promote agribusiness development for reduction of rural poverty
- **BMGF**: support of several IITA projects including (but not limited to) COMPRO, N2Africa, and the Weed Management Project.
- **UNEP/GEF**: the International Nitrogen Initiative in collaboration with Global Partnership for Nutrient Management with the Support of Global Environment Facilities of UNEP has retained the Lake Victoria Basin as demonstration site for improve nitrogen management to increase it is agronomic use efficiency in crop production. It is expected that the knowledge that will be generated will be useful for other SSA regions

Digital soil mapping

Digital soil mapping in Ethiopia to inform agricultural decisions and interventions has been developed the Agricultural Transformation Agency (ATA) (Figure 4). This was particularly important to inform ISFM interventions to address the current agricultural land degradation due to several factors including nutrient depletion (e.g., N, P, K, S, B, Cu and Zn), erosion,
removal of crop residues and insufficient application of yard manure, reduction of soil productivity, water logging, acidity, and alkalinity, and minimum fertilizer use.

Figure 4: Digital soil mapping results for Ethiopia, highlighting the level of organic matter status in the country.

3. OPPORTUNITIES

3.1. Integrated Soil Fertility Management

Integrated Soil Fertility Management (ISFM) is a means to increase crop productivity in a profitable and environmentally friendly way (Vanlauwe et al., 2010), and thus to eliminate one of the main factors that perpetuates rural poverty and natural resource degradation in sub-Saharan Africa (SSA). ISFM has been 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. All inputs need to be managed following sound agronomic principles’ (Vanlauwe et al., 2010).

Kofi Annan stressed that the African Green Revolution should be 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). The ‘local adaptation’ component of ISFM is aligned to this request and operates at plot scale by dealing with alleviating plot-specific constraints to enhanced fertilizer nutrient AE that are not sufficiently addressed by the introduction of improved germplasm and the application of organic inputs (Table 1). For instance, application of lime is required where soil acidity-related constraints are important. Application of micro-nutrients will be necessary where these are absent. Under drought stress, water harvesting techniques can increase the uptake of applied fertilizer.
Table 1: A selected set of constraints that can prevent the uptake of nutrients applied with ‘standard’ fertilizer, or fertilizer that's commonly available and often composed of N, P, and/or K, and the potential of improved germplasm, organic resources and other amendments and/or soil management practices to alleviate these constraints.

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Potential of improved germplasm and organic resources and specific traits required</th>
<th>Other amendments or soil management practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil acidity resulting in large amounts of exchangeable Al</td>
<td>Limited and short term – organic inputs with high decomposability, and preferably concentrated around the planting hole</td>
<td>Application of lime (calcite or dolomite) depending on Ca:Mg ratios and target crops</td>
</tr>
<tr>
<td>Secondary nutrient deficiencies</td>
<td>Limited – high quality species are required to supply a sufficient amount of secondary nutrients; high quality manure may contain sufficient secondary nutrients</td>
<td>Application of multi-nutrient fertilizer</td>
</tr>
<tr>
<td>Drought stress</td>
<td>Limited – Surface mulch with low quality (e.g., high lignin content and C-to-N ratio) can reduce evaporation and enhance soil moisture availability</td>
<td>Water harvesting techniques (e.g., zaï, tied ridges) can substantially increase water available for crops</td>
</tr>
<tr>
<td>Hard pan formation</td>
<td>Limited – Some deep-rooting trees or grasses may facilitate crop root growth</td>
<td>Deep tillage</td>
</tr>
<tr>
<td>Surface sealing</td>
<td>Appropriate – Surface mulch inhibits the formation of surface sealing</td>
<td>Surface tillage</td>
</tr>
<tr>
<td><em>Striga hermonthica</em> damage</td>
<td>Appropriate – Use of crops triggering suicidal germination of Striga, surface mulch reduces Striga emergence</td>
<td>Use of Striga-tolerant/resistant varieties in combination with integrate Striga management options</td>
</tr>
</tbody>
</table>

The definition for climate-smart agriculture builds on 3 main pillars: (i) short-term livelihood benefits like increase in productivity, decrease risks or increase income, (ii) climate change adaptation, and (iii) climate change mitigation. ISFM respects above conditions (i) by enhancing crop productivity and income (since ISFM is based on maximizing the use efficiency of inputs which is equivalent to their value: cost ratio), (ii) by associating fertilizer use with other implements that increase its use efficiency (e.g., water harvesting in drought-prone areas, and (iii) by providing more biomass in the form of crop residues that could lead to soil C sequestration. Strategies and technologies for CSA are context specific and need to be planned for in this way but this is not enough. Often, opportunities discussed for climate-smart agriculture are limited to plant and plot level (Jassogne et al., 2013).

Current interest in and uptake of ISFM partly results from widespread demonstration of the benefits of typical ISFM interventions at plot scale, including the combined use of organic manure and mineral fertilizers (e.g., Zingore et al., 2008), dual purpose legume – cereal rotations (e.g., Sanginga et al., 2003) or micro-dosing of fertilizer and manure for cereals in semi-arid areas (e.g., Tabo et al., 2007). ISFM can increase crop productivity and likely enhance other ecosystems services and resilience by diversifying farming systems, mainly with
legumes, and by increasing the availability of organic resources within farms, mainly as crop residues and/or farmyard manure.

Conditions for uptake of ISFM practices include (i) availability of appropriate fertilizer blends and associated supply chains, (ii) access to profitable markets for farm products to allow farmers to re-invest in crop production, (iii) seed systems for improved varieties, and (vi) existence of service providers supporting, amongst others, advisory services, credit, and insurance. Uptake is also affected by farmer’s resource availability (land, labor, capital), agricultural dependency, market orientation, food-self-sufficiency, intra-household decision making with a perspective of gender equality and his/her attitude and ambitions with respect to farming (Giller et al., 2006).

3.2. Legume integration and biological nitrogen fixation

A key component of all approaches to enhancing agricultural productivity and achieving food and nutrition security is the diversification and intensification of farming systems – to increase the range of crops grown, productivity of the system and to reap the benefits of integrated crop-livestock systems. Legumes integration into the farming systems plays a key role in the farming systems intensification and diversification. Legumes are important cash crops for smallholder farmers, with diverse opportunities for value-addition through local processing in particular by women and youth, who should be included centrally in all initiatives to improve agricultural outcomes.

A lot of progress have been made in enhancing biological nitrogen fixation (BNF) and yields of grain legumes through identification and promotion of effective agricultural commercial products such as inoculants (I) and phosphorus (P) fertilizers (and also those that address limitations of K, Ca, Mg S and Zn), seeds of improved varieties and good agricultural practices appropriate to various agro-ecologies and cultural contexts. Beyond inoculants for soybean, great progress has been made in the identification of new elite strains of rhizobium for the other major grain legumes – common bean, cowpea and groundnut; and will be made available to inoculant producers for scaling up the technology.

Through many interventions, legume production has expanded (in hectare, number of smallholder farmers and number of countries) and many other aspects of legume integration and BNF being taken up by other value chain actors and supporters. Through IITA initiatives alone, we shall have reached 550,000 households by 2018. Currently, over 90,000 smallholder farmers have been reached (awareness creation and training) with selected legume technologies. A proportion of these farmers (especially in countries where dissemination of these technologies have been ongoing for more than two years), have either adopted one or two aspects of the technologies. Examples of such include the following: uptake of new varieties, management practices, intercropping and rotation of legumes with other crops. In addition, some smallholder farmers also taking up legume production as new crop in addition to their original growing crops. Farmers have also shown interest.

A number of conditions need to be fulfilled along the legume value chain to enable uptake of legume integration and BNF into cropping systems. The strides being made in legume uptake is mainly because of development of effective and strategic public-private-partnerships (PPPs) that address all conditions through series of activities along the legume value chain. The PPPs creates a platform for all actors along the value chain to identify emerging issues, ways of resolving such issues including disseminating legume technologies and share outcomes that
lead to long-term impact. Conditions such as access to input and output markets by smallholder farmers, tailoring the technologies to the needs of the smallholder farmers, building the capacities of institutions (both private and public) to support legume technology development, etc are critical to fulfill for successful uptake. The partnerships bring together major public and private partners to support the proliferation of local business clusters in key production areas to support value chain development. To mention but few partners include; AGRA SSTP in Ethiopia, Catholic Relief Services in Nigeria, Tanzania and Ethiopia, IFDC in Nigeria, World Vision in Uganda, Export Trading Group in Tanzania, Guts Agro industries and ACOS in Ethiopia, ACDI-VOCA- Agriculture Development and Value Chain Enhancement (ADVANCE) Program in Ghana.

3.3. Soil conservation and erosion control

Erosion continues to be a major threat to agricultural production and development in Africa. About 65% of the arable land in Africa is affected by degradation (The Montpellier Panel, 2013, p. 6). A quarter of the total land area in Africa is classified as degraded (Bai et al., 2008, pp. 29–31). The resulting loss in NPP is ten million tons annually (Bai et al., 2008, pp. 29–31). Currently Ethiopia alone is losing one billion tons of topsoil every year. In most parts of Africa erosion rates are increasing due to a combination of reduced fallow periods, tree cover and crop ground cover resulting from nutrient mining. Wind erosion affect large areas but since these have low population density and low productivity the economic effect is limited when viewed at the continental level. It is water erosion that has by far the biggest impact on production and nutrient loss and affects the largest number of people in Africa.

Erosion control does no longer require extensive research, control measures are well known, at present however what is lacking are farmer affordable and simply implementable measures to avoid or reduce erosion. Thus one major activity to stabilize agriculture on sloping land would be to raise awareness of the consequences of erosion, the principal causes and to develop simple measures to control erosion. The latter should preferably focus on measures taken in food crop systems if conditions allow (less steep slopes, less high rain intensity) so to not compromise on food production and income. Where conditions are severe and erosion risk is high, long term planning may need to include infrastructural and financial support to farmers willing to invest in erosion control structures. Erosion control methods have been promoted by governments and NGOs for almost a century with varying success—initially with a focus on physical structures like terraces but over the last three decades increasingly utilizing biological approaches in the form of agroforestry, perennial crops, and fodder grasses on contours lines. Recent approaches to nutrient management, including Integrated Soil Fertility Management and Conservation Agriculture can reduce erosion significantly through the better ground cover and improved soil structure.

A common challenge to uptake of most erosion control measures has always been the relatively high upfront investment required and the long payback time. This is particularly evident for terracing which can even reduce yield in the short term but has a huge positive impact when measured over decades or centuries. Where physical erosion control has been widely adapted, like Rwanda which has almost 80% of the cultivated land protected against soil erosion, a combination of secure land tenure, enforcement of anti-erosion regulation and subsidies have usually been important factors. However, there are examples of smaller areas where farmers’ investment horizon has been long enough to appreciate terracing and consequently implemented it on their own accords. Examples include several localities in Ethiopia as well as the Machakos and Kitui in Kenya (Nkonya and Anderson, 2015).
Erosion control measures have seen greater adoption rates and less resistance when they have been piggy backing on agricultural technologies that were adapted for other reasons. Examples include agroforestry systems, cover crops for soil fertility improvements, Integrated Soil Fertility Management, and Conservation Agriculture. Integrating erosion control into technology packages whose primary focus is increased production and income therefore appears the best approach to erosion control. Particular in hilly and mountainous areas effective erosion control can only be achieved if it implemented at the watershed level and therefore requires collective action. Both participatory and regulatory approaches have been used to bring about collective action. The outcomes have been very site specific, indicating that there is no one best approach.

3.4. Water harvesting and small-scale irrigation

Low soil quality and limited water availability in SSA’s arid zones lead to low efficiency of fertilizers and low crop yields. Water harvesting and conservation measures, however, have limited effects on yields under continuous non-fertilized cropping. Fertilizer use is low due to a lack of economic motivation to increased use of plant nutrient sources (.). A number of techniques are used to increase soil water content and to control runoff and erosion. Most common indigenous techniques are stone or rock bunds, earthen contour bunds, straw mulching, the Zai or Tassa and the half-moon system. Other techniques focus on macro-catchment runoff collection in larger earthen structures such as micro reservoirs (Barry et al. 2008).

The efficiency of stone bunds increases with decreasing distance between bunds. Soil chemical properties, water content and yields increased up to 33 m distance between bunds in Burkina Faso. However, highest yields were only attained when compost was added. Using the half-moon technique to harvest water produced highest yields only when compost was added to the planting hole. Similar results were obtained in Niger using the Zai technique: crop yields were 2-6 times higher when manure was applied and generally exceed the yields on flat soil. In Niger it was demonstrated that the positive effects of stone bunds (+40% millet yield) were maintained for at least 15 years after establishment. Important to all water harvesting techniques is the economic analysis. Zougmore et al. (2004) demonstrated that water harvesting alone was not economically viable and that only through nutrient addition (urea or compost) the overall system produced economic benefits. Generally the synergistic effects of water harvesting / runoff control measures and nutrient and organic matter inputs have been shown across a large number of studies throughout the Sahel and thus can be considered as the two essential factors to increase and stabilize food production and security in the arid zones.

Due to the generally positive effects on yields and livelihoods, various government and non-government programs are promoting the introduction of the technique at scale and provide technical and logistical backup for procuring and transporting stones for bunds. However, other techniques such as zai, tassa, the half-moon tillage and the micro reservoirs require manual labor and thus are limited in spread to areas where awareness has been raised and positive effects have been demonstrated. Over the last 25 years, in Burkina Faso alone, water harvesting techniques have contributed to farmers restoring 200,000 to 300,000 hectares of degraded land, producing an additional 80,000 to 120,000 tons of cereals. Concrete estimates and location of the land area that would benefit from these techniques would be a major advantage to guide future efforts, highlighting further the importance of improved soil information systems.
The fact that water harvesting alone is cost and labor intensive with limited effects on yields compared with the combined use of water harvesting plus fertilizer of other nutrient sources requires the establishment of the input supply sector in the entire zone. Further, any measure to increase livestock integration to produce manure and compost would enhance effects of water harvesting. Veterinary services and market structures would support such efforts. For the basic water harvesting operations incentives need to be created such as technologies that require a minimum amount of labor on establishment and maintenance, better community support to foster large scale implementation, technical support to optimize labor use, research efforts to develop mechanized water harvesting and related tillage systems to use larger areas and improved land tenure systems to promote perennial systems, agroforestry techniques to stabilize the soil, the water regime and create a sustainable fodder base for increased livestock rearing.

4. SUGGESTED ACTIONS / THE WAY FORWARD

4.1. Global vision for sustainability

Unlocking the potential of land for productivity and resilience will require a medium-to-long term commitment to ensure that the longer-term benefits can be appreciated by farming communities. Intensifying land use and ensuring a continuously supply of produce even under suboptimal growth conditions will require investments in land, water, and soil fertility management by farming communities and such investments will only be sustained if the greater and more stable production will yield the financial means to re-invest. While subsidies and other incentive mechanisms are essential in the short term, in the longer term, returns-on-investment should be generated through the agricultural value chains themselves, requiring engagement of the private sector (e.g., agro-input supply, logistics, processing and value addition), the financial sector (e.g., credit provision, insurance), and government (e.g., extension services, credit guarantee, rural and market infrastructure, inclusion approach).

4.2. Preliminary notes

The proposed actions should not been independently form other strategy documents. For instance, while below actions include capacity development for agro-dealers and households in relation to appropriate fertilizer provisioning and use, the important or production of fertilizer itself is not included in these actions since this is the major focus of a complementary strategy document. Capacity development for farmers and last-mile delivery agents (e.g., agro-dealers, extension agents) is embedded in all below suggested action points as is the valorization of ICT tools for the collection and sharing of knowledge and information.

The prioritization in terms of land area is based on 2 nested criteria:

1. At the highest level, all agricultural land having specific constraints is calculated based on soil, weather, and elevation information. For nutrient-related constrains, FAO soil types are used to differentiate between N, P, and acidity-related limitations. For erosion-related constraints, land with a slope above 5% is considered while for drought-prone areas, agricultural land in semi-arid conditions is considered.
2. Within above areas, it is envisaged that some prioritization will take place. While this prioritization strategy is not clear yet, below calculations are based on the assumption that such priority areas will cover 10% of the total agricultural area with specific constraints. Note that investment needs can be readily recalculated with different figures.
The overall areas with specific conditions that require investments are summarized in Tables 2 and 3.

Table 2: Estimated agricultural areas with high potential for P and acidity-related deficiencies, based on the presence of specific soil types.

<table>
<thead>
<tr>
<th>FAO Dominant Soil</th>
<th>Agricultural land under FAO dominant soil (hectare)</th>
<th>High potential for specific limitations (1 = yes, 0 = no)</th>
<th>Area with a high potential for specific limitations (hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P limitations</td>
<td>Acidity problems</td>
<td>P limitations</td>
</tr>
<tr>
<td>Andosols</td>
<td>3,170,097</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Arenosols</td>
<td>37,384,821</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Calcisols</td>
<td>2,339,571</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cambisols</td>
<td>29,162,824</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ferralsols</td>
<td>39,207,186</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fluvisols</td>
<td>12,726,751</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gleysols</td>
<td>3,460,524</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kastanozems</td>
<td>1,312,174</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Leptosols</td>
<td>15,832,205</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lixisols</td>
<td>23,095,582</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Luvisols</td>
<td>25,278,530</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitisols</td>
<td>7,669,817</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Phaeozems</td>
<td>5,067,856</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Planosols</td>
<td>3,792,187</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Regosols</td>
<td>24,130,846</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Solonchaks</td>
<td>1,319,157</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vertisols</td>
<td>29,595,398</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>264,545,525</strong></td>
<td><strong>169,285,725</strong></td>
<td><strong>107,357,406</strong></td>
</tr>
</tbody>
</table>

Table 3: Estimated agricultural areas with high potential for erosion and drought stress.

<table>
<thead>
<tr>
<th>Slope class</th>
<th>Agricultural land area under slope (hectare)</th>
<th>Class</th>
<th>Agricultural land under precipitation class (hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope &lt;5%</td>
<td>191,893,986</td>
<td>Non Arid</td>
<td>157,729,764</td>
</tr>
<tr>
<td>Slope &gt; 5%</td>
<td>75,953,977</td>
<td>Semi-Arid/Arid</td>
<td>117,397,984</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>267,847,963</strong></td>
<td><strong>Total</strong></td>
<td><strong>275,127,748</strong></td>
</tr>
</tbody>
</table>

4.3. Establishment of a soil and land quality monitoring and evaluation framework

Why?
In Africa, soil and land quality is very variable, partly due to variation in inherent soil properties and relief attributes, and partly driven by long-term management of land for agricultural and other purposes. While soil fertility conditions under climax natural vegetation are sufficient to maintain this vegetation, and land cover is often maximal avoiding severe water and wind-related degradation, upon conversion to agriculture, soil fertility conditions deteriorate rapidly,
productivity and land cover decline, and land is increasingly exposed to erosion processes. With time, degradation processes become more severe and rehabilitation measures more complex and costly, as outlined above. Decisions on when and how to reverse these degradation processes towards unlocking the potential of land for productivity and resilience requires a framework that details the status of land quality and soil fertility at appropriate scales for decision-making on site-specific land and soil rehabilitation measures. Decisions on whether or not to invest in land and soil rehabilitation also require such information. Lastly, once investments have been initiated, monitoring positive changes in relation to these is also critical to determine the appropriate levels of investment required to continue producing crops at acceptable levels without deteriorating the land and soil resource base.

**What?**
Above framework consists of several components: (i) a system for assessing critical soil and land attributes, (ii) databases that assemble this information, (iii) procedures to interpret the collected information at the appropriate scales, and (iv) tools to monitor changes in soil and land quality as affected by improved soil and land management, using direct or indirect (e.g., satellite imagery, drones) means.

**Who?**
Each of the above components require its own skill sets, expertise, and infrastructure. While during the initial phases of the investment, external expertise may be sought to set up the infrastructure, sampling protocols, and analytical tools, these skill sets should be gradually handed over to 5 regional teams (West, Central, East, southern, and North Africa) consisting of 2 experts each, housed within an organization or structure that will guarantee to do so for the next 2 decades. The teams will have technical and administrative support staff and call upon national scientists and support staff to engage as needed. The teams will also liaise with initiatives that advance the state-of-the-art of soil diagnosis and geospatial analysis, including integration of satellite and drone imagery, to ensure that the tools and approaches are continuously updated towards greater efficiency and effectiveness.

**When?**
In the short to medium term, critical investments include (i) setting up of regional offices (1 per region) with 2 senior staff and required data management infrastructure, (ii) assessing soil conditions, following, e.g., the EthioSIS model, and (iii) setting up a continuous monitoring system. In the longer term, the monitoring system would need to be used to update soil conditions. It is expected that revenues generated through specific requests for information will assist the functioning of this structure, eventually towards a break-even point and beyond.

**Sustainability?**
Above framework will only be sustainable if (i) the services provided are paid for, (ii) new developments in land and soil diagnosis and interpretation are continuously embedded, (iii) technical capacity at national and regional level is continuously enhanced, (iv) data capture and management infrastructure is continuously upgraded, and (v) the information collected is aligned to changing demands. While some of the above will require investments in the short term, it is expected that this service will become financially self-supporting over a period of 10 years.
4.4. Facilitation of access to crop- and site-specific fertilizer blends and application rates

Why?
Recent evidence shows that (i) different crops require different nutrient combinations, (ii) in many cases, nutrients limiting crop growth include others besides NPK (e.g., Zn, S, B, or Mg), and (iii) appropriate management of fertilizer is required to ensure that the nutrients applied are taken up more efficiently. While there are many efforts to facilitate the importation and production of multi-nutrient fertilizers on the African continent (see other strategic documents), these efforts require additional investments in the capacity development of last-mile delivery agents (including agro-dealers) and farming households towards the most efficient use of the most appropriate fertilizer in relation to the most important cropping systems, soil fertility conditions, and economic context.

What?
This investment consists of the following components: (i) provisioning of infrastructure for agro-dealers (and other last-mile delivery agents) to engage in the formulation of site-specific recommendations (includes diagnostic tools), (ii) training of agro-dealers in providing recommendation services, and (iii) training households on the proper use of appropriate fertilizer. In all of the above, ICT tools will be used as appropriate. Specific tools and applications, e.g., the SoilDoc for diagnosing soil fertility conditions or the Nutrient Expert Decision support tool that provides site-specific recommendations based on soil conditions, production objectives, and prices for inputs and products will be integrated in the agro-dealer ‘toolbox’.

Who?
The main targets of this investment are agro-dealers, each of these estimated to serve 2,500 hectares of land (or about 1,000 households). The investment mainly concerns (i) the training of agro-dealers to diagnose soil fertility constraints and provide site-specific fertilizer recommendations, partly based on this, and (ii) the provision of tools and applications to support the above. A number of trainers will need to be engaged while linkages with organizations and initiatives developing the above tools will be required to ensure that these are continuously upgraded.

When?
In the short to medium term, critical investments include (i) the provision of tools and applications to agro-dealers and (ii) training of agro-dealers on how to use these (and link the information back to fertilizer procurement and types). In the longer term, ‘refresher’ training events will be needed to ensure that new developments in the area of diagnosis and recommendation formulation are availed to agro-dealers.

Sustainability?
Sustainability will only be guaranteed if the user of information pays some service fees to the provider of this information. While in the initial stages of the investment, facilitation of training events will be critical, eventually, agro-dealers should recover their investment costs through increased sales of more adapted fertilizer products.
4.5. Promotion of multipurpose legumes in farming systems

Why?
Legumes have the ability to fix nitrogen from the atmosphere through a biological process while at the same time providing goods and products of interest to farming communities, including grain, fodder, or firewood. Most African farming systems contain one or more legumes but often at low densities or on a limited area of land. Increasing the area and density of legumes within farming systems will increase nitrogen inputs into farming systems, provide high quality biomass, and provide the nitrogen needed for increased soil carbon sequestration.

What?
This investment consist of the following components: (i) facilitation of seed systems for dual purpose legumes (annual and perennial), (ii) facilitation of access to inoculants for legumes that benefit from the application of rhizobia, (iii) training of extension agents to provide information on how to increase the proportion of legumes in existing farming systems, including access to profitable legume markets and nutritional training, and (iv) training of farming households in relation to the above (led by extension agents).

Who?
This investment is built on a network of trainers, interacting with a vast network of extension agents, each of those linked in to about 500 households. Information on the best legume types and varieties, agronomic practices, and seed systems will be provided by agricultural research institutes with a mandate to deliver this information.

When?
In the short to medium term, critical investments include (i) the facilitation of appropriate legume seed systems (including community-based approaches and tree nurseries), (ii) the facilitation of access to appropriate legume inoculants, (iii) training of a network of extension agents, and (iv) training of households by extension agents. In the longer term, refresher training will be required to update extension agents with new information on legume technologies.

Sustainability?
Support for extension agents to deliver on their responsibilities will continue to require some direct engagement of the government. Private sector engagement in legume seed systems has been limited and this is not expected to change in the short term so community-based approaches will be required. Private sector engagement in inoculant delivery has advanced substantially in the last few years. Ultimately, revenue generated from increased legume production and productivity should provide the basis to farmers for continuing investing in legume production. Anticipated positive impacts on crops associated with these legumes should be another driver for sustaining this investment.

4.6. Valorization of locally available sources of rock phosphates to address phosphorus deficiencies

Why?
Ironically, while most of the phosphate reserves are in Africa, the soils with the highest P deficiencies are also in Africa. Many African countries are richly endowed with local rock phosphates that can potentially serve as economic alternatives to (or partially substitute for) costly fertilizer use. This requires mining and processing into practical agronomic products
(e.g., partial acidulation of PR). Ample scientific evidence is available showing that similar crop yields can be obtained with e.g., PR and soluble P fertilizer, provided the PR is applied in conjunction with proper agronomic practices. As for fertilizer, policies should aim at creating incentive and demand for such local sources, which will require quality control and knowledge dissemination for effective use.

**What?**
This investment consist of the following components: (i) construction of local production facilities near rock phosphate mines, (ii) training of agro-dealers in the agronomy and economics of the use of rock phosphate-based products, and (iii) training of households. Contrary to fertilizer, the feasibility of marketing these resources is uncertain and needs to be assessed before any investment is made. An R4D investment will be needed to identify the most efficient ways to produce rock phosphate-based fertilizer and to use this agro-input based on prevailing soils, environments, and farming systems.

**Who?**
This investment will require the engagement of (i) scientists evaluating the best ways to valorize rock phosphates, (ii) entrepreneurs interested in turning these processes to scale through small- to medium size manufacturing units, and (iii) agro-dealers who will commercialize rock phosphate-based inputs. A large scale capacity development network will be required to ensure that actors in the supply and use chains of these inputs will be informed about their best use.

**When?**
In the short to medium term, critical investments will include (i) an R4D program to valorize the agronomic and economic contributions to rock phosphate-based inputs to priority farming systems, (ii) rock phosphate transformation plants (with a capacity of about 10,000 ton per year, good to cover about 100,000 ha, (iii) training of agro-dealers on the use and commercialization of these inputs, and (iv) training of households by agro-dealers (about 1,000 households per agro-dealer). In the longer term, rock phosphate-based inputs could be diversified and their efficiency of use improved so regular refresher training of agro-dealers will be required as will the continuation of an R4D program of limited scale.

**Sustainability?**
The sustainability of the production and use of rock phosphate-based inputs will depend on their agronomic and economic performance in relation to standard P fertilizer. Private sector engagement is very likely in view of earlier private sector-led initiatives, although initially, some government support, e.g., through input subsidies, may be required.

4.7. Facilitation of access to crop- and site-specific sources of lime and application strategies

**Why?**
Many soils in Africa are inherently acidic or have become so because of inappropriate soil management practices. The best way to address soil acidity-related constraints is through the application of lime. Although most Africa countries have lime deposits, its utilization is very limited to non-existent in most countries that need this soil amendment. Most deposits consist of calcite or dolomite, the latter containing significant amounts of magnesium, and important nutrient for certain crops, e.g., banana. The appropriate deployment of these resources could provide large benefits to farming communities in Africa.
What?
This investment consists of the following components: (i) an R4D program aiming at identifying the most appropriate ways to valorize lime deposits, (ii) lime processing plants of small to medium capacity (max 50,000 tons) near such deposits, (iii) agro-dealer training in the use and commercialization of lime products, and (iv) training of households led by agro-dealers.

Who?
This investment will require the engagement of (i) scientists evaluating the best ways to valorize lime raw materials, (ii) entrepreneurs interested in turning these processes to scale through small- to medium-size manufacturing units, and (iii) agro-dealers who will commercialize lime-based inputs. A large scale capacity development network will be required to ensure that actors in the supply and use chains of these inputs will be informed about their best use.

When?
In the short to medium term, critical investments will include (i) an R4D program to valorize the agronomic and economic contributions to lime-based inputs to priority farming systems, (ii) rock phosphate transformation plants (with a capacity of about 50,000 ton per year, good to cover about 100,000 ha, (iii) training of agro-dealers in relation to the use and commercialization of these inputs, and (iv) training of households by agro-dealers (about 1,000 households per agro-dealer). In the long term, lime-based inputs could be diversified and their efficiency of use improved so regular refresher training of agro-dealers will be required as will the continuation of an R4D program of limited scale.

Sustainability?
The sustainability of the production and use of lime-based inputs will depend on their agronomic and economic performance. Private sector engagement is very likely in view of earlier private sector-led initiatives, although initially, some government support, e.g., through input subsidies, may be required.

4.8. Establishment of small to medium water harvesting practices and infrastructure

Why?
Climate change, and more importantly in the short term, climate variability is a fact of life for many farming families in Africa. Even in areas that have the right rainfall conditions for agriculture, within-season drought often hampers crop production. Small- and medium-scale water harvesting practices and infrastructure do exist that can alleviate temporary drought stress, including land management practices (e.g., tied ridges, broad bed furrows) and small-scale rainfall collection structures (e.g., micro-dams). Such investments are commonly less capital-intensive than large-scale irrigation programs. As for the latter, a careful evaluation of the success factors governing existing schemes is required to inform future investments.

What?
Establishing small and medium water harvesting structures and scaling up the use of such techniques requires primarily easy access to the basic tools and equipment to implement the proven approaches such as building micro dams, contour bunds and stone or rock bunds. Here earth moving equipment will allow establishing reservoirs with increased capacity. Improved surveying techniques will permit optimized site selection to attain maximum water yields at lowest investment. The second approach, the large scale use of tillage based water harvesting
techniques such as the zai, tassa or half-moon methods requires simple manual tools but the use would be scaled up faster and to a larger extent if these methods could be mechanized. For both approaches a large portion of the investment will have to cater to the tools and equipment needs and the development of improved tools and methods. Both approaches require training and dissemination activities at trainer and farm household level. Trainers need to engage extension agents in water harvesting techniques and improve their knowledge to the state of the art methods of implementation and most suitable approaches to engage farm household members.

Who?
Trainers from the region will train extension agents of the NARS and NGOs. International Agricultural Research Institutions (IAR) in collaboration with the relevant Sub-regional Institutions would conduct the selection and recruitment of trainers. NARS would select and second extension agents for training at relevant national agencies. Training NGO staff would add expertise and outreach and ensure wider dissemination. The trained extension agents will directly engage with farming households and conduct group training in a hands-on manner. Development of decision support tools and mobile phone based dissemination tools would be initiated by IARs and tested, verified and updated with the NARS.

When?
Immediate action will be the identification, selection and recruitment of trainers, the identification of expertise in IARs to develop decision support tools and mobile phone based dissemination tools. In the short term the training of extension agents would be priority along with feasibility studies on decision support tools. In the mid-term training of farming households on the implementation of techniques will lead to large scale expansion of water harvesting approaches. Within a 5-year time frame decision support tools are developed, tested, verified and made accessible to the public. Extension agents are trained in using decision support tools to facilitate farmers’ uptake of technologies. In the long term Farmer to Farmer dissemination will partially replace training conducted by extension agents.

Sustainability?
Due to low cost equipment and relatively simple technical approaches which will be supported by low cost decision support systems open to be public, the sustainability of this investment is likely to be secured. Support from the input supply sector (fertilizer) will further increase benefits of farmers and communities using water harvesting technologies and thus strengthen the income and thus reinvestment situation.

4.9. Facilitation of the establishment of appropriate soil conservation structures

Why?
On land with slopes above 5%, soil erosion is a common feature. Depending on the soil profile properties, topsoil losses can result in significant degradation, often resulting in total loss of productive capacity, e.g., in situations where the B horizon surfaces. Deeper soils can sustain erosion losses for a longer period of time but will ultimately end up in the same situation. Technical options to minimize soil erosion exist (e.g., biological barriers, terracing, contour hedges) but are often hard to implement at scale because of the high investments required per unit area of land and the relatively long period of time for benefits to become visible to farming communities. Institutional issues, including land ownership, also affect the uptake of soil conservation options. Success stories with soil conservation, e.g., in Ethiopia or Rwanda, have
been based on specific incentive structures to engage farming communities (e.g., food-for-work schemes).

**What?**
This investment consist of the following components (i) incentive schemes to facilitate farming communities to set up soil conservation structures, (ii) training of extension agents to assist farming communities in engaging in this effort, and (iii) training of households in the establishment and maintenance of soil conservation structures.

**Who?**
This investment will be led by a network of extension agents, each working with about 500 households.

**When?**
In the short to medium term, critical investments include (i) facilitation of installation of soil conservation structures (760,000 ha in first instance), (ii) training of extension agents to assist households in installing these (each extension agent is envisaged to work with about 500 households). In the longer term, the same strategy will be implemented for another 760,000 ha.

**Sustainability?**
It is unlikely that the installation of soil conservation structures will happen without incentive mechanisms in place. Continued investment from government or other actors will be required. It is envisaged that the maintenance of soil conservation structures can be handled by farming communities, especially if the benefits of such structures becomes visible.

**5. ESTIMATED COSTS (as detailed as possible)**

**5.1. Short to medium term needs (years 1-5)**

Based on above proposed interventions, a total investment of US$1.1 billion will be required for the first 5 years (or an equivalent of about US$220 million per year). The individual interventions vary between US$70 and $273 million for a 5-year period. Obviously, investment costs alone cannot be the major criterion to prioritize since returns on investment can also vary substantially. Moreover, co-investment of different actions create extra benefits beyond those created by individual investments. For instance, co-application of rock phosphate-derived products and legume inoculants is likely going to result in added benefits, superseding those created by the individual application of rock phosphate products and inoculants.

**Table 4: Proposed short to medium term investments and their estimated respective costs.**

Note that the costs are based on the assumption that 10% of the agricultural land with a specific constraints will be targeted by the African Agricultural Transformation Agenda.
### INVESTMENT REQUIREMENTS

#### SHORT- MEDIUM TERM (yrs 1-5)

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit cost</th>
<th>Yearly?</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A soil and land quality M&amp;E framework</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target area (ha):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional infrastructure</td>
<td>5</td>
<td>Regional center</td>
<td>500,000</td>
<td>1</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Technical staff</td>
<td>5</td>
<td>Teams (2 pp)</td>
<td>200,000</td>
<td>5</td>
<td>5,000,000</td>
</tr>
<tr>
<td>Note: All agricultural land</td>
<td>Baseline data collection</td>
<td>267 Million ha</td>
<td>200,000</td>
<td>1</td>
<td>53,400,000</td>
</tr>
<tr>
<td>Note: Organized per regions (5 regional centers)</td>
<td>Monitoring process</td>
<td>267 Million ha</td>
<td>25,000</td>
<td>5</td>
<td>33,375,000</td>
</tr>
</tbody>
</table>
| Sub-total: | | | | | | **94,275,000**

#### 4.2. Facilitation of access to specific fertilizer blends

| Total area that requires fertilizer (ha): | | | | | |
| Agro-dealer infrastructure | 10,680 | Agrodealers (1 per 2,500 ha) | 2,500 | 1 | 26,700,000 |
| Agro-dealer training | 10,680 | Agrodealers (1 per 2,500 ha) | 250 | 1 | 2,670,000 |
| Note: 10% of the total area targeted | Extension information | 11,608,696 | Households in target area | 3 | 1 | 34,826,087 |
| Note: Does not include prod/import costs | Engagement of trainers | 534 | Trainers (1 per 20 agro-dealers) | 10,000 | 1 | 5,340,000 |
| Sub-total: | | | | | | **69,536,087**

#### 4.3. Promotion of legumes in farming systems

| Total area for legume integration (ha): | | | | | |
| Legume seed systems | 1,335,000 | Acreage (5% under legumes) | 50 | 3 | 200,250,000 |
| Inoculant provision | 1,335,000 | Acreage (5% under legumes) | 5 | 3 | 20,025,000 |
| Note: 10% of the total area targeted | Training of households | 11,608,696 | Households in target area | 3 | 1 | 34,826,087 |
| Note: N is limiting nearly everywhere | Engagement of trainers | 1,161 | Trainers (1 per 20 ext. agents) | 10,000 | 1 | 11,608,696 |
| Sub-total: | | | | | | **272,514,130**

#### 4.4. Valorization of locally available rock phosphates

| Total area with potential P deficiency (ha): | | | | | |
| R4D on best ways to use RPs | 1 | R4D program | 5,000,000 | 5 | 25,000,000 |
| Local manufacturing systems | 22,100,000 | Units for 10,000 ton | 5,000,000 | 1 | 100,000,000 |
| Note: 10% of the total area targeted | Training of agro-dealers | 8,840 | Agrodealers (1 per 2,500 ha) | 2,500 | 1 | 22,100,000 |
| Training of households | 9,608,696 | Households in intensification zones | 3 | 1 | 28,826,087 |
| Engagement of trainers | 442 | Trainers (1 per 20 agro-dealers) | 10,000 | 1 | 4,420,000 |
| Sub-total: | | | | | | **180,346,087**

#### 4.5. Facilitation of access to lime and application strategies

| Total area with acidity-related constraints (ha): | | | | | |
| R4D on lime quality/production | 1 | R4D program | 5,000,000 | 5 | 25,000,000 |
| Local manufacturing systems | 12,300,000 | Units for 50,000 ton | 5,000,000 | 1 | 100,000,000 |
| Note: 10% of the total area targeted | Training of agro-dealers | 4,920 | Agrodealers (1 per 2,500 ha) | 2,500 | 1 | 12,300,000 |
| Training of households | 5,347,826 | Households in target area | 3 | 1 | 16,043,478 |
| Engagement of trainers | 246 | Trainers (1 per 20 agro-dealers) | 10,000 | 1 | 2,460,000 |
| Sub-total: | | | | | | **155,803,478**

#### 4.6. Establishment of water harvesting practices

| Target area under semi-arid climates (ha): | | | | | |
| Small-scale tools/equipment | 1,170,000 | Units (for 1 ha) | 100 | 1 | 117,000,000 |
| Training extension agents | 10,174 | Agent (1 per 500HH) | 250 | 1 | 2,543,478 |
| Note: 10% of the total area targeted | Training of households | 5,086,957 | Households in target area | 3 | 1 | 15,260,870 |
| Engagement of trainers | 509 | Trainers (1 per 20 ext. agents) | 10,000 | 1 | 5,086,957 |
| Sub-total: | | | | | | **139,891,304**

#### 4.7. Facilitation of soil and water conservation structures

| Total area prone to soil erosion (ha): | | | | | |
| Establishment of structures | 760,000 | Ha (10% of target area) | 250 | 1 | 190,000,000 |
| Training of households | 7,600,000 | Households in target area | 3 | 1 | 991,304 |
| Note: 10% of the total area targeted | Training extension agents | 681 | Agent (1 per 500HH) | 250 | 1 | 165,217 |
| Engagement of trainers | 33 | Trainers (1 per 20 ext. agents) | 10,000 | 1 | 330,435 |
| Sub-total: | | | | | | **191,486,957**

#### OVERALL TOTAL

**1,103,853,043**

### 5.2. Longer term needs (6-10 years)

Based on above proposed interventions, a total investment of US$451 million will be required for the second 5-year period (or an equivalent of about US$90 million per year). The individual interventions vary between US$25 and 191 million for a 5-year period. The only investment...
that’s not substantially less during the second 5-year period is the continued construction of soil conservation structures which will require continued incentives.

Table 5: Proposed longer term investments and their estimated respective costs. Note that the costs are based on the assumption that 10% of the agricultural land with specific constraints will be targeted by the African Agricultural Transformation Agenda.
### INVESTMENT REQUIREMENTS

**MEDIUM TERM (yrs 5-10)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit cost</th>
<th>Yearly?</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. A soil and land quality M&amp;E framework</strong>&lt;br&gt;Target area (ha): &lt;br&gt;Regional infrastructure</td>
<td>267,000,000</td>
<td>5 Maintenance</td>
<td>25,000</td>
<td>1</td>
<td>125,000</td>
</tr>
<tr>
<td>Technical staff</td>
<td></td>
<td>5 Teams (2 pp)</td>
<td>200,000</td>
<td>5</td>
<td>5,000,000</td>
</tr>
<tr>
<td>Note: All agricultural land</td>
<td></td>
<td>Baseline data collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note: Organized per regions (5 regional centers)</td>
<td></td>
<td>Monitoring process</td>
<td>267 Million ha</td>
<td>15,000</td>
<td>20,025,000</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25,150,000</td>
</tr>
<tr>
<td><strong>4.2. Facilitation of access to specific fertilizer blends</strong>&lt;br&gt;Total area that requires fertilizer (ha): &lt;br&gt;Agro-dealer infrastructure</td>
<td>267,000</td>
<td>2,670 Agrodealers (1 per 2,500 ha)</td>
<td>2,500</td>
<td>1</td>
<td>6,765,000</td>
</tr>
<tr>
<td>Agro-dealer training</td>
<td></td>
<td>2,670 Agrodealers (1 per 2,500 ha)</td>
<td>250</td>
<td>1</td>
<td>667,500</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Extension information</td>
<td>2,902,174 Households in target area</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Note: Does not include prod/import costs</td>
<td></td>
<td>Engagement of trainers</td>
<td>134 Trainers (1 per 20 agro-dealers)</td>
<td>10,000</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17,384,022</td>
</tr>
<tr>
<td><strong>4.3. Promotion of legumes in farming systems</strong>&lt;br&gt;Total area for legume integration (ha): &lt;br&gt;Legume seed systems</td>
<td>267,000</td>
<td>1,335,000 Acreage (5% under legumes)</td>
<td>50</td>
<td>1</td>
<td>66,750,000</td>
</tr>
<tr>
<td>Inoculant provision</td>
<td></td>
<td>1,335,000 Acreage (5% under legumes)</td>
<td>5</td>
<td>1</td>
<td>6,675,000</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Training extension agents</td>
<td>5,804 Agent (1 per 500HH)</td>
<td>250</td>
<td>1</td>
</tr>
<tr>
<td>Note: N is limiting nearly everywhere</td>
<td></td>
<td>Training of households</td>
<td>2,902,174 Households in target area</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Engagement of trainers</td>
<td></td>
<td>290 Trainers (1 per 20 ext. agents)</td>
<td>10,000</td>
<td>1</td>
<td>2,902,174</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17,384,022</td>
</tr>
<tr>
<td><strong>4.4. Valorization of locally available rock phosphates</strong>&lt;br&gt;Total area with potential P deficiency (ha): &lt;br&gt;R4D on best ways to use RPs</td>
<td>22,100,000</td>
<td>1 R4D program</td>
<td>2,500,000</td>
<td>5</td>
<td>12,500,000</td>
</tr>
<tr>
<td>Local manufacturing systems</td>
<td></td>
<td>20 Maintenance</td>
<td>500,000</td>
<td>1</td>
<td>10,000,000</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Training of agro-dealers</td>
<td>2,210 Agrodealers (1 per 2,500 ha)</td>
<td>2,500</td>
<td>1</td>
</tr>
<tr>
<td>Training of households</td>
<td></td>
<td>2,402,174 Households in intensification zones</td>
<td>3</td>
<td>1</td>
<td>7,206,522</td>
</tr>
<tr>
<td>Engagement of trainers</td>
<td></td>
<td>111 Trainers (1 per 20 ext. agents)</td>
<td>10,000</td>
<td>1</td>
<td>1,105,000</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30,200,870</td>
</tr>
<tr>
<td><strong>4.5. Facilitation of access to lime and application strategies</strong>&lt;br&gt;Total area with acidity-related constraints (ha): &lt;br&gt;R4D on lime quality and product</td>
<td>12,300,000</td>
<td>1 R4D program</td>
<td>2,500,000</td>
<td>5</td>
<td>12,500,000</td>
</tr>
<tr>
<td>Local manufacturing systems</td>
<td></td>
<td>20 Maintenance</td>
<td>500,000</td>
<td>1</td>
<td>10,000,000</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Training of agro-dealers</td>
<td>1,230 Agrodealers (1 per 2,500 ha)</td>
<td>2,500</td>
<td>1</td>
</tr>
<tr>
<td>Training of households</td>
<td></td>
<td>1,338,957 Households in target area</td>
<td>3</td>
<td>1</td>
<td>4,010,870</td>
</tr>
<tr>
<td>Engagement of trainers</td>
<td></td>
<td>62 Trainers (1 per 20 agro-dealers)</td>
<td>10,000</td>
<td>1</td>
<td>615,000</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30,200,870</td>
</tr>
<tr>
<td><strong>4.6. Establishment of water harvesting practices</strong>&lt;br&gt;Target area under semi-arid climates (ha): &lt;br&gt;Small-scale tools/equipment</td>
<td>11,700,000</td>
<td>585,000 Units (for 1 ha)</td>
<td>100</td>
<td>1</td>
<td>58,500,000</td>
</tr>
<tr>
<td>Training extension agents</td>
<td></td>
<td>2,543 Agent (1 per 500HH)</td>
<td>250</td>
<td>1</td>
<td>635,870</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Training of households</td>
<td>1,271,739 Households in target area</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Engagement of trainers</td>
<td></td>
<td>127 Trainers (1 per 20 ext. agents)</td>
<td>10,000</td>
<td>1</td>
<td>1,271,739</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64,222,826</td>
</tr>
<tr>
<td><strong>4.7. Facilitation of soil and water conservation structures</strong>&lt;br&gt;Total area prone to soil erosion (ha): &lt;br&gt;Establishment of structures</td>
<td>7,600,000</td>
<td>760,000 Ha (10% of target area)</td>
<td>250</td>
<td>1</td>
<td>190,000,000</td>
</tr>
<tr>
<td>Training of households</td>
<td></td>
<td>330,435 Households in target area</td>
<td>3</td>
<td>1</td>
<td>991,304</td>
</tr>
<tr>
<td>Note: 10% of the total area targeted</td>
<td></td>
<td>Training extension agents</td>
<td>661 Agent (1 per 500HH)</td>
<td>250</td>
<td>1</td>
</tr>
<tr>
<td>Engagement of trainers</td>
<td></td>
<td>33 Trainers (1 per 20 ext. agents)</td>
<td>10,000</td>
<td>1</td>
<td>330,435</td>
</tr>
<tr>
<td><strong>Sub-total:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>191,486,957</td>
</tr>
<tr>
<td><strong>OVERALL TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>451,265,978</td>
</tr>
</tbody>
</table>
5.3. Cost-sharing measures and potential financial resources

The scale of investments required is substantial. The first necessary investors are African Governments. In Maputo, African Heads of State committed to investing 10% of their GDP in agricultural development. Having a considerable proportion of these funds invested in above actions will go a long way towards their implementation.

Secondly, various donor organizations are interested in above actions, including Bill & Melinda Gates Foundation (e.g., on-going investments in legumes and N fixation, in digital soil mapping), IFAD, USAID, DGIS, DGD, EU, amongst others. Alignment of their investments to an overall African Agricultural Transformation Agenda would certainly increase the efficiency and effectiveness of these often uncoordinated investments and avoid often substantial activity duplication.

Thirdly, part of the investment costs should be recovered through the implementers themselves. For instance, payments for land and soil information services should facilitate their continued functioning. For instance, extra production generated thanks to the improved utilization of rainfall or locally available resources should allow farmers to re-invest in those production factors.

Fourthly, where possible, private sector engagement would be the most durable way forward in terms of sustaining investments. Initial facilitation of private sector engagement may be required, e.g., through credit guarantee mechanisms, but ultimately, a profitable African agriculture will ensure a continued interest of private investments.

Lastly, while cost-sharing mechanisms may be critical during the initial phases of its implementation, the African Agricultural Transformation Agenda will only continue to deliver its benefits to smallholder farmers and national economies over the medium to long term if sustainability principles are embedded in every component of the prioritized actions.
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