BACKGROUND PAPER

Science, Technology and Innovation for Agricultural Transformation

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EXECUTIVE SUMMARY

In the last decade or so, many national, regional, Pan-African and international organizations have talked about the need for African economic transformation from the current state, and it seems a consensus is building toward agriculture as the driver for the desired transformation. African leadership accepts that science, technology and innovations for agricultural transformation are essential for any advancement. Indeed, the agricultural revolution (transformation) in Asia that happened about half a century ago, was driven by scientific research in agriculture, that produced high-yielding varieties of rice and wheat, conducive government policy favoring increased investment in agricultural input, especially fertilizer, irrigation, mechanization, information, farmer training, transport infrastructure, and improved grain storage to avoid post-harvest losses. This resulted in Asia moving from a food-deficit nation to a net exporter of rice and wheat to Africa.

Africa is currently spending over US$ 45 billion on food imports, mainly grain from all over the world, and it is common knowledge to everybody that these commodities can be locally produced. African Union, through New Partnership for Africa's Development (NEPAD) program, has made considerable effort to address the problem. Other organizations such as Alliance for Green Revolution in Africa (AGRA) have been on the same endeavor, and while some progress has been made, the overall impact remains relatively low. However, it is widely believed that Africa is the continent of the 21st century, with capacity to feed itself and to export to other countries, considering the natural resource base; available agricultural arable land, water from rivers, and young labor force; untapped oil and mineral deposits; current information and communications technology (ICT) and other related technological innovations in mobile telephony; proven biotechnology in tissue culture; and genetic transformation that are currently available for application in the transformation of agriculture. The challenges that prevent Africa from achieving agricultural transformation stem mainly from poor leadership that is unwilling to commit to good policies that promote investment in agricultural development and increased productivity at the national level. Low productivity also results from limited use of improved seeds, fertilizers, irrigation and mechanization, degradation of soils, post-harvest crop losses and wastage. Experiences and lessons learnt from developed countries such as European nations and USA, and developing countries such as South Africa, India, China, Brazil and Argentina, which have made remarkable progress in agricultural transformation, indicates that African leadership need not re-invent the wheel, but can consolidate current gains, and make quick wins towards agricultural transformation.

To do this, we need a meeting of minds where African leaders change their attitude and consider agriculture as a business, which only brings gains when investments are made - a message that is well articulated by the current President of Africa Development Bank Dr Akinwumi Adesina from his experience in Nigeria as Minister of Agriculture, where he led the agricultural transformation from the front, by investing in four major crops (rice, cassava, palm oil and sorghum) value chains, with remarkable results and impact. From the Nigerian and Kenyan experiences, investment ICT and mobile phone money transfer technology, are essential to

transfer subsidized money-stamps to farmers to enable them to access improved seed and fertilizer.

Africa Harvest's experience – working in sorghum and banana value chains in Kenya - suggests that investments need to be made along the whole value chain from:

- information and training,
- support to local private seed companies to supply good quality seeds,
- investment in farmer knowledge on good agronomic practices in order to increase productivity, post-harvest and storage skills to reduce wastage, and in some cases, adding value to create new products for household consumption, and for local, regional and international markets.

In this regard, the high-level conference being organized by the Africa Development Bank in Dakar, Senegal, focusing on strategic approach to apply scientific and technology solutions, which have worked elsewhere, for agricultural transformation in Africa is on target. African challenges in agriculture can be turned to great opportunities with proper investment strategies, yielding major gains considering the African market for goods and services, worth the US$ 45 billion serviced through food imports.

1. BACKGROUND

According to the latest United Nations (UN) projections, world population will rise to 9.5 billion in 2050. Nearly all of the population growth will occur in developing countries. Sub-Saharan Africa's population is expected to grow the fastest to reach 2.4 billion with over 40% (about 1 billion) being youth. FAO projects that food production must increase by 70% in order to address this growth in population, and the attendant increase in global demand for food. (Conforti, 2011).

Global malnutrition statistics indicate that about 795 million people are undernourished-, unable to get enough food for an active and healthy life. While Africa's growth trajectory has been positive over the past decade (2000-2010), earning it the acclaim of being the world's fastest-growing continent (WB Africa Pulse) - exports booming and foreign investment on the rise - agriculture still remains the mainstay of economic activities for most regions in the continent. African agriculture has a unique opportunity for growth as the continent has land, water and human resources to feed herself and contribute towards meeting the growing global demand for both food staples and higher value added food. Recent estimates suggest that Africa has the potential to increase the value of its annual agricultural output from about $280 billion (in the late 2000s) to around $800 billion by 2030 (McKinsey Global Institute, MGI 2010: 8).

In the last 30 years, agricultural growth has occurred against the backdrop of an unprecedented demographic shift in which Africa's population has doubled overall and tripled in some urban areas, and there are now more mouths to feed. Yet, cereal production has been unable to keep pace with population growth and has only increased by a factor of 1.8. Cereal yields in Africa have consistently been well below those of other regions in the world since the early 1960s (World Resource Institute). The gap is even wider for processed products and meat, which are increasingly required by the large urban populations. In short, Africa has regressed significantly from being food self-sufficient in the 1960s to becoming a net importer of cereals and other foodstuffs. Today, Africa imports products that compete with those produced in the continent, such as meat, dairy products, cereals, and oils. Overall, imports account for 1.7 times the value of exports. As a result, African agricultural exports have fallen by half since the mid-1990s. According to the World Bank, the continent remains a food-importing region, with just 5% of Africa's annual cereal requirements coming from within Africa.

Despite our dependence on imports, agricultural production in Africa has been increasing steadily. Its value has almost tripled, and is almost identical to that of South America although it is still below that of Asia. Africa is one of the few regions in the world with vast ranges of still unutilized land suitable for agricultural activity. It is estimated that more than 60% of the global available and unexploited cropland is located in Sub-Saharan Africa. Most important, its geographical location across the equator implies that there are adequate water resources to support larger agricultural yields, adding to the continent's growth potential. In the Democratic Republic of Congo, for example, less than 10% of 80 million hectares of suitable land is being cultivated; and in Sudan, only 16% of suitable available land has been cultivated, as of 2009. Considering that approximately 65% of the African working population is employed in the

agricultural industry, it has been found that GDP growth originating from the agricultural sector is two to four times more effective in raising the incomes of extremely poor people than growth in any other sector of the economy. Hence, fostering investment in agriculture is not only important but crucial for moving this continent forward.

The influence of science and technology in agriculture is growing. Agriculture – encompassing food, tree, and cash crops, livestock, pasture, fisheries and forestry – is the predominant source of employment and livelihood for the vast majority of Africa's poor who live and work in rural areas, as smallholder farmers. The International Food Policy Research Institute (IFPRI) has found that on average, agricultural growth reduces poverty roughly twice as much as growth in other sectors. It is estimated that the sector contributes about 32% to Africa's overall economic activity. For several countries, agriculture is also the single most important foreign exchange earner, making it more productive and efficient to guarantee food and nutritional security in the future. Unlocking the productive potential of agriculture would enable Africa's farmers to strengthen their contribution to growth and to share more equitably in the benefits. For this to happen and for the sector to play a stronger role in reducing poverty, triggering a uniquely African green revolution and a transformation in Agriculture is imperative. This agricultural transformation will require the concerted effort of all stakeholders: African leaders, researchers, development partners and actors in the private sector and NGOs. It is an accepted fact that investments in agriculture bring high returns both economically and socially, and that such investments should take full advantage of the catalytic power of science, technology and innovation (NEPAD Agency, 2013).

CAADP framework for Science, Technology and Innovation in African Agriculture

In 2003, African leaders launched the Comprehensive Africa Agriculture Development Programme (CAADP) as an important framework for revitalizing agriculture on the continent (AU, 2003). To date, CAADP has helped countries to refocus attention on agriculture. It has also encouraged and facilitated a refreshing and complete overhaul of national agricultural sector strategies, investment plans and programs (NEPAD Agency, 2012). The Framework for African Agricultural Productivity (FAAP), which is a reference document for implementing the CAADP tenet on agricultural science and technology (otherwise known as CAADP Pillar IV), challenges African governments to invest prudently in agricultural research and farm technology so as to increase productivity of staples, and enable farmers to also engage in the production of more remunerative, high-value products (FARA, 2006). Development of the science, technology and innovation agenda for agriculture in Africa is premised on the recognition of its importance in bringing about a productive and efficient food and agricultural sector for sustainable economic growth, wealth creation, food and nutrition security, as well as for political stability.

To give CAADP some traction, in 2006, African leaders committed to allocate 10 % of national GDP to research and development (AU-NEPAD, 2006). In June 2006, the African Union Special Summit of the Heads of State and Government adopted the Abuja Declaration on Fertilizer for the African Green Revolution, which, inter alia, committed the AU Member States

to increase fertilizer use to at least 50 kg of nutrients per hectare by 2015 (AU, 2006). It should be noted that to achieve the aims of CAADP and other intentions to accelerate the generation and application of new technologies and innovations for agricultural growth, Africa's scientific and technical information capacity needs to be strengthened through education and training to produce the requisite human and institutional capacity. Evidently, strengthening local research and regulatory capacity is also of utmost importance to enable African countries exploit the potentials provided by global advances in science and to adapt technologies to their own conditions (FARA, 2014). Bold and informed decisions, investments and an all-inclusive approach is therefore needed to catalyze sustainable agricultural productivity growth, resilience in rural economies and socio-economic transformation leveraging on the tools of innovation, science and technology. In addition, investing in and empowering the human resource component, especially the youthful demographic that is expected to be 1 billion in 2050, is critical to the success of this transformation agenda.

When developing a new science, technology and innovation strategy for agricultural transformation in Africa, it is imperative to consider the achievements of the African and international scientists who have developed and used scientific innovations to impact African agriculture. The application of tissue culture in banana promoted by Africa Harvest has impacted thousands of households in East Africa. The regional biosciences platforms

Biosciences eastern and central Africa (BecA) Hub, which is a center of excellence for science and technology in Africa for AU-NEPAD has innovations emerging from its research that include disease-resistant banana and new diagnostics and vaccines for livestock diseases that have potential for major impact. A successful example of developing new crop varieties that meet market demand is the development of NERICA rice, well adapted to African conditions by the Africa Rice Center, Cote d'Ivôire.
Genetically Modified (GM) crops also offer an alternative technological approach in situations where non-GM alternatives are not feasible; for example, insect-resistant cotton and insect-resistant maize, which are cultivated commercially in Burkina Faso (cotton) and South Africa (cotton and maize). The Institute of Agricultural Research (IAR) Nigeria, and Kenya Agricultural and Livestock Research Organization (KALRO) have field trials of Africa Biofortified Sorghum (ABS), which has enhanced Vitamin A, zinc and micro nutrients. KALRO also has confined field trials on Water Efficient Maize for Africa (WEMA) that are drought-tolerant varieties and insect-resistant maize, all with potential to significantly transform African agricultural productivity. Other tools of biotechnology, such as genotyping and marker-assisted selection, accelerate plant breeding, and enable new crop varieties with desirable traits to be bred more quickly; for example, halving the time taken to develop new cereal varieties. Wider application of these new breeding strategies, when combined with more customer-focused design of new crop varieties, will lead to increased crop productivity, for both food security and income generation.

Certain situations will require solutions that require integrated application of several technologies. For example, the Index-Based Livestock Insurance (IBLI) scheme developed by the International Livestock Research Institute (ILRI), and its partners in Kenya, is based on

using satellite imagery to estimate green ground cover (and thus feed availability) as an index of drought and a basis for insurance cover. This involves the interaction of banks, insurance companies and mobile phone companies to underwrite the risk to the farmers. ICT-based agricultural marketing systems in Kenya such as M-Farm, empowering farmers by providing up-to-date market prices via an app or SMS is a success story that promptly provides market information and delivery arrangements. M-PESA is a leading mobile phone-based financial transaction scheme that has benefited millions in Kenya by providing prompt money transfer and payment system even in remote locations. M-Shwari provides phone-based savings and micro loans without any physical interaction with the bank staff, further improving financial inclusion. All these are innovations that can be replicated and scaled up for major impact at the continental level.

2. THE CHALLENGES

The challenges facing Africa in its quest for an agricultural transformation can be summed up as: low productivity; climate change; heavily degraded and depleted soils; problematic land tenure systems; poor access to input and output markets; inadequate levels of mechanization; pests, diseases and weeds; and limited coherent and conducive policies for application of science, technology and innovation in agriculture (FARA, 2014). Land, energy, water, and weather constraints place unprecedented pressure on Africa's ability to access food that is produced sustainably. In order to succeed, Africa will require well informed and targeted investments in agriculture and a leadership that leverages on the tools of innovation, science and technology to develop and scale-up adoption of workable solutions.

2.1 Low productivity

The growth of agricultural productivity in Africa continues to lag behind every other region of the world, growing at rates that are roughly half of the average rate of developing countries (Nin-Pratt, 2015). Low productivity across all farming systems is, therefore, arguably the single most important bottleneck for agriculture in Africa.
The main drivers of this are:

- over reliance on rain-fed agriculture despite the reducing amounts and frequencies of rains as a result of climate change;
- cultivation of small land sizes result in diseconomies of scale;
- limited mechanization and application of existing yield-increasing technologies or research on new ones;
- expansion of land areas to increase production as opposed to intensification of production through use of fertilizer, improved varieties and hybrids and improvement of input use efficiencies;
- low investments in land improvement; (in much of the region, there is long-term deterioration in soil fertility);
- armed conflict and civil unrest;
- high rates of untreated HIV/AIDS infection (Fuglie & Rada, 2013).

Others factors include a lack of coherent and conducive policies, poor incentives, and poor access to input and output markets. In addition, Africa has insufficient investment in agricultural production value chain development (FAO, 2009) and support services, which calls for substantial investment in public goods that support agriculture -- research and extension, irrigation and power supply, rural roads, storage facilities, education and health care.

The impact of climate change will further exacerbate the stresses on crops, potentially causing major yield reductions. Maintaining and enhancing the diversity of crop genetic resources is vital to facilitate crop breeding and thereby enhance the resilience of food crop production.

Enhancing productivity in agricultural systems calls for an increase in investment in Africa-specific agricultural research and development (compatible with African conditions), to facilitate farmers' access to technologies, markets, and the necessary support services for raising agricultural productivity (Nin-Pratt, 2015). Investments in seed systems, access to and affordability of fertilizers, irrigation and mechanization should be prioritized in tandem with the development of the human resource base, especially women and youth, which will drive the agenda.

a) Post-harvest losses

Post-harvest losses in Africa range from 20 to 60%, across various countries and for various commodities. Food is lost or wasted throughout the supply chain, from initial agricultural production, storage and right through to household consumption (food wastage). The causes of food losses and waste in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems (FAO, 2011). The net impact of this is manifested in food deficits at the household as well as at the national level, thereby increasing the cost of food on account of limited supply. A major obstacle in the efforts to achieve post-harvest losses mitigation in Africa is the lack of clear knowledge of the real magnitudes of losses, which makes it impossible to measure progress against any loss reduction targets (Affognon & Mutungi, 2012).

Such losses could be reduced through more efficient post-harvest processing, handling and storage systems. Innovations are needed to address this bottleneck by developing affordable and easily accessible equipment and machinery closer to where production occurs. Increasing the knowledge base and skills that farmers, especially smallholders, require to minimize these losses, is also critical to the process.

b**)** Degradation of soils and depletion of natural resources

Degradation and depletion of soils as well as degradation of natural resources is a major challenge facing Africa. Healthy soil and efficient use of environmental resources are important in order to eliminate extreme poverty and to promote sustainable development and prosperity in Africa. . Rapid population growth and expanding economies have placed greater demands on land, water, forests, minerals, and energy resources. The rate of deforestation in sub-Saharan Africa has been alarming due to expansion of arable land to feed the increasing population. This has resulted in loss of nutrient-rich top layer soil, loss of biodiversity and general environmental degradation. The loss of forests threatens the livelihood of poor people, destroys the habitat that

harbors biodiversity, and eliminates an important carbon sink that helps moderate impact of the climate. Conservation efforts focus on proper regulation and management of human activities that affect the natural environment to minimize degradation, including but not limited to deforestation, loss of habitat, and loss of biodiversity, pollution and soil erosion. Protecting forests and other terrestrial and marine areas helps protect plant and animal habitats, and preserve the diversity of species. Africa needs refocus from use of wood fuel-based energy to more environmental friendly renewable energy sources such as the sun and the wind. In addition, agricultural transformation efforts should take cognizance of their effects on the natural resource base and incorporate measures to mitigate any negative effects for posterity.

c) Access to finance

Challenging legal and financial environments are constraining the growth of African agriculture. For smallholders, especially, credit is often inaccessible or unaffordable. Without appropriate financing, farmers are not only less able to invest in their operations, but also much more vulnerable to market volatility and unpredictable weather. Appropriate and inclusive financing options and products targeting smallholder producers should be part of the tools for agricultural transformation, if resilience and sustainability are to be enhanced over a long term.

d) Dysfunctional or non-existent markets

Farmers generally can earn higher prices outside of harvest season – yet few African smallholders have access to proper storage to take advantage of price fluctuations. Further, many smallholders live in isolated, rural areas. Infrastructure such as paved roads, reliable energy, warehouses and cold storage not only benefits farmer livelihoods but also improves food security by reducing post-harvest loss. According to FAO, 40% of the population in Sub-Saharan Africa lives in landlocked countries, vis-à-vis only 7.5% in other developing countries. That means, farmers in this region require greater access to primary cross-border markets – access that is made slow and costly by poor roads, long delays at borders and other issues. In many countries, agricultural production is moving from subsistence systems to more market-led systems. Increased agricultural productivity, combined with viable agribusiness that adds value to farmers' production and improved access to markets, can drive broader economic growth across the continent, and vastly improve food security. The market access dimension is of key importance to the Science Agenda, as it determines the degree to which farmers are exposed to and incentivized by the 'pull' of agricultural markets, and domestic or international demand for their products, thus influencing considerably, the extent to which innovations occur and are nurtured. Developing and promoting inclusive business models through which smallholders can have better access to end-user markets is one other option that is worth the investment to scale up tested alternatives, like the aggregator model.

Tools of science and innovation, e.g., mobile telephony, can be leveraged upon to address market information asymmetry that limits access and participation, in lucrative end-user markets, by rural-based smallholder farmers/producers.

e) Limited coherent and conducive policies

Policy challenges facing individual countries must be confronted to create new opportunities for growth. Africa desperately needs policies that will foster development and application of science and scientific innovations in drought-resistant seeds; in higher-yielding varieties; and the use of water, fertilizer, machinery, pesticide and GM crops, which helped transform

agriculture in other regions. Governments have to create an enabling environment for science to deliver, which means investing in the infrastructure, developing markets, and creating regional trade opportunities needed to increase the social and economic returns to investment in agriculture.

A favorable policy environment for the performance of science will require clear legislation and regulations. This includes biosafety and other regulatory systems, seed regulation and control, enforcement of plant breeders' rights/UPOV (International Union for the Protection of New Varieties of Plants) and a country-specific approach to intellectual property rights. The agenda also embraces policy research because of the importance of appropriate policies in resolving technical problems and in increasing incentives for solutions.

f) Climate change

Closely linked to low productivity is the challenge of climate change. The continued rise in greenhouse gas emissions leaves billions of people vulnerable to the impacts of climate change. Rising temperatures, changes in precipitation patterns, rising sea levels, and more frequent weather-related disasters pose risks for agriculture, food, and water supplies. Although Africa contributes the least to greenhouse gas emissions, it is expected to be among the most negatively affected by climate change. Global warming contributes to environmental degradation, e.g., through droughts and floods, which will have an impact on the availability and quality of arable land, thereby increasing relative demand as supply decreases. The impact of climate change on yields of maize may be most pronounced in southern Africa, where losses of 18% to more than 30% have been predicted by mid-century. Across Africa, reductions in yield have been estimated at approximately 15% for sorghum and 10 percent for millet by 2050. In the Sahel, millet yields could fall by 20 percent with a warming of 2°C. Many of the crops at risk, such as maize, sorghum and millet play a vital role in the cropping systems of Africa's farmers, and in regional food and nutrition security. In the absence of alternatives, production losses will reduce incomes and affect food and nutrition security.

Climate change challenges increase agronomic complexity and risks of shocks at the farm and community levels and imply additional changes in crops, cropping, timing, agronomic practices, and seed needs. In terms of adaptation in Africa, what is required is strengthening of capacities of African agriculture and food systems to adapt to climate change, via improved technology generation and adoption systems, more and better irrigation and drainage, better markets, and greater ability to import foods in bad years or on a year-round basis, greater preparedness for extreme weather events, and better safety nets.

However, all these improvements are also most urgently needed even if there was no climate change to deal with. Climate change, therefore, does not require a separate agenda for agricultural and rural development; it only reinforces the existing agenda with adaptation to climate change as the main thrust in this agenda. The effects of climate change are complex and will require a multidimensional approach involving adaptation, increased resilience and the development of "climate-smart" agriculture. Africa's farmers have demonstrated their ability to adapt. They have adopted land and water management practices aimed at reducing soil erosion, capturing more rainfall, increasing soil organic matter and replenishing nutrients. Their efforts provide valuable lessons in the types of strategies needed to restore the productivity of cropland and produce enough food for a growing population facing climate change.

The extreme vulnerability to climate change means that adaptation should receive higher priority in funding decisions. One tool that has considerable power to help people cope with climate shocks is insurance, which is an investment in risk management. Index-based insurance allows individual farmers to protect themselves against production risks through mechanisms that pay out in the event of an observable trigger event, such as reduced rainfall. Because the event can be independently monitored and verified, it reduces the cost of assessing claims and cannot be influenced by the actions of individual farmers. Several projects have demonstrated the considerable potential of index-based insurance, including the Index-Based Livestock Insurance program for Kenyan pastoralists and *Kilimo Salama* ('safe agriculture') in Kenya and Rwanda. This suggests a potential for scale-up, but that potential should not be exaggerated as few of these projects operate on a non-subsidized basis. Many countries and rural areas lack the necessary weather-station infrastructure and therefore, the involvement of governments and other development agencies in this mix cannot be over-emphasized.

3. OPPORTUNITIES

3.1 Availability of novel technologies with potential for up-scaling

For Africa, the question of whether a technology is new or not is a contentious one. While biotechnology and genetic engineering, agricultural drones, farm robotics and nanotechnology may be considered new, compared to conventional plant breeding, the latter may be considered new by many farmers who have no access to new planting materials, such as tissue culture banana plantlets. There are also technologies "sitting on the lab shelves" or those that have been deployed with varying success. Against this complex backdrop, Africa has had mixed success in the implementation of new technologies. Companies and governments have been trying to get smallholder farmers to improve yields and adopt new technological solutions, but change requires time and effort. The Africa Report (2015) narrates how the Cameroon government has been promoting a campaign dubbed 'second-generation' (2G) agriculture, aimed at encouraging farmers to abandon rudimentary methods and embrace mechanization, new irrigation techniques and subsidized fertilizers and pesticides.

Elsewhere, the Forum for Agricultural Research in Africa (FARA) has been implementing DONATA (Dissemination of New Agricultural Technologies in Africa). DONATA's goal has been to catalyze widespread adoption and use of new and proven technologies. This is to enhance agricultural productivity and growth for increased food security and poverty reduction on the African continent.

Evaluating agricultural value chains may point to appropriate technologies to address identified constraints, but even then, economics and social cultural considerations could affect technology adoption.

DONATA's experience is that "it is necessary to identify promising dissemination pathways that will fit the prevailing social, environmental, and market conditions to enable profitable investments."

Africa Harvest's experience in technology dissemination

Africa Harvest has been very successful in technology dissemination of clean tissue culture banana plantlets in East Africa, reaching over 500,000 farmers in its first 10 years of existence. The organization seeks to replicate and scale up its success in at least 10 African countries in the next decade, as part of its strategic plan. This success is rooted in the delivery and institutional mechanisms through which it learns by doing and pilots its approaches. It has excelled in the understanding of the banana value chain and strategically created core competencies in what it calls "the last mile" or the provision of clean planting material as well as capacity building and training of farmers in the agronomy of these plantlets. Within the banana value chain, Africa Harvest's approach has been to partner with other stakeholders along the value chain players, to ensure that challenges affecting farmers are dealt with comprehensively. These stakeholders include commercially oriented rural men and women, youth and farmers' organizations, private sector, community-based, and other public sector delivery or enabling institutions. Experience from TC banana technology transfer confirms that detailed implementation design studies are required. Inclusive private sector development approaches and instruments are also necessary. In the initial phase, the critical outcomes of technology adoption need to be measured through clear indicators that will inform the expansion phase. Other lessons learned include the need for infrastructure development; in the case of TC banana, this included laboratories, nurseries and fruit collection centers. Alongside the infrastructure, value chain development is critical, especially where there are no formal markets. It is also important to monitor the increase in farmer incomes and establish the sustainability of different role players, such as rural entrepreneurs engaged in different places of the value chain.

3.2 Large market potential

According to UNICEF, Africa has the greatest number of countries with a high proportion of undernourished people (25 percent and above). Africa is home to 216 million people who are undernourished – that is, about 30 per cent of the population. Though the proportion of undernourished has decreased from the 1990-92 level of 34 percent, the numbers have increased by 43 million. This means that progress in reducing hunger is not keeping pace with population growth. In 16 countries, more than 35 percent of the population is undernourished. Africa's nutrition challenge can only be solved if the full potential of agriculture development to improve human welfare is recognized and channeled properly.

FAO reckons that "this will require that the multiple roles of agriculture being recognized, and that the diverse opportunities to deal with the many social and economic issues affecting the well-being of the poor are exploited as best possible."

Just as awareness is increasing of the very significant link between food and nutritional security, the challenge of climate change on both these issues has become a great concern. However, "there is no broadly accepted and comprehensive analytical framework for the analysis of the impacts of climate change on food and nutrition security (SUNRAY 2012)"

Nevertheless, there is consensus that agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability. Several countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change is likely to reduce the length of the

growing season as well as force large regions of marginal agriculture out of production. Yield reductions in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected. This would adversely affect food security in the continent.

Africa Harvest's experience in arid and semi-arid lands

Africa Harvest has implemented several projects in Arid and Semi-Arid Lands (ASALs) in Kenya since 2010. One of the projects is designed to develop commercially sustainable Sorghum for Multiple Uses (SMU) in Kenya and Tanzania, and is funded by the European Union (EU) in partnership with The International Fund for Agricultural Development (IFAD). Implementation is overseen by ICRISAT, with Africa Harvest playing the role of a development partner on farmer outreach and market access for surplus produce.

Some of the key lessons from this project relate to ensuring farmer participation in project design and especially selection of the preferred sorghum varieties and hybrids. Farmers have improved the sorghum crop agronomic practices, thanks to the project's training and capacity building. Sorghum small holder farmers involved in SMU project have increased their yields from 400 kg per acre to 1,000 kg per acre without additional inputs like fertilizer. With the release of the hybrids in the pipeline and increased use of fertilizer, supported by good agronomic practices, yields are projected to increase three fold.

The project seeks to resolve challenges that lie in the intersection of climate change and rural poverty. The EU/IFAD funded project has helped farmers access improved sorghum varieties that are drought tolerant thus developing resilience to the droughts and food crises that regularly affect millions of people in Africa. The SMU Project targets communities that live in ASALs of Eastern Province of Kenya. About 5 million people live here, and it represent a major ecological zone in sub-Saharan Africa). The ASALs

3.3 Leverage the wealth of natural resources to modernize agriculture and stimulate growth

According to the World Bank (World Bank, 2008), agricultural growth is the precursor to sustainable economic development as was the case for most developed countries. More recently, rapid agricultural growth in China, India, and Vietnam led to industrialization and sustainable economic growth. What is required is a comprehensive policy approach to stimulate agricultural growth that includes four key elements: improving producer incentives, providing core public goods and a better climate for private investment, building effective institutions, and ensuring sustainable use of natural resources.

Mbabazi et. al 2015 argue that reliance on subsistence production and weak productivity growth in the agriculture sector prevents the workforce from moving out of this sector into manufacturing and services. They propose four interventions:
1) develop innovative, commercially sustainable agricultural business models;
2) make markets competitive;
3) elevate the pace and quality of multi-stakeholder collaboration, and
4) commercialize smallholder production and make agricultural SMEs more resilient.
The argument is that smallholder farmers represent 80% of all farms in Sub-Saharan Africa and contribute up to 90% of food production in some countries. Within loosely structured value chains, the risks and unit costs are often too high for smallholders to viably access markets, inputs and services.

The Grow Africa Secretariat calls for the establishment of professional management for the hub business rather than expecting smallholders to collectively manage rapidly growing commercial operations; forming smallholders into "joint liability groups" with which to establish credit agreements or off-taker contracts; investing in smallholder capabilities to improve productivity and engaging stakeholders to overcome off-farm constraints to smallholder viability, such as last mile infrastructure or policy changes.

> *Africa Harvest's experience in provision of tissue culture banana plantlets to smallholder farmers in East Africa is that the private sector is an integral part of sustainably fighting poverty, hunger and malnutrition. Africa's agricultural transformation must start with the seed and seed systems using both public as well as private systems.*

Technology advancement has placed Africa in a unique position to massively and rapidly revolutionize the breeding process. Even "lost genetic variation" can be selectively reintroduced into modern breeding pools. Unlocking the full potential of these technologies requires a fundamental shift in the way genomic information is applied to the design and execution of breeding. A combination of mathematicians, optimization specialists, statisticians, computer scientists, software engineers, and breeders/geneticists has resulted in a suite of algorithms and techniques to optimize efficiency and maximize returns across the entire breeding process.
Africa can, for example, tap into the research and development techniques, able to safeguard future African species through plant breeding methods that will lead to improved and sustainable varieties of tomorrow. Modern propagation techniques based on tissue culture, such as somatic embryogenesis, can be customized according to the crop, the country and the volume of the demand. Africa has the opportunity to tap into a comprehensive suite of tools by which genetic diversity can be evaluated in a thorough and unbiased manner (using DNA sequence data) over a large array of genetic material relevant to each agricultural species. These tools allow breeders to assess the overall level of natural genetic diversity in their own breeding programs, relative to their competitors as well as genetic diversity that might be accessible elsewhere, including gene banks.

3.4 Leveraging the use of ICT

The rapid uptake of ICTs -- mobile telephony, radio, geographic information systems (GIS), and satellite imagery technologies -- in Africa, provides an important opportunity to improve the performance of agricultural value chains (AVCs) from the farm to the market.

At the pre-cultivation stage, ICTs have several uses, ranging from land and crop selection to the development of crop insurance products; they can also enhance land and water management and use. Egypt, for example has developed a soil and terrain database for the Sinai Peninsula and other regions. Satellite imagery data and GIS have also been used in Ethiopia and Mozambique to enable land registration and crop inventories. India has many applications using GIS technology to support sustainable agricultural development. One of those applications is a cropping system analysis that identifies low-productivity areas.

ICTs can generate valuable information on land preparation and sowing, crop health, input management—particularly the choice and use of fertilizer—and pest and water management. ICTs can also be used to get information to farmers, particularly smallholder farmers who would otherwise be out of reach. They can provide market information that is crucial to improving market efficiency. A lack of sufficient information — including information on prices and market conditions — along with price information asymmetries makes it difficult for farmers to get fair prices for their crops.

3.5 A growing youthful human capital base

The 2015 African Green Revolution Forum (AGRF) meeting in Lusaka, Zambia, concluded with a firm call to action and clear sense of the concrete solutions that can "walk the talk" of putting women and youth at the forefront African agribusiness. A communiqué delivered at the end of the meeting noted that women are "the backbone of African agriculture" and warned that "Africa's very survival depends on attracting young people to the agriculture sector."

Youth under 25 now account for 65% of the African population, but both women and youth face significant barriers obtaining the finance, inputs, land and machinery required to take advantage of the business opportunities in Africa's fast-growing domestic food market. This indicates that for most African countries, agriculture remains the largest employer of any sector in the economy. Agriculture employs about 65% of the total work labour force in SSA. Though there has been a decline in the relative number of agriculture workers, it still accounts for a majority of the working population in the region.

The report laments that fact that youth are leaving agriculture in most African countries. This is because of a lack of role models in agriculture, and a large number of role models in white-collar professions. Other factors that make agriculture unattractive to youth include the high risk and uncertainties associated with African agricultural practices and the drudgery that comes with traditional farming methods..

The question is whether trying to attract and/or retain youth in agriculture is the right policy avenue. The answer to this depends on the peculiarity of each country. However, unless the profitability of agriculture can be demonstrated and its attractiveness made obvious, African youth are not likely to take up agriculture in the near future.

In one of its projects, Africa Harvest helped the formation of the Gitero self-help youth group in Nyeri (Africa Harvest Annual Report, 2014, p20). Experience underscores the need to create groups where like-minded individuals can interact with one another. Young people also show a propensity to the business of farming, more than the actual manual labor on the farm. Although there is an interest in modern agronomic practices, Africa Harvest showed that youth gravitate more towards entrepreneurship and agribusiness associated with science, technology and innovation. This is vital to our economic and social progress and high levels of investment in research and innovation are essential, both for economic competitiveness, and to yield innovations in agricultural transformation in Africa.

History shows that investments in agriculture can be a catalytic force in the fight against hunger, poverty and malnutrition, and a well-performing farm economy can be an instrument to achieve sustained structural economic transformation. Agricultural growth was the precursor to industrial growth in Europe and, more recently, in large parts of Asia and Latin America, through the Green Revolution, which bypassed Africa. In every industry, science, technology and innovation is needed to drive advancements, improvements and growth – and agriculture is certainly no exception. The following actions are suggested to transform agriculture in Africa.

4. SUGGESTED ACTIONS: THE WAY FORWARD

4.1 Application of Tissue Culture technology for vegetatively propagated crops: A case study of TC banana in East Africa by Africa Harvest

Africa is the only continent in the world where the total number of hungry people has gone up since 1990. The challenge of transforming the vision of a food secure Africa into reality is daunting one.

For hundreds of years, farmers in Africa who rely on bananas, sweet potatoes and cassava as food security crops used conventional seed systems such as suckers, cuttings and vines respectively to propagate new orchards and fields. However, these methods are wrought with many challenges such as being carriers of pests and diseases, degeneration over time and resulting in low yields. Moreover, conventional material is not always available in sufficient quantities when farmers need it. Africa Harvest believes the game changer will be provision of seeds and clean planting materials to farmers. Tissue Culture (TC) technology is one of the promising technologies and is used to multiply crops that are vegetatively propagated.

TC technology is a micro propagating technique that allows multiplication of growing of points of healthy vegetative material in sterile conditions. Initial work started about 100 years ago but it is only in the last 30 years or so that its use has gained prominence, especially in Africa. South Africa is one of the Sub-Saharan countries that has successfully integrated TC technology into its seed systems. However, many developing countries such as Kenya, Ethiopia, Uganda and Tanzania have not fully integrated this technology into their seed systems. In Kenya, TC technology was introduced in the 1990s in response to declining yields caused by fusarium wilt infection, black and yellow sigatoka, weevils and nematode complexes. The small-scale farmer practice of using untreated suckers aggravated the problem further. The farmers were achieving yields of 15 to 30 kg per bunch of banana and their orchards were degenerating.

Africa Harvest has been working on the promotion of TC technology in Kenya for the last 12 years. The collaborative work has mainly been in the eastern, central and south western areas of the country. Close to 80% of the farmers in this region are small-scale farmers who cultivate banana both for domestic use and for commercial purposes. Using the whole value chain approach, the focus of Africa Harvest is to remove barriers and bottlenecks, improve and increase productivity, enhance farmers' access to products and services and eventually link

them to the markets. In improving seed systems, Africa Harvest has been working with the private sector to ensure access to TC technology to communities at an affordable price. The cost of TC bananas has been identified as the greatest bottleneck in increasing the uptake among farmers. The costs of seedlings alone takes up 50% of the initial orchard establishment. Capacity building in establishment and management of banana orchards is done by Africa Harvest's technical field staff in collaboration with the extension officers from the Ministry of Agriculture. Finally, Africa Harvest supports the market activities of the farmers and helps them work on aggregating the produce and linking them to banana traders for marketing. Africa Harvest has focused on unlocking more returns to banana farmers by tackling the inefficiencies inherent in the supply and distribution system of TC banana technology. Starting with 1,691 small-scale farmers in three small villages in Central Kenya, 83,000 TC seedlings have been planted., With Africa Harvest's work with collaborators such as KALRO and others, close to 200,000 small-holder farmers have directly planted more than 6 M plantlets. In terms of production, banana is now the number one fruit produced in Kenya. In 2012, a total of 1,394,412 MT was produced by small-holder farmers netting them a value of 23.4B KES or 241,680 USD.

The above case study of TC technology adoption in Kenya proves that this can be one the technologies that can help Africa achieve agricultural transformation. However, from Africa Harvest's experience, its dissemination must be offered as a package. The private sector is crucial to the delivery of quality and quantity TC material. Public and private laboratories must be strengthened in both infrastructure and in the development of technical skills of their personnel. A study carried out by Africa Harvest with the support of Bill and Melinda Gates Foundation on the capacities of TC laboratories to produce high quality, pre-basic and basic planting materials for banana, sweet potato and cassava in East Africa showed that most of the TC labs visited can only be described as "start-up businesses" that operate under conditions of extreme uncertainty with respect to access to technologies, supplies, labor, financing, distribution channels, market information and demands. The extension services to the farmers must be robust, for without technical knowhow, productivity per unit area will slide again, no matter how good the seed is. Market linkages are paramount, in order to drive the development of the value chain. Farmers must start looking at agriculture as a business and give it the required attention.

4.1 Use Genetic Modification (GM) Technology for Agricultural Transformation

In 2007, in response to a request by African heads of state and government, Prof. Calestous Juma and Dr. Ismail Serageldin authored the report *Freedom to Innovate: Biotechnology in Africa's Development* [Juma, C. and Serageldin, I. (lead authors). 2007. Freedom to Innovate: Biotechnology in Africa's Development: Report of the High-Level African Panel on Modern Biotechnology. African Union (AU) and New Partnership for Africa's Development (NEPAD). Addis Ababa and Pretoria.]. In summary, the report stated that "In the context of the African Union (AU), African leaders resolved to take a common approach to address issues pertaining

to modern biotechnology and biosafety by calling for an African common position on biotechnology."

The report recommended that African heads of state and government place urgency on the strategic role that technological innovation plays in economic transformation, by stepping forward "with courage and firmness so that their footprints can guide future generations."

Globally, biotech crops are considered as the fastest adopted crop technology in the history of modern agriculture. According to ISAAA (International Service for the Acquisition of Agri-Biotech Applications), in 2014, the global area of biotech crops continued to increase for the 19th year at a sustained growth rate of 3 to 4% or 6.3 million hectares (~16 million acres), reaching 181.5 million hectares (~448 million acres). Biotech crops have set a precedent in that the biotech area has grown impressively every single year for the past 19 years, with a remarkable 100-fold increase since the commercialization began in 1996.

In 2012, developing countries – including China, India, Brazil, Argentina, and South Africa – grew about 52% of global biotech crops, compared with 48% accounted for by the industrialized countries [James C. 2012. Global status of commercialized biotech/GM crops: ISAAA Brief No. 44. ISAAA, Ithaca, New York, USA]. Of the 90% of total farmers (17.3 million), 15 million were smallholder farmers in India and China.

In Africa, like elsewhere in the world, despite various challenges, farmers have continued to adopt these GM technologies. They would not do this if there were no clear benefits. However, only four African countries – South Africa, Burkina Faso, Sudan, and Egypt – have commercialized GM crops (out of 29 countries globally). Altogether, these four countries plant about 2.9% million hectares, a very small part of the average for global or developing countries. However, this represented a 26% increase in 2012, compared with the increase in the previous year.

In Africa, nowhere is the contrast of GM benefits' clearer than in West Africa. Burkina Faso – the largest cotton producer in Africa – has seen yields increase by about 20% (due to Bt cotton adoption). The net gains per hectare of Bt cotton have increased by US$ 95.35, compared with the figure for conventional cotton. In neighbouring Ghana, since the evolution of cotton production in 1968, the trend in volumes produced has rather been erratic and production has never reached 40,000 tonnes. Burkina Faso's cotton production is 10-fold greater than that of Ghana. Year-on-year, production jumped 57.5% to 532,000 tonnes in 2013. In contrast, in Nigeria, cotton's contribution to the GDP fell from 25% in 1980, to 5% by 2015. Although there are many factors that beset the cotton sectors in Ghana and Nigeria, there is no doubt that adoption of Bt cotton would turn things around.

Across the continent, there is emerging consensus that GM technologies can and should play a bigger role in agricultural and economic transformation. Calestous Juma argues that GM technologies can be the trigger to agricultural innovation: "Biotechnology is only a starting point. The introduction of Bt cotton, for example, requires system-wide investments along the entire cotton value chain. This means that the adoption of biotechnology can serve as a trigger for investments in R&D, rural infrastructure, technical training and entrepreneurship." [*Leap-frogging in African Agriculture: The case of GM crops*

[http://www.brookings.edu/~/media/Research/Files/Reports/2014/foresight-africa-2014/06-foresight-african-agriculture-juma-gordon.pdf?la=en].

Juma also argues that "too often, the biotechnology decisions made in African countries are politically motivated and do not reflect the balance of scientific evidence. Creating offices of science and technology advisors to presidents or prime ministers would allow African leaders to act strategically and analytically, adopting agricultural biotechnologies when and where it makes sense to do so."

Florence Wambugu has a similar argument: "the problems in Africa can in a nutshell be traced to the politicizing of biosafety law about regulating biotech crops." [Florence M. Wambugu. 2014. *The importance of political will in contributions of agricultural biotechnology towards economic growth, food and nutrition security in Africa*. In: Biotechnology in Africa: Emergence, Initiatives and Future (Wambugu, F., and Kamanga, D., eds.)]. Both Juma and Wambugu see that the private sector is integral to GM as a trigger to agricultural transformation. Wambugu argues that "the private sector's ability to commercialize biotech crops and products" despite stiff anti-GM opposition, and its willingness to donate its technologies, makes this sector an important ally.

Former president of the Alliance for a Green Revolution in Africa (AGRA), Jane Karuku in an article titled "*Africa shouldn't take GM crops lightly, but neither can it ignore their potential*" [<http://www.theguardian.com/global-development/poverty-matters/2013/sep/17/food-security-gm>], argued that "Africa – a continent where one in four people still go hungry, and where annual food imports exceed $20 bn – must carefully examine the potential of all new technologies to boost food production."

Transforming African agriculture through the use of the GM technologies requires several huddles to be overcome, among them "limited or lack of in-house regulatory expertise to work in a highly regulated environment." [*Biotechnology in Africa: Emergence, Initiatives and Future*. (Wambugu, F., and Kamanga, D., eds.)]. Wambugu and Kamanga argue that many public-good projects on the African continent are naively optimistic, unaware that biosafety regulations can ensure their products never see light of day.

The issue of biosafety regulations is so critical that the Network of African Science Academies (NASAC), under the auspices of the African Academy of Sciences (AAS) and the Inter Academy Panel (IAP), found it necessary to make the "voice of science" to be heard by policy and decision makers within Africa and worldwide. The group – with the support of the African Union (AU) – released a report, *Harnessing Modern Agricultural Biotechnology for Africa's Economic Development: Recommendations to Policymakers*, which called for African governments to, among other things, "undertake comprehensive reviews of their biotechnology policy and regulatory frameworks to emphasize the benefits of the technology and base their decision making on scientific evidence."

The group also asked African governments to play a more proactive and facilitative role in regional initiatives designed to harmonize biotechnology policies and biosafety regulations and thus create an enabling environment for a flourishing biotechnology enterprise in Africa driven by the specific needs of the continent.

4.2 Market Access; Use of the Aggregation Model and Market Information System to Increase Market Access

a) The Aggregator Model – Kenya

Smallholder farmers in Sub-Sahara Africa are estimated to number about 33 million. One of their greatest challenges in farming is the limited access to markets, which is brought about by the remoteness of their farms, low productivity, low farm gate prices, and lack of information. If the markets accessed by these farmers are developed, there would be a tremendous reduction of hunger and poverty in these countries. However, what remains a challenge for many of the smallholder farmers is the low output of their farms, sometimes compounded by low-quality produce. One model that has brought much benefit to the smallholders is the aggregation or bulking of produce for the purpose of marketing. Aggregation allows smallholder farmers to access markets that would otherwise remain inaccessible to them.

In Kenya, Africa Harvest has been working with sorghum farmers in the semi-arid eastern part of the country. Six years ago, the farmers were producing 450 kg/ha of sorghum grain using local varieties, and more often than not, had only the local disorganized markets to sell the surplus, if any. Africa Harvest partnered with a major company, East African Breweries Ltd (EABL), who had just started using sorghum in the manufacture of affordable beer. The groups mobilized were given new varieties of sorghum, given extension services by Africa Harvest field staff together with local extension staff. They were eventually linked to the aggregators that had contractors with EABL for marketing. Currently, the 2,500 plus farmers growing sorghum in the region are able to achieve a yield of 1 tonne/ha and are assured of a market for their grain, which they do through aggregators.

The aggregators have become a one-stop shop, providing the farmers with certified seeds; they have invested in threshers with a capacity to process 25 bags (of 90 kg each) per hour, compared to the 3 bags per man-day that the farmers were doing before. The aggregators are also providing other inputs as the farmers require, while some of them have even ventured into the value addition of sorghum. This shows that market-driven development of a value chain is bound to increase benefits for smallholder farmers, especially when they can see value.

b) Market Information System – Mobile Telephony – Tanzania

The inability of smallholder farmers to access markets beyond the farm gate is a major driver behind the vicious cycle of low returns, low input-use, and low productivity that is characteristic of this crucial demographic. Information asymmetry, low quality and quantity of produce, limited organizational capacity of producer groups and unfavorable policy environments are some of the bottlenecks that limit access and the potential for impact. Providing smallholders with a tool or a mechanism to enhance their integration into markets, for surplus produce, is one way to redress this situation.

In late 2013, Africa Harvest and the International Institute of Tropical Agriculture (IITA), funded by IFAD, worked with smallholder farmer groups in Kenya and Tanzania to enhance their participation in value chains through capacity building and organizational strengthening.

Working in partnership with MVIWATA, a national association of small-scale producers in Tanzania, the project facilitated scaling out and adoption of the Mviwata Agricultural Market Information System (MAMIS) among 31 farmer groups in Mwanga, Moshi, and Rombo districts of the Kilimanjaro region. MAMIS is a mobile telephony based platform that provides farmers real-time information on market prices, available buyers and the quantity required by the market through Short Text Messaging (SMS). It operates through a partnership with a mobile service provider and a network of market information agents in various markets across Tanzania.

The project facilitated the training of 575 smallholder farmers (58% women and 42% men) in 31 groups on how to access – via their mobile phone – market prices, quantities demanded, and the prospective buyers for their produce. The project also developed 500 posters to help farmers with the information on how to access the MAMIS platform, and distributed these posters in the target areas to be displayed in meeting places, local chief's camps and market places.

Smallholder farmers in the three districts are now able to access information from 31 different markets and for 38 different commodities at a minimal cost of 4 US cents (70 Tanzanian Shillings) per short text message. The target smallholder farmers as well as others within Mwanga, Rombo and Moshi areas are now able to get information on prices from as far as Dar-es-Salaam while remaining in the comfort of their homes. Earlier, farmers had to send a representative to physically visit traders, collect information, and bring it back to the group members. This normally used to take a couple of days to accomplish, at a cost of approximately USD 31.25 per person for the return bus fare from Rombo to Dar-es-Salaam, 1,100 kilometers away.

Benefits accruing to these farmers include: access to up-to-date information (updated twice every week) on prices, buyers, and required quantities, reduction in transaction costs, and hence more income, ability to produce what the market needs, in terms of quality and quantity, and overall enhanced access to markets.

In addition to sensitizing and building the capacity of target beneficiaries in the use of MAMIS, the project helped to bring on board three additional markets (cereals, Irish potatoes, bananas and horticulture) around the Kilimanjaro province (Mbuyuni, Mwika and Himo). Further, 15 cereal traders were added to the network to provide market outlets for farmers in the northern Tanzania region – Kilimanjaro and its environs.

4.3 Integration of Soil Fertility Management (ISFM) Techniques to Boost Productivity

The long-recommended use of fertilizers, pesticides, and other synthetic chemicals to address problems in agricultural production has been leading to poor soil health and increased levels of resistance in insects, diseases and weeds. Soil fertility degradation has been described as the single most important constraint to food security in Sub-Saharan Africa (SSA). Nutrient deficiency apart, the problem is further compounded by inappropriate crop varieties and cropping system design. Other challenges are the links between poverty and land degradation, obstructive national and global policies that act as disincentives, and institutional failures.

Food security in Africa is one of the most pressing problems facing the continent. While the rest of the world has seen significant increases in per capita food availability over the past 45 years, the situation in SSA has only improved slightly, with devastating effects on millions of people on the continent. Malnutrition is widely recognized as an underlying cause of death associated with infectious diseases, and projections suggest that undernourishment will worsen in SSA over the next decade. Malnutrition is projected to increase by an average of 32% in Africa (UNDP, 2006).

When measuring soil quality, it is important to evaluate the physical, chemical, and biological properties of the soil.

- Physical properties addressed include bulk density, water content, infiltration rate, aggregate stability, slaking, and morphological estimations.
- Biological properties measured include soil respiration and earthworms.
- Soil chemical properties measured include pH, electrical conductivity (EC), and soil nitrate levels. The chemical tests are also useful to evaluate water quality of well-water, tile drainage waters, and other water bodies linked to farm activities.

A number of significant advances have been made over the past decade in both the science and practice of soil fertility management in Africa. The key ones are outlined below:

1. The application of approaches developed by landscape ecologists using new remote sensing and geographic information systems (GIS) tools has led to major breakthroughs in objectively assessing the spatial variation in soil quality and soil degradation. This area will be instrumental in problem diagnosis, but also in better targeting interventions.

2. Significant adoption of a range of improved technologies has been documented across a number of countries in SSA. These technologies include soil and water conservation structures such as ‘Zai’ pits in the Sahel, organic nutrient management systems such as high-quality manuring in intensive dairy systems in Kenya, and more integrated soil management practices. Available evidence shows that these technologies increased productivity in the environments in which they were adopted, and provided farmers with new options.

3. The integration of other scientific disciplines including ecology, economics and participatory social science has helped formulate a more holistic approach to soil fertility management. We recognize that soil fertility management practices need to be more than just technically sound.

This integrated approach leads to the development of approaches that are socially and economically acceptable.

4. Integrated Soil Fertility Management (ISFM) principles have influenced diverse stakeholders in SSA to alter the ways they address soils and their management, on a variety of scales.

Integrated Soil Fertility Management (ISFM)

ISFM focuses on the relationships of soil fertility to the overall function of farming systems. ISFM is defined as the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which maximize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm.

The integrated soil fertility management (ISFM) paradigm has been accepted by the research and development community, including the Alliance for a Green Revolution in Africa, as a viable set of principles to foster agricultural intensification.

What needs to be done

1. Macroeconomic conditions, policies and institutions that encourage soil conservation. Farming must be profitable, land and labor must be valued appropriately, and farmers must have easy access to functioning (liberalized) markets. Policies must promote investment in infrastructure and transport, and encourage the private sector to invest in markets for inputs and outputs.
2. Land tenure is a major influence both on the maintenance of soil fertility and on the ability to intensify farming in a sustainable way. Recognizing that farmers must have robust access rights to land if they are to invest in it, donors have supported land-reform programs that increase the security of tenure.
3. Support is needed for research to adapt existing fertility-management methods to specific areas, and to promote these techniques. Research on problems faced by the poorest farmers has been limited. A better understanding of the synergistic effects of soil amendments (such as manure and compost) and inorganic fertilisers is necessary. Institutional capacity is limited and also requires support.
4. Farmer empowerment and ownership, leading to planning of research and joint experiments, are critical. Extension and farmer-training are needed to advise farmers on how to save labor, manage livestock, and care for their soils. Programs that equitably involve women farmers should be prioritized.
5. ‘Smart’ (targeted and time-bound) subsidies might encourage farmers to adopt integrated soil fertility management methods, stimulate the availability of mineral fertilizer and mechanized transport, and increase possibilities for poorer farmers. The subsidies can be phased out at the end of the transition to effective soil fertility management. Long-term investments may be needed to protect marginal regions from desertification. Time-bound subsidies may be desirable.

6. Governments also have a role to play in ensuring that development messages within farming communities; a number of such organizations are still advocating against the use of fertilizer and strongly promoting organic agriculture, which, based on ISFM.

4.4 Remote Sensing and Satellite Imagery for Agricultural Activities

Remote sensing for agriculture can be defined simply as "observing a field or crop without touching it", and incorporates new technologies that provide increasingly efficient, complete, accurate, and timely information.

At the farm level, remote sensing and imagery could have many applications:

- Monitoring crop status; to check if the crop is distressed, diseased, etc.
- Estimating plant population and future yield (crop yield estimation)
- Identifying fertilization and pesticide requirements
- Early warning for insect attacks
- Establishing an irrigation regime
- Precision Crop Management (via GIS)

At the national level, using the USA as an example, the World Agricultural Outlook Board (WAOB) of the US uses remote sensing to assess crop conditions; monitor, manage and administer natural resources; and conduct remote sensing research.

Remote sensing and imagery are used to conduct surveys and prepare estimates of US agricultural crop production, supply inventories and agricultural production revenue and costs. Federal, state and local governments use this information to help form public policy and legislation controlling agricultural commodity production, storage, marketing, and distribution.

The Joint Research Centre (JRC) of the European Commission (EC) controls the research activity for country members of the European Union (EU). The remote sensing and imagery tool used is called MARS (Monitoring Agriculture with Remote Sensing) and it provides the necessary technical support and image data to EU organizations such as the Directorate General for Agriculture and the European Statistical Office. Satellite data is used to measure crop acreage, type and yield. The resulting agricultural statistical information assists the EU in monitoring member states' compliance with EU agricultural policies.

In order to progress agriculture in Africa, governments through their NAR need to invest in these technologies in order to impact agriculture both at the farm and national levels. Also, international research bodies need to help governments boost their capacity in the diagnostic laboratories and other equipment.

4.5 Renewable Energy – Lake Turkana Wind Power Project: the largest wind farm project in Africa

The renewable energy sector in Kenya is among the most active in Africa. In Kenya, investment grew from virtually zero in 2009, to US$1.3 billion in 2010 across technologies such as wind, geothermal, small-scale hydro and biofuels. This is not saying that Kenya was never active in the renewable energy sector. Kenya is Africa's first geothermal power producer and the world leader in the number of solar power systems installed per capita. It is still the largest producer of geothermal power in Africa today at 200 MW, with only one other African country – Ethiopia – producing geothermal power. Connectivity to the national grid in Kenya currently stands at 28%. In 2011, Kenya was also the first country in Africa to open a carbon exchange.

The Lake Turkana Wind Power Project represents the largest wind farm project in Africa. It represents a large-scale demonstration of clean energy technology and can be scaled up and replicated in a number of African countries.

The main objective of the project is to provide clean, reliable, low-cost power by increasing Kenya's national power generation capacity to approximately 17%.

Kenya's Lake Turkana Wind Power Project is an example of innovative financing for energy projects:

The project had a unique public-private aspect in terms of generation (private sector, by Lake Turkana Wind Project) and transmission (with the ancillary 428 km transmission line being procured and delivered by the public sector). All stakeholders worked closely together to minimize project-on-project risk.

The African Development Fund (AfDB) applied its first partial risk guarantee to the associated T-line to mitigate T-line delay risk (which is otherwise covered by delay payment obligations of the Kenyan Government to the project company and its lenders).

AfDB used its B-Loan structure, allowing participant banks to benefit from its preferred creditor status.

The European Investment Bank, with guarantee structures from the Danish Export Credit Agency (political and commercial cover) and from the two South African banks – The Standard Bank of South Africa Limited and Nedbank Limited (commercial cover) – could leverage a huge €200 million into the project.

The application of the EU-Africa Infrastructure Trust Fund (EU-AITF) financial instrument (which blends development finance institution monies with grant monies from the European Commission) was crucial in filling the equity gap.

The Lake Turkana project showed innovation in how the liquidity risk was managed (by a combination of letters of credit and escrow account arrangements) that demonstrated some out-of-the-box thinking by government, sponsors and lenders alike.

This same model can be used to replicate similar projects across Africa.

4.6 Technology Transfer – Increase Linkage Between Research Instructions and Farmers

More often than not, there is a disconnect between agricultural research and the farmers – who are the final consumers of the research. One of the probable reasons for this state of affairs is the fact that scientists are generally poor communicators and they would rather engage in discourses with fellow colleagues and students that get involved in robust public engagement. Many universities and research institutions have only recently started the initiative to get involved in applied research, where farmers are key participants and their needs are being addressed. In Sub-Sahara Africa, farmers have been using improved seeds and hybrids that were released over 30 years ago, and which now have started succumbing to new pests and diseases. Ways and means must be found to ensure that there is a convergence between research and farmers. In the last three years, Africa Harvest has partnered with ICRISAT and KALRO in an IFAD-funded project called *Sorghum for Multiple Uses*. Africa Harvest's role has been to ensure that ICRISAT's and KALRO's research products reach the farmers. New and old varieties were planted on-farm, and farmers were part of the participatory variety selection during a major field day. This goes to demonstrate that partnerships that bring together organizations with unique strengths can convey great benefits to the farmers.

5. ESTIMATED COSTS

The resource estimate for transforming agriculture is immense and will include substantial investment in:

- Well-developed national agricultural research systems
- Investment in human resource capacities
- Economic policy reforms
- Investment in infrastructure

Some encouraging signs indicate that African countries have become increasingly focused on investing in agriculture for economic growth in recent years, evidenced by a number of influential initiatives and regional and sub-regional processes that have put agriculture firmly back on political and donor agendas. Many countries have developed solid agricultural development and financing plans to strengthen agricultural production and food security.

5.1 Research, Policy, Human Capital and Infrastructure

Investments in international agricultural research

This is investment in "knowledge capital." And it involves capital stock, or the accumulation of past annual research investments. Like physical capital, knowledge eventually depreciates through technology obsolescence, but unlike physical capital, knowledge capital accumulates

with a lag: it takes several years for the knowledge generated from research to be fully incorporated into higher farm productivity and output.

For example, by 2005, new technologies from the Consultative Group for International Agricultural Research (CGIAR) had been disseminated over 34 million hectares, or about 21% of SSA cropland; output from these hectares was increased by 65%, on average. Each $1 invested in technical improvements by CGIAR yields an estimated $6 in benefits. The CGIAR system of international agricultural research allocates from 40 to 50% of its global research budget to SSA (CGIAR Annual Reports). By the mid-2000s, annual spending for SSA (in constant 2005 US$) exceeded $200 million.

Investments in national agricultural research systems

Countries to target spending at least 1% on agricultural research. Studies have shown that SSA countries returned about $3 in benefits for every $1 spent, on average. Thus, if annual spending on national research was doubled, a potential increase in productivity of 3.4% could be expected. Several NARS are very small, with fewer than 100 scientists employed. Only four countries – Nigeria, Ethiopia, Sudan, and Kenya – employ at least 1,000 scientists (Agricultural Science and Technology Indicators). But both small and large systems are affected by unstable funding, low levels of operational funds, relatively few staff with doctoral degrees, and human capital attrition. Overall investment levels in most countries remain below the levels required to sustain viable agricultural R&D programs that address current and future priorities. In fact, almost all West African countries still fall short of the minimum target of 1% of Ag GDP recommended by NEPAD and the United Nations.

Improve economic and trade policy reforms

There should be improved agricultural terms of trade, and increased incentives for farmers to adopt new technology and raise productivity. Policy reforms have a potential upside of 5% on agricultural production.

Many countries outside of Africa subsidize their agricultural sectors, many governments in SSA maintain discriminatory agricultural, trade, and macroeconomic policies that reduce earnings of farmers (Anderson and Masters, 2009). The World Bank's nominal rate of assistance (NRA) to agriculture, reported annually for 18 SSA countries (including South Africa) through 2005 in Anderson and Masters (2009), provides a comprehensive measure of the economic distortion caused by government policies. The NRA gives the net effect of policies on prices paid and received by farmers as a percentage of what prices would have been in an undistorted market. A related measure, the relative rate of assistance (RRA) to agriculture, compares the NRA of agriculture to the NRA for non-agricultural sectors and is available for 14 SSA countries. For the SSA region as a whole, the average NRA has been consistently negative and the RRA even more so (Fig. 6). Structural adjustment policies implemented by some SSA countries in the 1980s and 1990s reduced – but did not eliminate – this bias against agriculture. The regional average, however, hides considerable variation among countries. Between the 1970s and the early 2000s, Cameroon, Ghana, Madagascar, Mozambique, Senegal, Tanzania, and Uganda

improved incentives for farmers (their NRAs became less negative, or, in the case of Mozambique and Kenya, slightly positive), while Côte d'Ivoire, Zambia, and Zimbabwe maintained policies that heavily discriminated against agriculture. Mali, Burkina Faso, Togo, and Benin maintained NRAs close to zero or only slightly negative throughout most of the period (Anderson and Masters, 2009).

Investment in human capital: education and health

Countries with higher rates of labor force schooling witnessed more rapid adoption of new agricultural technologies. The human capital of the labor force includes its skill level and health status. Barro and Lee (2010) have recently updated their internationally comparable average schooling-level estimates for the working-age population, by country and over time. Their estimates, which are for the labor force as a whole and not just for agricultural labor, show that average schooling in SSA rose from about 2 to 5 years between 1970 and 2005. If the more educated workers are more likely to migrate to non-farm or urban jobs, these estimates may overstate the average schooling level of farm labor. Nonetheless, changes in average schooling levels, like literacy rates, reflect the importance countries give to general education, particularly since most labor in SSA is employed in agriculture.

Investment in infrastructure

The availability of good infrastructure is one of the main factors that can reduce transaction costs and induce private sector participation. The key infrastructure investments are: construction of access roads to ease transport of inputs and farm produce, and accessible market facilities (Abubakar, 2002; Abernethy, 2002); rural electrification, which is a major constraint to the implementation of productivity-enhancing inputs and technologies in many crop-growing rural areas; and a good communication system to facilitate the transition from subsistence to commercial operations. The introduction of mobile telephones and SMS-services in rural areas has been shown to strongly stimulate the connection of smallholder farmers to markets in countries such as Kenya, Senegal, India, and the Philippines, and greatly reduce the role of middle-men. The MSMEs can play a key role once the government has set the rules. This is a particularly interesting area for further commercial and technical development.

Rural roads reduce travel times, transportation costs, and in-transit spoilage; raise the prices that farmers receive for their products; and lower the prices they pay for inputs (Dorosh et al., 2009). We measure infrastructure as road density (km of roads/ km^2 land area), using data from the International Road Federation (2006).

5.2 Potential Sources of Financing and Cost Sharing

The range of products available for banks to support agriculture and agribusiness is slowly increasing. Different innovative financing approaches for agriculture have emerged over the past few years, linking large capital investments to agricultural development – facilitating

access to financial capital for investment in the agriculture sector, and reducing risks to attract private investors. Examples include public-private partnerships, agricultural insurance schemes and credit guarantee schemes.

Another way to increase access to agricultural capital is financial intermediation through agents in the value chain (input suppliers or output processors). They are in a good position to cost-effectively monitor on-farm behavior and enable financial institutions to accept crops as collateral. For instance, the Agricultural and Trade Investment Fund (AATIF) finances local projects and companies along the agricultural value chain and develops financial markets across SSA.

Commercial banks are active in trade finance, e.g. providing funding for the export of commodities from SSA. They also finance global companies importing into SSA for infrastructure development.

The development of commodities exchanges in SSA may encourage banks to do more agricultural lending in ranges between microfinance and big trade deals, through more possibilities of warehouse-receipt financing. The Ethiopia Commodities Exchange (ECX) has managed warehouses and helped grade produce to be traded on the exchange, allowing farmers to be paid promptly the next day. It also deployed electronic information and trading systems, disseminating full knowledge of prices. It also drove a better understanding of clearing and settlement, with more modern banking technologies.

5.3 Cost Sharing Mechanisms

The table below describes how the various capitals can be funded from diverse sources.

Potential Financing Sources						
Investment Decisions: Dimensions (Horizontal) and Types (Vertical)	Sources of Finance/Facilitators	Human Capital (Skill, Health, Knowledge, Labor, Ambition)	Social Capital (Organizations, Institutions, Policies, Laws)	Financial Capital (Income, Savings, Loans)	Natural Capital (Water, Land, Plant and Animal genetic resource, Climate	Physical Capital (Purchased Inputs, Equipment, Infrastructure)
Individual Farm Households	Family, Friends, CBO, NGO, RPO, GO	E.g., provide information and training on technologies and best practices in land and water management	E.g., increase awareness of benefits of collective organizations	E.g., arrange farm output markets; facilitate access to banking and micro credit	E.g., improve security of for the land and water tenure	E.g., offers baskets of technologies
Farmer groups and Communities (RPOS, WUAs, FOs)	CBO, GO NGO, PPP, RPO, WUA, SME	E.g., organize exchange visits and study tours	E.g., create technology information centers; promoting learning alliances and networks	E.g., create and manage revolving funds and communal funding schemes	E.g., judicious development of land and water; arrange for communal land and water rights	E.g., encourage local manufacturing of inputs and post-harvest processing; improve access roads
Enterprises (MSMEs)	Development banks, PPP, Industrial partners, GO	E.g., sponsor agricultural training programs and study: contract farming	E.g., participate in public-private partnerships, including RPOs and WUAs, learning alliances	E.g., identify opportunities for contract farming, credit schemes	E.g., develop private sector service providers	E.g., adopt improved techniques, norms and standards

Government	International financial and development institutions, International trade and research organizations	E.g., organize exchange visits and study tours	E.g., encourage community organization and appropriate institutional framework	E.g., provide a good investment climate (incentives, market connections	E.g., develop effective land and water laws at national and provincial levels	E.g., provide basic infrastructure for improved input and output market access

Notes: RPOs-Rural Producer Organization**; WUA- Water Users Association; FO - Farmers' Organizations; MSME - Micro, small and medium enterprise; C government Organization; GO – Government Organization; PPP- Public-Private Partnership; SME- Small and medium enterprise

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PART TWO

Jump-starting African Science and Technology Innovation in an Agricultural Transformation Agenda

While adopting global innovations in science and technology for transforming agriculture in Africa has had enormous value (both proven and potential), the long-term growth and sustainability of the agricultural sector in Africa will require a commitment to promote a comprehensive program of innovation, invention, and critical adaptation of systems, procedures, processes, tools, applications, and material aimed at the exponential transformation of agriculture in Africa.

There are many compelling reasons for such a strategy. They include the following:

1. Africa cannot remain the world's basket case forever. At some point, we must find the courage to embark on a coherent and enlightened program of increased self-reliance with corresponding reduced dependency predicated on short-, medium-, and long-term strategies that increase Africa's capacity irreversibly at each evolving stage.
2. Subsistence survival is not a healthy mode of human existence. While societies might find themselves immersed in such conditions either by accident of history or by default, the only intelligent response is for such society to strive relentlessly to dig itself out of such conditions as quickly and as smartly as possible.
3. At some point, Africa must contemplate becoming globally competitive in every way, in the shortest time possible, and by all means noble, no matter what it takes.
4. Africa must find the courage to do so, grateful to those who have held our hands while we were weary and uncertain, sensitive to those who have become so used to seeing Africa as the ward of the global community that they cannot imagine a new dispensation and relationship, but determined to transform itself and its people to a modern state – equal to, but by no means less than any other state or society – while preserving the uniqueness of its rich culture, history and humanity.
5. Such an Africa will by no means reduce global trade, but will simply engage in trade among equals, with a resulting exponential growth in the scope and value of such trade, as is the case with trade between and amongst developed economies.
6. Such a strategic paradigm shift is long overdue. Africa has nothing to benefit from any further postponement of the D-Day, and we can and must begin now if we are to make up for lost time and still have the opportunity to cut across the global divide that has us burdened by a vast and unrelenting handicap, losing faith by the day of any possibility of our catching up with the rest of the world and, not impossibly, superseding it in some way, shape or form.

Agriculture as a Critical Socio-Economic Engagement of Human Society

Agriculture, along with hunting and related activities was one of the earliest socio-economic enterprises of human society. Critical to the survival of man, literally, it was the quintessential economic undertaking from the earliest times, as people produced to feed themselves, and traded the surplus in return for either other agricultural products they did not produce, or not in sufficient quantities, or for non-agricultural items that they needed for their life and well-being. As such, to the extent that knowledge, and, therefore, science and technology derive from lessons learned from experience and experimentation, agriculture would seem to be a natural treasure-trove of innovative ideas.

Furthermore, the sheer enormity of the component of the economic activity of society that is agricultural or agriculture-related, especially in Africa where the proportion is more than all other economic activities combined, would make this sector an ideal source and forum for innovation and experimentation. This would enable us achieve a respectable place of pride in the global socio-economy.

Given further that Africans have engaged in agriculture for centuries, it is only reasonable to assume that there exists innumerable lessons learned, experimentation and problems solved that there could be a legacy and quantum pool of innovation, which, if properly identified, analyzed and durable value extracted, could prove to be the seed for innovation when extrapolated through the intervening years to our contemporary needs, circumstances and goals.

Knowledge-Driven Agricultural Transformation

Much more than just data, knowledge – the sum total of insights gleaned from experience and history, and lessons learned from engaging human experience in an effort to solve existing problems and meet new challenges – is the quintessential driver of development. Any serious effort at the quantum development of agriculture in Africa would have to be predicated on the accumulation and deployment of knowledge (old, traditional, new and yet to be), to inform our strategies for building a solid, self-sufficient, globally competitive agricultural sector in Africa. To understand this and get the strategy right, we would then have to consider the African farmer not as a hapless rustic poor person who must be taken care of, but as an enlightened citizen who holds the key to both the well-being and the transformation of society and those who inhabit it.

Research and Development as the Drivers of Knowledge

In the context of a knowledge-driven agricultural transformation, research and development become the key fuel for knowledge development, which in turn promotes expertise and

excellence. R&D takes numerous forms, from formal inquiry to intuitive experimentation triggered by a quiet suspicion that there is more than meets the eye.

Science and Technology

R&D has its place in every aspect of human inquiry and covers in all such situations, matters of history, sociology, culture and civilization as well as matters of science and technology. Science and technology capture essentially the how and why of the existence and functioning of natural or man-made phenomena, while technology is what we create from the knowledge of such science to facilitate our mastery and engagement with such phenomena with a view to a variety of objectives.

These go from getting more from less, improved efficiency, improvement of processes, creating new objects and phenomena from old ones, or simply creating outcomes that make life a bit easier, and in the process permit more time for leisure, relaxation and reflection while increasing production exponentially. Technology basically reduces the need for manual or hard labor in the production process. Wealth generation and its distribution become matters of economic policy crafted to manage such increased output.

Innovation in Agriculture in Africa

Innovation, in this context, is simply the creation or derivation of new ideas, new insights into old ideas, new processes for managing existing issues, situations and circumstances, and overall crafting or inventing of new approaches to doing old things better, more efficiently, more productively, and more cost- or time-effectively, thus stimulating new prospects of further innovation by the benefits they accord the enlightened human process.

Against all of this, it becomes clear that knowledge, R&D, science and technology, and innovation are the core strategic activities of man and society that drive their struggle for excellence, and the individual and communal pursuit of self-actualization. When this pursuit gathers extraordinary momentum that it shakes up the old lethargy and recalcitrance of society and peoples into an irresistible common effort, society is propelled towards a Renaissance.

Towards An African Agricultural Revolution

This irresistible momentum to excel and reach well beyond the popular perception of the limit of human possibilities is what we need to develop as the fuel and energy to propel Africa's strategic transformation to a globally competitive position and to sustain us in that mode, ready and able to continue to excel.

Given the fact that agriculture is the prime and quintessential economic engagement of all societies, especially for Africa, what we need in order to achieve this *Renaissance Africa* is, first and foremost, to fuel an Agricultural Revolution in Africa, not in terms of miniscule advances most often overtaken by constantly changing demographics and from unpredictable

socio-political nuances, but in terms of building a robust continental effort driven by a shared dream too high to be contaminated by fear, anxiety and the self-handicapping impact of relentless castigation by everyone that Africa is poor, hapless and always needing to be assisted or led.

In order to motivate and mobilize the largest number of Africans, the best and the brightest included, to participate in or embrace such an Agricultural Revolution, we need to set a very high goal, high enough for most to feel the pulsation of the undertaking with the dream of success promising extraordinary gratification for all Africa. Sentimental and philosophical as this might sound, one firmly believes that one cannot transform society with pedestrian objectives and goals. Africa has slowly come to acquiesce to an unacceptable unambitious position in the global dispensation that we need to jumpstart a new drive and one goal that can trigger the quantum force and include everyone in an Agricultural Revolution.

Science, Technology and Innovation in Transforming Agriculture in Africa

What is called for in order to achieve the desired transformation of agriculture in Africa is a comprehensive, bold, audacious yet eminently feasible program of massive innovation in agro-related science and technology, driven by an insatiable search for all knowledge about agricultural science and technology throughout history, most especially in the African experience, the extrapolation of lessons learned, and the use of the wide range of existing scientific and engineering specialties to construct or create new products, processes and procedures for achieving the exponential productivity that we will have set as our target. The achievement of such a revolution will have an immediate and direct impact on corresponding efforts in virtually all other fields of endeavor, together resulting in the modern and globally competitive, free, relaxed and inspired Africa that is our highest dream.

The fields in which we should focus such a bold effort in R&D in agricultural science and technology should cover the whole spectrum – from land use, soil cultivation, conservation and management, seed development (including biotechnology), planting techniques, harvesting, storage, logistics, processing and other value addition, marketing, to the more sophisticated areas of telemetric, ICT, remote sensing, robotics, research techniques and more. It should also include expertise in the relevant pure sciences and the culture, sociology and even anthropology of agriculture.

The knowledge and specialties required for achieving all of the above already exist in the not-insignificant number of African experts at home and around the world, and the young graduates fresh out of college who have both the knowledge and the enthusiasm to engage in building the kind of Africa that we need and should be able to begin to build now, half a century and counting, from political independence.

It is important to underscore two principles in this configuration:

1. The process of innovation as conceived will start from the African farm and farmer, draw from his or her experience, needs and instincts, and, using the expertise and the possibilities of science and technology, create solutions that directly address such articulated objectives.
2. The dialogue upon which such innovation is predicated will be two-ways. The former has a lot to teach and tell the researcher/innovator, and the researcher/innovator has technical knowledge to share with the farmer.

Towards A Holistic Cross-Sectorial Innovation

Because agriculture is the centerpiece of all economies, it has a direct bearing on virtually all other sectors. It is easy and fair to assume, therefore, that innovations in agriculture will have significant implications and opportunities for advancing all other sectors, and that, collaterally, advances in innovation in other sectors will hold possibilities for agriculture, if smartly adapted. This holistic approach is what will create the critical mass for the uptake of the innovations, even if the return per user is relatively small. As innovation in one sector stimulates innovation is another sector, an exponential growth in innovation all round will eventually result, which will drive the massive continental development that we all crave.

The Challenge and the Clarion Call

With the strategy defined here, we can get the best of two or more worlds by benefitting from existing and continuously emerging innovations from the global arena, while we make massive efforts to create our own indigenous innovations which, in addition to deploying them for our ends, we will, sooner than later, also make available to the global market, thus building the foundation of an economy of intellectual property.

This is an inclusive agenda, not otherwise. What is paramount is that – as Dr. Joseph Okpaku has said in *From Poverty Management to World-Class Competitive Self-Development: Mobilising Africa's Global Intellect, Knowledge and Expertise to Build a Smart Modern 21st Century Society*, an address to the Conference of Rectors, Vice Chancellors and Presidents of African Universities in Tripoli in 2007[1] – "there comes a time in the lives of a people when, no matter how embattled, they must find the courage to take their destiny in their own hands, and armed with their own resources, no matter how miniscule, strike out to build their future in the image of their highest dreams. They must be prepared to do so, with the help of friends, if possible, but alone if inevitable."

[1]Joseph O. Okpaku, Sr., *From Poverty Management to World-Class Competitive Self-Development: Mobilising Africa's Global Intellect, Knowledge and Expertise to Build a Smart Modern 21st Society. An address to the Conference of Rectors, Vice Chancellors and Presidents of African Universities (COREVIP), Association of African Universities. Tripoli, Libya, October 21-25, 2007.*