Science Agenda for Agriculture in Africa

"Connecting Science" to transform agriculture in Africa

African Union

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FARA

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Forum for Agricultural Research in Africa
12 Anmeda Street, Roman Ridge
PMB CT 173, Accra, Ghana
2014

Citation

FARA, 2014. *Science agenda for agriculture in Africa (S3A): "Connecting Science" to transform agriculture in Africa.* Forum for Agricultural Research in Africa (FARA), Accra, Ghana.

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ISBN 978-9988- 310-x-45 (print)

ISBN 978-9988-324-8-10 (pdf)

Design: BluePencil Infodesign, Hyderabad, India (www.bluepencil.in)

Printing: Pragati Offset, Hyderabad, India (www.pragati.com)

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Preamble

Africa's impressive economic performance, sustained for more than a decade, has inspired optimism about the realisation of Africa's vision of a continent free from hunger and extreme forms of poverty. The distribution of the benefits flowing from Africa's resurgence has however not been equitable. The poor who happen to be concentrated in rural areas and depend on agriculture have been left behind. A further concern is therefore about whether Africa will be able to sustain this level of growth over the long term.

These concerns are legitimate and merit careful attention. An essential response to addressing them lies in the transformation of the agriculture sector by substantially increasing its productivity, reforming the related institutions towards increasing competitiveness, especially of the private sector, and by rebranding agriculture as a business rather than a way of life.

There are encouraging signs that African nations are once more recognising the importance of agriculture as a key driver of growth, and not just growth but inclusive and more sustainable growth. The African Union's declaration of 2014 as the year of agriculture and food security in Africa is a testament to renewed commitment to this sector.

The development of the Science Agenda for Agriculture in Africa (*Science Agenda*) under the auspices of FARA is an important step on the road to the transformation of Africa's agriculture. This Science Agenda is all the more important because it is Africa-owned and Africa-led. For a very long time Africa has outsourced much of the Science for its agriculture thereby undermining its own capacity to fully mobilise this science for improving the livelihoods of its people, particularly towards deriving the solutions that address needs peculiar to Africa.

It has been a privilege to Chair the Expert Panel that put together the discussion documents and subsequently this *Science Agenda* document. What I found most gratifying in performing this role is the exceptionally high interest and ownership by African stakeholders in this Science Agenda. This assures me that this *Science Agenda* will serve its intended purpose. This is significant because past attempts at this kind of exercise have not realised this expectation.

That said, I wish to point out that this continental *Science Agenda* will only translate into stronger nations and better lives for the people of Africa if it is supported by coherent investment in science for agriculture-for-development and will inspire reform of the related institutions. Most of these investments are expected to come from national public and private sources. Their mobilisation will require domestication of this framework agenda into national strategies action plans. This next stage of actions will require as much political, financial and stakeholder support as that extended towards the development of the continental agenda document itself.

I congratulate FARA for successfully coordinating the development of this *Science Agenda*. I also applaud the African Union Commission and the NEPAD Planning and Coordination Agency for recognising the game-changing potential of science and ensuring that it is strategically integrated into the continent's agricultural transformation agenda encapsulated in the Comprehensive Africa Agricultural Development Programme (CAADP).

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for Agricultural Development

Chairman and Patron of the Expert Panel
Commissioned to develop the Science Agenda

Foreword

This Science Agenda for Agriculture in Africa has been crafted at the most opportune moment in Africa's history. The economies across Africa are growing, agriculture is rebounding, but there are still high expectations for agriculture because Africa is still the most food insecure continent, and environmental sustainability is becoming increasingly challenging. The world's population is growing, and by 2040 when it is estimated to hit 9 billion, Africa is expected to emerge as the world's breadbasket on account of vast but untapped land and water resources. This unfolding destiny poses significant expectations on Africa's science and technology capabilities. The challenge for Africa to feed itself and become a major food supplier for the world is compounded by the need to produce healthier, safer and more nutritious food on less land, using less water and chemicals, and producing less waste and less greenhouse gasses. These demands explain why Africa resolved to develop a Science Agenda with a vision aptly defined as: *"By 2030 Africa is food secure, a global scientific player, and the world's breadbasket"*. The Science Agenda represents a delayed yet urgent and realisable opportunity for Africa to fulfil this destiny. **It articulates the science, technology, extension, innovations, policy and social learning that Africa needs to apply in order to meet its agricultural and overall development goals**. The Science Agenda is therefore conceived as a vehicle to support the implementation of the Comprehensive Africa Agriculture Development Programme (CAADP), which is the broader framework for transforming agriculture in Africa. Science and technology is an essential part of the CAADP strategy to instigate an agricultural-led social and economic transformation. In that regard, the Science Agenda identifies a suite of issues and options for increasing and deepening the contributions of science to agriculture in Africa, at the local, national, regional and continental levels. The Science Agenda's vision aligns with, and contributes to the African Union's Science, Technology and Innovation Strategy for Africa (STISA) and Agenda 2063. In developing the Science Agenda, the FARA Secretariat worked with stakeholders to generate the "Accra Consensus" which ensured that the process of crafting the Science Agenda was in line with AU principles of African ownership and leadership, and wide consultations.

The AUC and NEPAD Planning and Coordinating Agency implore all stakeholders to give priority to the operationalisation of this Science Agenda. Science for agriculture in Africa is too important to be outsourced to international investors. African countries are called upon to increase domestic investments in science for agriculture. Moreover, every country requires a basic science capacity—at least a capacity to "borrow intelligently". African solidarity for Science is the most significant strategy in achieving this vision—by joint efforts to overcome challenges and to take advantage of opportunities; and by sharing technologies, information, skills and facilities

In conclusion, all levels of stakeholder groups are encouraged to embrace this vision and to champion its realisation. Most importantly, member states are to adopt and adapt the agenda at national level and implement it without delay or hesitation.

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Key messages

1. **Africa should commit to strengthening its role as a player in global science for agriculture to drive the transformation of agriculture and society**

   Science crucially contributes towards making agriculture in Africa more productive, competitive, sustainable, and inclusive. Scientific solutions for agricultural transformation need to be pursued further without losing sight of the fragility of African environments, the continent's rich biodiversity and the complexity of its agricultural production systems. Transforming Africa's agriculture requires a science system that produces both 'technical' and 'institutional' innovations. It is therefore essential that Science becomes main streamed as an essential part of agriculture-led social and economic transformation in Africa.

   To this end, Africa's leaders must undertake to: (i) ensure a basic science capacity in all countries of Africa, including a capacity to deliver science-based solutions on the ground; (ii) support regional centres of excellence to share knowledge and facilities; (iii) maintain an open flow of people, knowledge and resources among African countries through policies that facilitate exchanges within and beyond Africa; (iv) contribute to a new African Science for Agricultural Transformation Initiative that will provide incentives for all countries to invest in science; and (v) put the moral and financial support of the African Union and its agencies behind such national, regional and continental initiatives to transform the role of science for agriculture in Africa.

2. **Science for agriculture in Africa is too important to be outsourced. African leaders must take responsibility for enhancing the role of science in their societies.**

   African leadership at all levels must take responsibility for establishing institutions that are capable of envisioning, conceptualizing, strategizing and crafting scientific and developmental models and solutions for the continent. In this regard, it should be noted that: (i) every country requires sufficient science capacity to participate in the transformation of agriculture; (ii) each country should have some capability to generate new knowledge as well as the capacity for "intelligent borrowing" of scientific discoveries elsewhere for adaptation to local situations; (iii)each country must determine the most productive directions of its investments in science for agriculture; (iv) no country has built a science and technology capacity by short-term projects alone - building science capacity is a long-term commitment; (v) science needs to be responsive to the changing needs of farmers, producers, consumers and agribusiness entrepreneurs, and must therefore be main streamed into Africa's economic and social development; and (vi) African countries can and must make increased domestic investments in science for agriculture, commensurate with their size and economic status.

3. **Science is critical for the preservation and use of Africa's rich biological heritage and indigenous and local knowledge.**

   Africa's biological heritage is at risk from expanding economic growth, unsustainable intensification of agriculture, impacts of climate change and changing land use. Building on indigenous and local knowledge, science offers new opportunities for Africa's biological heritage to be better characterized, conserved and used by current and future generations.

4. **Agricultural transformation in Africa will not happen without realizing the potential of women and young people.**

   Vibrant rural communities depend on empowering women and the increasing numbers of youth in rural areas with the means and opportunities to contribute to and make a living from profitable agricultural enterprises.

5. **Now is the time to increase investments in science for agriculture in Africa, when countries have the means and opportunities to invest, and gain returns.**

   i. ***Investing in science is necessary***: Science underpins the solutions to many of the dynamic problems Africa is facing, including the sustainable intensification of agriculture at all scales in order to keep food prices competitive in growing cities. Science makes possible the productivity increases that reduce encroachment of farming onto fragile environments. Research-based solutions will be needed to promote value addition to agriculture products whose demand is rising through urbanization and expanding export markets both within and outside Africa. ***Andis feasible***: Africa is one of the last frontiers of arable land and a new focus for mining of minerals and oil. With proper land management regimes, social responsibility and fiscal management of extractive industries, Africa will have the financial resources for science support and rational management of its agricultural and economic development.

   ii. ***The private sector is increasingly important in agribusiness***: The role of the private sector will grow as value adding processing and new products enter markets. Private sector innovations (e.g. mobile banking, index-based crop insurance and market information) have made transformative changes for smallholders with a promise of still more changes to come.

   iii. ***National financial commitment*** by government is the key that unlocks other support, from public and private investors.

   iv. ***High rates of return on investments*** in science for agriculture, in the order of 40-60%, have been shown consistently in several global studies carried out in many different countries at various stages of development (Alene&Coulibaly 2009, Beintema & Elliot 2009, Nin-Prat & Fan 2010).

6. **African Solidarity in Science is an important dimension of the strategy for harnessing the power of science**

   Africa's partnerships in science shall be based on the principles of: i) mutual benefit; ii) mutual responsibility and iii) mutual accountability.

   In advancing the cause of science for agricultural transformation, no country should be left behind. Continental and regional organisations within Africa as well external national and international organizations can contribute towards achieving the aim that all countries of Africa are enabled to share in the advances of science. This can be accomplished by supporting the sharing of knowledge and research facilities amongst countries in order to better address common challenges, thus increasing African agricultural competitiveness.

Africa's political leadership could demonstrate their willingness to take *responsibility* for helping all countries to strengthen their science base by establishing an *"African Science for Agricultural Transformation Initiative".* Such a commitment by African Heads of State to a solidarity initiative and its funding would bring with it a commitment to openness, regional collaboration, and academic and scientific mobility, the elements of a new approach to science and agricultural transformation across Africa.

Executive summary

Background and rationale

The rationale for this Science Agenda for Agriculture in Africa (also referred to as the Science Agenda or S3A) is the imperative of having an overarching strategic framework to guide the broad areas of science that have to be developed by the African countries, their stakeholders and partnerships. The Science Agenda is about the necessary transformation of national science and technology institutions in order to achieve the desired social and economic transformation of Africa. Of priority is bringing about a more productive and efficient food and agricultural sector that as minimum guarantees food and nutrition security. The Science Agenda is an organizing framework of issues, science options, and partnerships to bring about that desired future. The Comprehensive African Agriculture Programme (CAADP), established in 2003, provides the larger frame in which the Science Agenda is operationalized. The S3A therefore is the broader framework for the implementation of 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). S3A also provides African decision-makers with the rationale for increased investments in science and technology.

Overall, the Science Agenda provides the framework and guidelines for:

- Identifying the broad areas of science to be developed in partnership with the main stakeholders
- Facilitating the necessary transformation of national science and technology institutions
- Help focus on the need for human capacity building at all levels
- Facilitate increased funding from diversified sources to support science
- Facilitate alignment of actions and resources to ensure value-for-money and desirable impact
- Facilitate effective partnerships among mandated African institutions at sub-regional/ regional levels and between these actors and their external partners.
- Committing to solidarity in science by sharing information, technologies, information, facilities and staff in pursuit of common challenges and opportunities.

One of the defining features of the Science Agenda is the premium it places on African ownership and leadership. The Forum for Agricultural Research in Africa (FARA) led the development of the S3A through a consultative process involving the broader agricultural science community and the CAADP constituency, both within Africa and globally, as well as high-level decision-makers. The Science Agenda refers to the science, technology, extension, innovations; policy and social learning that Africa needs to apply in order to meet its evolving agricultural development goals. The Agenda identifies the key strategic issues that will impact on science and agriculture and presents a suite of high-level actions/options for increasing and deepening the contributions of science to the development of agriculture in Africa at the local, national, regional and Pan-African levels.

The Science Agenda acknowledges that several studies exist that have attempted to describe an agenda, and indeed to outline priorities for science and research in Africa. Furthermore, the S3A has drawn out lessons from pertinent past continental visions, such as the *Special Programme for African Agricultural Research (SPAAR)*, the NEPAD's *Science and Technology Consolidated Plan of Action (CPA)*, as well as the AU STISA and AU Agenda 2063.

The Agenda does not purport to be a continental blue print on how Science could be nurtured and applied in support of agricultural transformation in a linear and undifferentiated manner. But rather, the Agenda should be looked at as an evolving and living framework that provides the inspiration and choices available for countries, regional, continental and global institutions and other key stakeholders in the private and not-for profit sectors.

The Science Agenda is about connecting, with a renewed vigour, science with the various dimensions and players that are critical for bringing about rapid agricultural transformation on the continent. These include connecting farmers operating at different scales with agricultural research, the new extension, and value chains. There is need for better connection between universities and agricultural research as well as communicating science more effectively with decision-makers as well as among professionals. Moreover science has to be better connected at the national, regional and continental levels with open portals to global science.

The challenge and the opportunity

The overarching agricultural challenge for science in Africa is that of low productivity across all farming systems. Among the main challenges are: a lack of coherent and conducive policies; poor incentives; poor access to input and output markets; predominant rain fed agriculture; inadequate agricultural R&D spending; heavily degraded and depleted soils; problematic land tenure systems; inadequate levels of mechanisation; many pests, diseases and weeds; and climate change. African agriculture, however, has a number of major strengths: the diversity of agro ecosystems and their natural resources providing for mixed and resilient livelihoods; active rural-urban linkages and expanding domestic urban demand for agricultural products; high efficiency of smallholder agriculture given appropriate inputs and management; large and youthful population; increased investment in education; acceleration in GDP growth; effectively coordinated agricultural development policy frameworks; rapidly growing mobile and internet connectivity; and expanding provision of infrastructure.

The strength of agriculture in Africa also lies in the multitude of successful agricultural initiatives that the continent has experienced in the immediate past and these include:

- Intensifying staple food production: e.g. banana, maize, rice, cassava

- Diversifying the value-chains: e.g. dairy, horticulture, livestock
- Developing growing export sectors: e.g. beef, coffee, cotton, tea
- Community-led soil fertility management: e.g. 're-greening of Sahel' in Burkina Faso, Niger
- Africa-global partnership to unlock production constraints: e.g. eradication of Rinderpest
- Building regional centres for excellence: e.g. CORAF's, ASARECA's commodity centres
- ICT-based marketing systems: e.g. Commodity Exchange initiatives in Kenya and Ethiopia

Africa's also has large agro-ecological diversity and farming systems. Of the 14 major farming systems, five host over 70% of Africa's rural poor, and the majority of cultivated area and livestock. These are a) Maize-Mixed; b) Agro-pastoral; c) Highland Perennial; d) Root and Tuber Crop and e) Cereal-Root Crop. The Science Agenda offers options across all the major farming systems.

The global context for African agriculture is changing rapidly and will continue to present both challenges and opportunities. The increasingly unpredictable weather events, changing pattern of disease in crops and livestock, depletion of fossil hydrocarbons and consequent increase in demand for biofuels will further heighten the challenge. Land, water and energy sources are being rapidly depleted. These developments globally have resulted in an acute demand for land, resulting in on-going controversial large-scale land acquisitions on the African continent by foreign investors seeking alternative investment options, as well as biofuel and food production. These new challenges and opportunities require Africa to have greater foresight and a science strategy for managing these anticipated global changes in agriculture and food systems. Urbanization comes with changing consumption patterns: 1) more rice and wheat (bread) at the expense of roots and tubers, 2) more high value fruits and vegetables, and 3) increasing meat, dairy and poultry consumption. The propagation of fast-food chains throughout Africa is a trend towards more processed (and in some cases less healthy) foods, thereby requiring more rigorous food safety measures.

By 2030, Africa will have to be a significant producer of food for the growing global population. This challenge is compounded by the fact that people worldwide are looking for healthier, safer and more nutritious foods and these are generally more costly to produce. In addition, the need to protect the environment also means that increasing production has to be achieved on less land, water, chemicals, waste, and GHGs. Public policies, however, have been slow in responding to these trends.

Fortunately, Africa is endowed with abundant natural resources, including about 60% of the world's arable land, some of it still virgin land. These resources, if effectively and efficiently harnessed, could reduce the threat of food insecurity. 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 S3A recognises the importance of the five 'i's: strengthening of institutions, availability and affordability of improved inputs; expansion of rural infrastructure; incentives for producers; and adequate and timely supply of information to support production and marketing decisions.

The Science Agenda in summary

The Science Agenda has six strategic thrusts: a) an enduring vision; b) CAADP as a short term priority; c) research themes that connect institutions and policies with producers, consumers and entrepreneurs; d) strengthening solidarity and partnerships at national, regional and international levels; e) sustainable financing of science and technology; f) creating a favourable policy environment for science; and g) establishing a special fund for the Science Agenda. These are discussed as follows:

1. Need for an enduring collective vision for science in Agriculture by Africa

   The vision for the Science Agenda is therefore that: ***"By 2030 Africa ensures its food and nutrition security; becomes a recognised global scientific player in agriculture and food systems and the world's bread-basket"***

   a. This calls for science to be valued better by Africa's ordinary citizens. Science can no longer be a mysterious activity, understood and appreciated by a few.

   b. Scientists, policy makers and politicians alike need to deploy a vision of science-driven agricultural transformation to African society at large.

2. **The immediate priority is implementing CAADP**

   In the short- to the-medium-term the Science Agenda is aligned with and implemented to advance CAADP's targets under the Sustaining the CAADP Momentum strategy.

3. **Research themes should connect science with needs and opportunities in African agriculture**

   a. In many countries, agricultural production is moving from subsistence systems to more market-led systems. Productivity is the result of several factors, including higher yielding crop varieties; better breeds, feed and health of livestock; the interactions of genetics with the environment; better management of natural resources, including water for rain-fed and irrigated agriculture; crop and animal husbandry; external agricultural inputs such as seeds, fertilizer, agricultural machinery and implements; access to credit to purchase inputs; availability of labour; and market access, through value chains, linking farmers to markets. The relative importance of these factors varies by country and community and by farming system. The priority themes are:

   b. ***Sustainable productivity in major farming systems***

      i. Transforming production systems

      ii. Crop improvement and crop protection

      iii. Livestock breeds, heath and feed

      iv. Aquatic and inland fisheries

      v. Agro-forestry and forestry

vi. Agricultural mechanization

c. ***Food systems and value chains***

i. Food and nutritional security, food processing, safety and storage

ii. Post-harvest handling, processing and storage

d. **Agricultural biodiversity and natural resource management**

i. Conserving and enhancement of biodiversity

ii. Land and water resources and irrigation management

e. ***Mega trends and challenges for agriculture in Africa***

i. Climate change, variability adaptation and mitigation

ii. Policy and institutional research, including market access and trade

iii. Improving livelihoods of rural communities

f. **Cross-cutting themes:** The S3A is also underpinned by three cross cutting themes:

i. Sustainable intensification: as an organising framework for enhancing productivity, at all scales of production.

ii. Modern genetics and genomics: to give better understanding of gene function, leading to more specific targeting of genetic improvement in agriculturally important species of crops, livestock, fish and trees;

iii. Foresight capabilities, including strategic planning, modelling, and analysis of 'critical technologies', as a means of systematic analysis and interpretation of data and perspectives to better understand trends and future challenges.

g. Transforming production systems in general is key across all farming systems in the African context. This includes: crop improvement and crop protection, constraints to crop production; customer-focussed plant breeding; horticultural and tree crops; and crop protection. Improving livestock production and productivity is increasingly a priority and the agenda includes: livestock production, better feeds, better breeds, better health; Aquatic systems and inland fisheries.

h. Other priorities in the agenda include: agro forestry and forestry systems; agricultural mechanization; food systems and value chains (including food and nutritional security); post-harvest handling, food processing, safety and storage; increased processing; improving food storage; and food safety; agricultural biodiversity and natural resource management; conservation and enhancement of agricultural biodiversity; land and water resources; irrigation and integrated natural resource management.

i. Mega trends and challenges for agriculture in Africa include climate change, variability, adaptation and mitigation, and urbanisation.

j. Sustainable intensification is presented as a "new paradigm" for global agriculture that Africa will pursue as a pathway to producing greater yields, better nutrition and higher net incomes while reducing over-reliance on pesticides and fertilizers and lowering emissions of harmful greenhouse gasses.

k. Biosciences, information and communications technologies

l. Information and communications technologies

m. Foresight capabilities must be strategic in orientation and must involve activities such as horizon scanning with the aim of identifying and analyzing trends, weak signals and ensuring early warning as well as developing effective strategic responses.

4. Strengthening institutional systems of science for agriculture in Africa

a. **Sustaining basic science capacity at the national level**. Each country needs its own strategy that defines its needs for science and agricultural research and a capacity to be a knowledgeable borrower of new technologies from the regional and global stock of knowledge. Weaknesses to be addressed in strengthening the national systems include poor linkages between research, education, and advisory services.

b. **Regional level**: Effective national systems are the building blocks for regional, continental and global partnerships:

i. An example of enhancing Sub-Regional Cooperation is with ASARECA, CORAF and CCARDESA, support regional commodity centres that share results with neighbouring countries (e.g. Kenya on smallholder dairying; Tanzania on rice; Ghana on roots and tubers; Burkina Faso on cotton).

ii. The SROs have represented NARS in the CGIAR and the Global Forum.

iii. RECs are supporting country implementation of CAADP.

c. **Global partnerships in science**: The CGIAR is key partner of the NARS and SROs. Recent reform of the CGIAR including CGIAR Research Programs (CRPs) targeting collaboration on specific themes is expected to improve alignment with CAADP.

5. Sustainable financing of the Science Agenda for Africa:

a. The S3A will encourage financial and technical partners, bilateral and multilateral agencies, and African partners to maintain and expand support. CAADP investment plans are a basis for commitment to financing science and technology.

b. Mobilizing revenues from Africa's growing economies is a priority of S3A. Specific activities include:

i. Building capacity of farmers' associations, finance institutions, and agribusiness agencies to work together

ii. Encouraging governments to offer tax incentives and make preferential procurement choices for companies that source from small farmers

iii. Developing inclusive financial models that combine incentives, reduce debt risk and promote longer term agribusiness models

iv. Corporate social responsibility and other philanthropic activities that could potentially endow a science foundation or similar body.

6. Creating a favourable policy environment for the performance of science

a. This will require enabling legislation and regulations. This includes biosafety, seed regulation and control, enforcement of plant breeders' rights and country-specific approach to intellectual property rights.

b. Policy messages must be "credible, salient and legitimate".
c. The Agriculture Committees of parliaments should be mobilised as allies for agricultural interests and investment in science and technology.
d. "Boundary spanning partners" or "intermediaries" may be used to interpret the scientific cause in the language of policy makers.
e. Governments may create an autonomous higher scientific body that establishes consensus on scientific issues to feed into the policy process.
f. Communication is a continuous process so that scientists keep up with a changing political landscape.
g. Strong commitment to youth and women and gender equity.

7. **A fund to promote African solidarity in science:**
   a. A special fund, the "African Science for Agricultural Transformation Initiative" (ASATI), is needed as major vehicle to ensuring that no country is left behind, and that each country has a minimum capacity to address its needs. Potential ASATI activities include: science honours; increasing scientist mobility; and engaging the African Diaspora.

In conclusion, the Science agenda is underpinned by important key messages:

- Science can and should drive transformation of agriculture and society in Africa.
- Science for agriculture in Africa is too important to be outsourced. African leaders must take responsibility for the role of science in society.
- Science is essential to preserve and use Africa's rich biological heritage, as well as indigenous and local knowledge.
- Agricultural transformation in Africa will not happen without realizing the potential of women and young people
- Now is the time to increase investments in science for agriculture in Africa, when countries have the means and opportunities to invest, and gain returns.
- African Solidarity in Science is an important dimension of the strategy for harnessing the power of science

Section I

Background to the Science Agenda

1. Introduction

1.1 Towards agricultural transformation in Africa: The rationale for a Science Agenda

Increased recognition of the role of Science and opportune timing for a Science Agenda

Agriculture – encompassing food, tree, and cash crops, livestock, pasture, fisheries and forestry – is the predominant source of employment and livelihood and a way of life for the majority of Africa's citizens. For several countries, agriculture is also the single most important foreign exchange earner (Annex 1). The growth linkages in agriculture – upstream to suppliers of inputs, equipment and services, and downstream in assembling, processing, warehousing, marketing and consumption – are greater than in other sectors. Judicious investment in smallholder agriculture is an important lever for combating food insecurity and contributing towards broader social and economic development. Moreover, Africa 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).There is a consensus within Africa that such a vital sector as agriculture needs to be transformed using the catalytic powers of science and technology.

Therefore, the development of the Science Agenda for Agriculture in Africa (S3A) stems from the recognition of the importance of science and technology in bringing about a productive and efficient food and agricultural sector on the continent. The latter is central for sustainable economic growth and wealth creation, food and nutrition security, as well as for political stability. African leaders, development partners and actors in the private sector and in the NGO and CSO communities all recognize that investments in agriculture bring high returns both economically and socially, and that such investments should take full advantage of the power of science and technology to transform agriculture (NEPAD Agency 2013).

The timing of crafting an overarching Science Agenda is opportune because it coincides with the substantial Africa-wide and global efforts being exerted to bring issues of agricultural transformation back to the centre stage of the development discourse. A strong social movement towards investing in agriculture pervades the continent complementing the resolve of political authorities to do the same. Now is also the right time to focus on a Science Agenda because Africa has the means and the necessary organizational frameworks to invest in its own agriculture and derive significant returns. Africa can now dare to invest prudently from its own resources in the science needed to transform its own agriculture (ONE 2013, NEPAD Agency 2013).

The institutional and policy context calling for a Science Agenda

In 2003 African leaders launched the Comprehensive Africa Agriculture Development Programme (CAADP) as an important framework for revitalising 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 programmes(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).

Africa has responded positively to such a clarion call by bringing back agriculture to the top of its development agenda and investing an increased proportion of its budget from a growing national income (see, for instance, Benin and Yu 2012).

However, CAADP will not achieve its aims, and the FAAP will not be meaningful, unless a strong pipeline of contextually relevant new knowledge and technologies is made available and applied to accelerate agricultural growth and is accompanied by the education and training needed to produce the requisite human and institutional capacity. Indeed, there is also a growing realisation among African policy makers that most of present day industrialised countries and emerging economies have moved up the developmental ladder by developing their own agriculture as a matter of national priority.

African leaders also appreciate the importance of investing in agricultural research and farm technology so as to lay the foundation for a more productive, competitive, and sustainable agriculture that is able to create decent job opportunities for millions of the African citizenry.

For example the Sirte Declaration on 'Investing in Agriculture for Economic Growth and Food Security', which was adopted by the Thirteenth Ordinary Session of the AU Assembly in July 2009, underlined the need for facilitating increased investment in agricultural research and development and support to strengthening Africa's scientific and technical information and knowledge base (AU 2009). In 2006, African leaders also committed to allocate 1 per cent of national GDP to research development (AU-NEPAD 2006). This was used as a basis by most analysts when deriving a target of 1 percent of agricultural GDP commitment to agricultural research (see, for instance, Flaherty 2011).

Also 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 fertiliser use to at least 50.0 kilograms of nutrients per hectare by 2015 (AU 2006). Moreover, in 2010, the Executive Council of the AU endorsed the *African Agribusiness and Agro-Industries Development Initiative (3ADI,)* which is aimed at bringing about highly productive and profitable agricultural value chains through, among others, promoting domestic value addition to agricultural commodities and effectively linking small and medium size agricultural producers to markets (AU 2010).

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. Cognisant of this, Africa has begun addressing the challenges of under-resourcing and fragmentation of public research, technology generation, education and extension services and weak linkages with broader development processes. The current move towards the establishment of national-level agricultural research councils among several African countries with the view to coordinating agricultural research and technology dissemination, and the growing emphasis given to pluralistic extension delivery mechanisms, are expected to bolster the value and impact of agricultural innovation in Africa.

Still, many African countries have national agricultural science and technology systems that are limited in terms of their capacity to effectively deliver relevant and innovative science for agriculture. Given that many small countries often straddle common agro-ecological zones and are characterised by lack of the necessary critical mass of scientists within their respective national (agricultural) research systems, regional/sub-regional collaborative research and scientific activities have become imperative. This is also in consonance with the AU agenda of regional and continental integration. Thus, along with building the requisite capacity at the national level, institutions operating at supra-national levels need to be revitalised for collaborative research and technology generation that would help address common challenges in cost effective ways.

Decentralization initiatives and the development of civil society have improved the ability of rural populations to participate in their own development and defend their interests. This, in turn, has created space for independent organizations of producers and business to flourish (NEPAD Agency 2012). The creation of the pan-African farmers' organisation (PAFO), the strengthening of regional agricultural producer organisations, as well as the rapidly increasing international private capital interest in investing in Africa's land sector, are cases in point in this regard. Under such circumstances, evidence-based policies and strategies – which are integral to the Science Agenda being advanced - are critical in mediating diverse interests and helping bring about sustainable and inclusive agricultural transformation.

This is an opportune time for Africa to be bold, aggressive and decisive in embracing and investing in a Science Agenda for its agriculture. For over a decade now, Africa has been on a growth trajectory that has enabled it to become the world's fastest-growing continent: human development in Africa has made huge leaps. A rising economy has made a big difference. Africa's growth acceleration resulted not just from a resource boom, but also from government actions aimed at improving macroeconomic conditions, bringing about political stability and creating a better business and investment climate. Africa's collective long-term growth prospects are strong, with several countries formulating credible development plans (See, for instance, The Economist 02 March 2013; MGI 2010: 8).

As will be elaborated in Chapter Two, addressing and managing emerging global trends, including the threat of climate change and climate variability and the heightened global interest in Africa's land and water resources, also require enhanced scientific capability that would enable Africa to assess the long-term impacts of such phenomena and put in place adequate safeguard measures.

The agricultural science community in Africa should seize the moment and play a vanguard role in entrenching science across the various agricultural initiatives and ensure that additional investments and policy interventions spur technical change in the sector, thereby leading to a dynamic and profitable rural economy and a source of high quality and safe food for a growing urban population on the continent and beyond.

The focus of this strategic document is on the role of science in agriculture; however, the application of science and technology alone will neither bring about the required improvement in productivity, food and nutrition security, nor reduce hunger. Other complementary, research-stimulated investments and evidence-based policies will also be required to achieve sustainable agricultural productivity growth, build resilient rural economies and bring about overall socio-economic transformation through a science-rooted agricultural development. Here, too, Africa has progressively increased investments in its technical and social infrastructure as well as in its Information Communication Technology (ICT) sector, including cellular connectivity (Brixiova et al 2011, CTA 2014).

1.2 Defining the Science Agenda for agriculture in Africa

Definition

The Science Agenda for Agriculture in Africa (S3A) refers to the science, technology, extension, innovations, policy and social learning Africa needs to apply in order to meet its evolving agricultural development goals. It identifies the key strategic issues that will impact on science and agriculture and presents a suite of high-level actions/options for increasing and deepening the contributions of science to the development of agriculture at the local, national, regional and continental levels in Africa. The Agenda's perspective encompasses the breadth of science, the meaningful engagements between disciplines and the effective transfer to end users, the outcomes of science that is necessary to unlock the potential of agriculture in Africa.

The Science Agenda recognises that advances in agricultural sciences alone are not sufficient in resolving all the challenges faced by the agricultural sector in Africa. Therefore, it is essential that a wide array of scientific disciplines be utilised to address the challenges that hinder agricultural transformation in Africa. This is why the present document is a *Science Agenda for Agriculture* and **not just** an Agricultural Science Agenda.

The Science Agenda is a long-term strategic framework that consists mainly of the range of science and technology opportunities available to bring about agricultural transformation in Africa. The Agenda also embraces the policy, financial, organisational and related institutional capacity strengthening measures that need to be put in place to realise a science-rooted agricultural transformation on the continent. These are undergirded by a vision aimed at enhancing the wealth creation potential of agriculture on the continent and strengthening Africa's capacity to feed itself and the rest of the world through embarking on world-class research and technology generation.

It should be noted at the outset that the Science Agenda cannot claim originality in terms of the specific scientific issues it proposes for agriculture in Africa to thrive. Neither does it claim to be an exhaustive document ready for guiding an enhanced application of science to agriculture in Africa. One of the main factors that distinguish the Science Agenda from previous such efforts include its realisation that technical excellence alone will not guarantee successful adoption of a science agenda. Thus, in addition to technical relevance, this Science Agenda gives due consideration to the importance of wider stakeholder buy-in and strong political commitment for its adoption and implementation.

1.3 The Science Agenda for agriculture in Africa: Purpose and expected outcomes

Purpose

The core purpose of the science agenda is, to advocate the importance of science as part of the transformation process of agriculture in Africa. As explained in the earlier section, the Science Agenda will delineate the strategic investments in science, technology and innovation for accelerated increases in productivity, equitable development and sustainably productive environments in Africa. By presenting a new vision for science and agriculture in Africa, it seeks to *influence* all stakeholders to take decisive and informed measures that would enable science to deliver on its full potential in the transformation of agriculture in Africa.

The S3A takes a multi-sector approach to development and is informed by relevant developments in other sectors beyond agriculture. Furthermore, the Agenda advocates for a balanced improvement of agricultural education and advisory services so that the potential for productivity gains can be realized both at the field and laboratory levels. The Agenda also embraces policy research because of the importance of appropriate policies in resolving technical problems and in increasing incentives for solutions.

The S3A also addresses the gender gap that exists through the marginalisation of women in access to land, farming assets, inputs and services, credit, and suitable technologies which would render their farming operations more productive and remunerative. The Agenda also takes cognisance of the imperatives for creating incentives to attract the youth into farming and agribusiness.

Several studies exist that have attempted to describe an agenda, and indeed to outline priorities for science and research in Africa. Some of the major studies include those by the Inter-Academy Council (IAC) and the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). These studies highlighted factors that were of major concern at the time and the conclusions reached were valid in that context (IAC 2004, IAASTD 2009). The Science Agenda for Agriculture in Africa builds on these previous efforts through framing the agenda in terms of the pressing issues of today and the global trends that are likely to have a bearing on the performance of agriculture in the decades to come.

Both the IAC and IAASTD studies did not put in place formal mechanisms to ensure that the outputs were acted upon and that lessons learned were documented and widely shared. Moreover, and notwithstanding the technical credibility of both the IAC and the IAASTD reports, there was insufficient effort to obtain political consensus around the findings and in cultivating an African ownership of their agendas. The Science Agenda takes this important lesson into account.

Furthermore, the S3A benefited from lessons learnt from previous and pertinent continental initiatives such as the *Special Programme for African Agricultural Research (SPAAR).* SPAAR's vision of an agricultural research system that includes institutional and capacity building dimensions has been duly considered as integral part of the innovation systems perspective advocated for in the Science Agenda. In addition, insights were also obtained from strategies and medium-term operational plans of sub-regional agricultural research organisations (SROs) and regional networks for higher education on the continent.

The Science Agenda is designed to benefit from, and add value to CAADP and other AUC-NEPAD strategic frameworks, including NEPAD's Science and Technology Consolidated Plan of Action (CPA), AU Science, Technology and Innovation Strategy for Africa 2024 (STISA2024), and the AU Agenda 2063.

The concept of sharing research and technical infrastructure among African countries and establishing 'centres of excellence' on science and technology has been a central recommendation of the various deliberations on the development of science and technology capacity in Africa. The Science Agenda for Agriculture in Africa endeavours to adopt this concept.

The Science Agenda recognises that the needs and specific capacity gaps characterising African countries vary considerably. Therefore, the Agenda does not claim to be a continental blue

Box 1: What the Science Agenda promises

Africa realises the imperatives of having an overarching strategic framework in the form of a Science Agenda for Agriculture so as to: guide the broad areas of science to be developed in partnership with the main stakeholders; The Science Agenda will therefore;

- facilitate the necessary reforms and transformation of national science and technology institutions;
- help focus on the need for human capacity building at all levels;
- facilitate increased funding from diversified sources to support science;
- facilitate the alignment of actions and resources to ensure value-for-money and desirable impact and;
- facilitate effective and need-based partnership among mandated African institutions at sub-regional/regional levels and between these actors and their external partners

print about how science should be nurtured and applied in a linear and uniform manner for agricultural transformation. But rather, the Agenda should be regarded as an evolving and living framework that provides options and choices in the pursuit of a science-rooted agricultural transformation in Africa. The Science Agenda should as well be considered as providing guidance to partners and African institutions on how they can support choices made at the lowest level where they can be achieved efficiently.

In a nutshell, the Science Agenda is about connecting, with a renewed vigour, science with the various dimensions and players that are critical for bringing about rapid agricultural transformation on the continent. These include connecting farmers operating at different scales with agricultural research, the new extension, and value chains; connecting universities and agricultural research to ensure more integrated planning for capacity needs and ensuring greater relevance for agricultural development; communicating science more effectively to decision-makers as well as among professionals; connecting science at the national, regional and continental levels with open portals to global science; connecting science and its application across such fields as life sciences, geographical sciences and information and communications breakthroughs; connecting fundamental knowledge about resources and constraints, modelling scenarios, and agricultural research; connecting scientists within Africa through joint programming and enhanced Africa-wide mobility.

Expected outcomes

It is expected that the Science Agenda will provide African decision-makers with the rationale for increased investments in scientific assessment, technology generation and use, for the enactment of evidence-based policies, and for innovation processes that will strengthen the contribution of Science to Africa's agricultural development.

It is also expected that the agricultural research system will be streamlined at all levels and that evaluation systems will be developed for measuring the impact and returns from initiatives and innovations for agricultural transformation. Furthermore, the Science Agenda is expected to enhance the engagement of Africa's tertiary agricultural educational institutions (TAEIs) in the national agricultural research systems and agricultural development frameworks such as CAADP.

It is further expected that the Science Agenda will provide guidance on the financing principles that would inform funding levels and priority areas of investments in science. In this connection, the Agenda is also expected to strengthen the human resources and institutional capacities and improve the processes and infrastructural assets required to transform agriculture into a dynamic economic sector that can shoulder the historic roles expected of it in the development process in Africa Therefore, the Science Agenda is expected to be of significant utility to a range of key stakeholders, including high-level decision makers at national level, science and agriculture techno-structures within the AU organs and institutions, national agricultural research institutes, sub-regional and regional research organisations, national universities, farmers and their organisations, agribusiness and value chain actors, CGIAR and other Advanced Research Institutions.

Finally, it is expected that, the Science Agenda will link the technical with the political and be institutionalised within the AU system.

1.4 The process of developing the Science Agenda

The formulation of a Science Agenda is sanctioned by the AU Commission and the NEPAD Agency and key recommendations of the Science Agenda work will be deliberated on by AU high-level organs, resulting in Summit-level Decisions in June 2014.

One of the defining features of the Science Agenda work is the premium it places on the imperatives of African ownership and leadership. Indeed, the Forum for Agricultural Research in Africa (FARA) has led the development of the Agenda, and this document has been prepared by an African-led Expert Group through a consultative process involving the broader agricultural science community and rural development professionals in Africa as well as high-level decision-makers on the Continent. In addition, the process ensured that buy-in was obtained from international technical and financial partners by involving them in providing inputs to the background documents as well as in providing space for them in the peer review and oversight structures established in support of the S3A.

The formulation of the Science Agenda has been informed by processes that began in January 2013 and continued in earnest with the development of a detailed Discussion Paper, which contains much of the background information that served as a basis for the formulation of this Science Agenda document. Furthermore, the present document distils the views of stakeholders on the critical issues that need to be considered for the implementation of a Science Agenda. Details on these issues have also been synthesised and documented separately. The reader is, therefore, encouraged to consult the 'Discussion Paper' and the 'Outcomes of Stakeholder Views' documents (www.fara-africa.org/science-agenda) for an in-depth understanding of the evolution of the issues informing the Science Agenda. (Annex 2 also provides a summary of the development process for the Science Agenda.)

1.5 Structure of the document

The document is presented in 3 sections. This first section presents the background to the Science Agenda includes 2 main chapters; the introduction and Chapter Two which provides an overview of the changing continent-wide and global context within which the Science Agenda will be pursued. This is discussed through an assessment of the production systems that characterise agriculture in Africa and the mega trends that are likely to affect agricultural transformation on the continent. The second section presents the science agenda itself and is organised under two chapters; Chapter Three which gives an account of the contribution of science to the performance of agriculture in Africa. On the basis of these assessments, and the mega trends described in the preceding chapter, this chapter concludes by providing an overarching vision for the Science Agenda for 21st century Africa. Chapter Four further elaborates the vision through identifying the critical thematic focus areas for a Science Agenda for Agriculture in Africa. The last section considers the critical elements for realising the science agenda vision to ensure sustainable implementation. This section contains 5 chapters; Chapters four, five and six discuss the organisational/institutional, human capital, financial, and policy commitments that need to be put in place to realise the vision of science-rooted agricultural development in Africa. The chapter places particular emphasis on the importance of partnerships and collaboration at national, regional and global levels in implementing the Science Agenda. Chapters seven, eight and nine outline key considerations that need to be taken into account to mainstream science in society and entrench the African ownership and leadership of the Science Agenda at all levels of implementation. The chapter also makes a case for strengthening African solidarity in the pursuit of the Science Agenda. Chapter nine provides a brief summary of the salient features discussed in this document.

2. Context for developing and applying the Science Agenda

2.1 Africa's diverse agricultural production systems and their potentials

The overarching agricultural challenge for science in Africa is that of low productivity across all farming systems. A review of performance of agriculture over the last 50 years showed that Africa has generally lagged behind other regions of the world, although there were periods where agriculture performed rather well. Moreover, the productivity gap is widening over time. Growth in agricultural total factor productivity (TFP) – a broad index that compares the total output of crops and livestock commodities to the total inputs of agricultural land, labour, capital and material resources – has been about 2 percent per year for developing countries as a whole, twice the rate of agricultural TFP growth in SSA (Fuglie&Rada, 2013).

There are many challenges that Africa faces in improving the performance of the agricultural sector These challenges include: a lack of coherent and conducive policies; poor incentives; poor access to input and output markets; a predominantly rain fed agriculture; inadequate agricultural research and development (R&D) spending; heavily degraded and depleted soils especially in densely populated regions; problematic land tenure systems; inadequate levels of mechanisation; many pests, diseases and weeds; and climate change. On the other hand, African agriculture also has a number of major strengths: the diversity of agro ecosystems and their natural resources providing for mixed and resilient livelihoods; active rural-urban linkages and an expanding domestic urban demand for agricultural products; high efficiency of smallholder agriculture given appropriate inputs and management; large and youthful population; increased investment in education; acceleration in GDP growth; effectively coordinated agricultural development policy frameworks; rapidly growing mobile and internet connectivity; and expanding provision of infrastructure.

The strength of agriculture in Africa also includes the many successful agricultural initiatives that have recently been implemented in the continent. Examples of such initiatives include the following:[1]

Intensification of staple food production: Over the years, considerable achievement has been registered in the domestication and intensification of a range of staple crops throughout the continent. Examples include the breeding of a wide range of varieties of banana in the eastern and central African highlands; the development and diffusion of high-yielding varieties of maize in east and southern Africa that are also credited with improving the productivity of millions of African farmers and moderating food prices for urban consumers; productivity gains in cassava through breeding and improved pest control measures. Also, successive campaigns to control mealy bugs and Green spider mites have demonstrated the essential role that advanced science and biological control can play. Critical contributing factors to these success stories were a comprehensive and long term public support package and the provision of public funding to critical stages of research as was the case for Cassava.

Commodity diversification: Dairy production in Kenya, spurred by improved veterinary services and availability of better feed and breeds and effective marketing systems, have liberated millions of smallholder farmers to grow out of poverty. Conducive government policy with respect to small scale dairy production and marketing were said to be key to the success of the dairying in Kenya.

Development of a booming export sector: Botswana has developed a modern beef exporting industry, serving this otherwise agriculturally ill-endowed country as the backbone of her economy. Productivity gains in cotton production, including the profitability of genetically modified (GM) cotton in countries like Burkina Faso, have made West Africa the world's third largest cotton-exporting block. In addition, integrated farm-level research and technology development, financed largely by the private sector, has enabled tea and floriculture to be dominant sources of export earnings in East Africa in general, and Kenya (tea and flower) and Tanzania (coffee and tea), in particular.

Instituting community-led sustainable soil fertility management regimes: As part of the drive towards 're-greening of the Sahel', in Burkina Faso and Niger, community-based knowledge in the form of traditional practices, as well as experimentation by small farmers, helped transform the Sahelian region into productive agricultural landscapes. Protection of trees, digging of pits to concentrate manure, and construction of contour bunds to control rainfall and run-off to combat erosion were innovations upon which "sustainable intensification" programmes can be built.

Effective Africa-global partnership to unlock key production constraints: Some of the successes depended on regional (including AU specialised technical agencies) and international scientific collaboration that involved national scientists. For instance, the successful eradication of Rinderpest was implemented in conjunction with AU/IBAR (Inter-African Bureau for Animal Resources) and the AU/PANVAC (Pan African Veterinary Vaccine Centre) and the OIE (World

1. This section leans heavily on two compilation of agricultural success stories in Africa: (i) Haggblade, Steven and Peter B. R. Hazel. 2010. *Successes in African Agriculture: Lessons for the Future.* Baltimore: The Johns Hopkins University Press (published for the International Food Policy Research Institute). (ii) Spielman, David, J., and Rajul Pandya-Lorch. 2009. *Highlights from Millions Fed: Proven Successes in Agricultural Development.* International Food Policy Research Institute.

Organisation for Animal Health) globally, together with national veterinary services and livestock keepers, especially pastoralists in Africa.

With regard to crop production, the New Rice for Africa (NERICA) was developed by the Africa Rice Centre, formerly the West Africa Rice Development Association (WARDA), as a cross between the Asiatic rice, known for its high yield, and the African rice species, known for its hardiness. As these rice species will not normally interbreed, modern tools of biotechnology were used. The release of NERICA in 1996 by Africa Rice gave a boost to rice production, especially in West and Central Africa. Tea and horticulture research in Eastern Africa has also benefited from international collaboration.

Building (sub-) regional centres for excellence: Sharing of research facilities and collaborative undertakings has also been tried out – with varying degrees of success – in Africa. The most recent examples in this respect include CORAF's and ASARECA's experience with regard to establishing at different locations of the sub-regions commodity-specific centres for excellence to also serve in the dissemination of pertinent technologies throughout the sub-region. On the other hand, BecA, an AU/ILRI (International Livestock Research Institute) institutional innovation, has to date offered the greatest opportunity for on-the-job training in genomics to African scientists, as well as sharing its advanced laboratories with many countries and regions of Africa.

Establishing ICT-based marketing systems: At the national level, institutional innovations in agricultural marketing, such as the Commodity Exchange initiatives in Kenya and Ethiopia are of considerable value, for such mechanisms improve produce marketing through assuring commodity quality and quantity and prompt payment and delivery arrangements.

In charting a new vision for the Science Agenda, due attention has been given not just to the individual success stories, but also to the critical factors that engendered such outcomes. This Science Agenda shares the view that past success cannot be a substitute for strategy and that in order for such successes to stimulate broader and more sustained processes, they have to be backed by effective policies and appropriate levels of investment. Details on these are provided in Chapter Five.

Africa's Agro-Ecological[2] diversity and Farming Systems[3]: The large size of the continent, its enormous agro-ecological diversity and different socio-cultural patterns of human settlements have led to the emergence of a wide range of distinct farming systems, each with its own agricultural land use rationale and organization. These systems differ both across and within the continent's major agro-ecological zones and range between large-scale capital intensive farming systems and small-scale intensive systems. A very high proportion of African farmers are small-scale producers whose farming embraces multiple cropping, tree products and livestock.

Dixon and Gulliver (2001) and Dixon *et al*. (2014) identified sixteen African agricultural systems using a variety of tools including agro-ecological and socio-economic variables derived from spatial data, agricultural statistics, household surveys, agricultural research results as well as expert knowledge (Figure 2.1). Characteristics of these systems are presented in Annex 3.

2. Agro-ecological zones are land regions sharing similar combinations of soil, landform and climatic characteristics
3. A farming system is a population of crop and livestock enterprises that share similar patterns of farm activities and household livelihoods, including their level of crop-livestock integration and their scale.

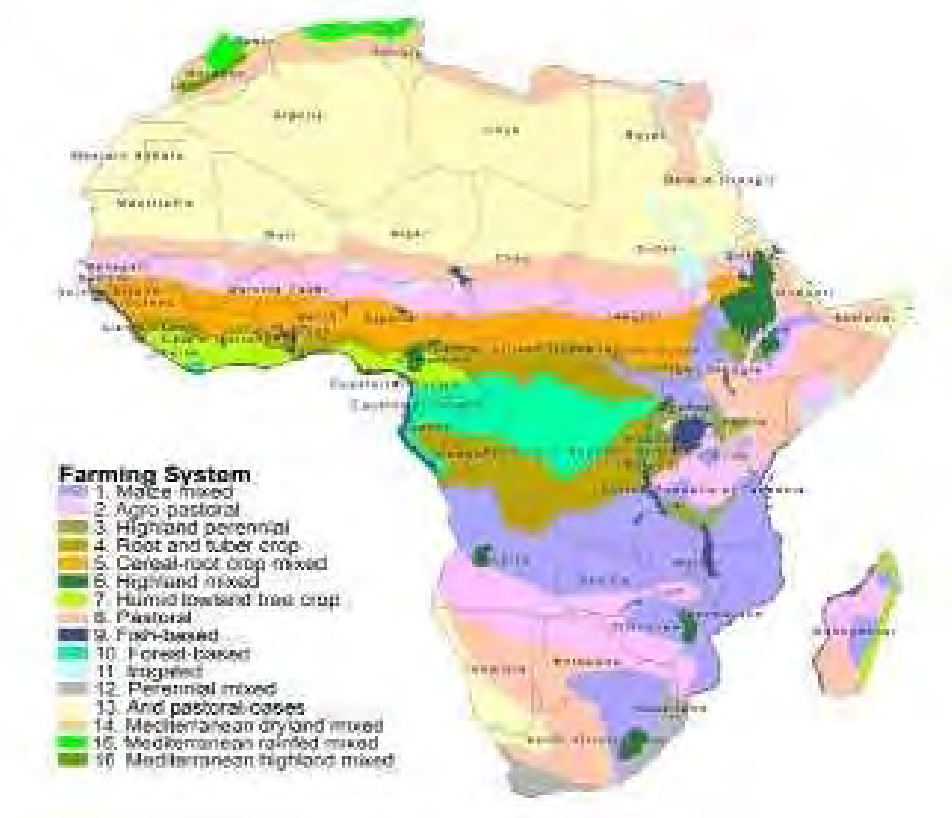

Figure 2.1. African Farming systems

Over 70% of Africa's rural poor who cultivate crops and rear livestock are found in 5 of the farming systems types, which are: Maize-Mixed; b) Agro-pastoral; c) Highland Perennial; d) Root and Tuber Crop and e) Cereal-Root Crop. Development strategies based on science and technology solutions vary from one system to the other and include: i) intensification; ii) diversification; iii) increased farm/herd size; iv) increased off-farm income; and v) exiting from agriculture

The complexity of the agricultural landscape in Africa can also be looked at from the perspective of the demand side of African agricultural markets. In particular, 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.

The "development domains" approach attempts to incorporate the dimensions of market access more explicitly, both in terms of proximity to roads as well as to population centres. When overlaid with measures of agricultural potential and suitability, it provides a stronger indication of where economic incentives might be more easily created and leveraged for agricultural growth and transformation[4].

2.2 Mega trends and associated challenges and opportunities for African agriculture

Global context impacting on agriculture in Africa

The global context for African agriculture is changing rapidly. This will present both challenges and opportunities for an African continent that is also changing fast. Africa's economies and agriculture are now growing following periods of stagnation and decline.

The Science Agenda for Agriculture in Africa is therefore contextualised in a dichotomy of a positively growing African economy, yet located in an increasingly unstable and unsustainable global agriculture and food system. The world's population is growing, reaching about 8.9 billion in 2050 (UN-DESA 2004: 4). Africa will be the only continent with sufficient land and water to feed the world (see, for instance, World Bank 2009, 2013, Nwanze 2013). The challenge is compounded by the need to produce healthier, safer and more nutritious food on less land, water, chemicals, waste, and greenhouse gases (GHGs) for sustainability. This is why the vision for the Science Agenda goes beyond Africa feeding itself to feeding the world through world-class research.

The main mega trends

Increased population and urbanization

Africa's population is set to double to about 2 billion by 2050 and urbanisation is projected to reach 50% by 2030. Africa maintains the highest population growth rate in the world of 2.465 per annum (UN DESA, 2013). This high growth implies a fast growing demand for food, feed and fibre. According to www.africa-youth.org/Africa youth about 65% of Africa's population is below 35 years old. No other continent has a more youthful population. Moreover, it is estimated that in the next few decades most countries in Africa will experience tremendous population growth in their major urban centres[5] (Losch et al 2013). This presents both challenges and opportunities for agriculture. The challenges centred on making agriculture attractive for the youth generally find it unattractive (see, for instance, Brooks 2013). The opportunity is the potential demographic dividend flowing from a youthful population. This will materialise only if it is deliberately and carefully nurtured.

Urbanization comes with changing consumption patterns: 1) more rice and wheat (bread) at the expense of roots and tubers, 2) more high value fruits and vegetables, and 3) increasing meat, dairy and poultry consumption. The propagation of fast-food chains throughout Africa is a trend towards more processed (and in some cases less healthy) foods, thereby requiring

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4. Chamberlin et al 2006; Wood et al 1999
5. Even at that point, rural development will still be of high importance because the rural population densities will have actually increased due to population growth.

more rigorous food safety measures. However, public policies have been slow in responding to these trends.

Climate change

The increasingly unpredictable weather events, changing pattern of disease in crops and livestock, depletion of fossil hydrocarbons and consequent increase in demand for biofuels will further heighten the challenge (see, for instance, SEI 2008: 18-19). Moreover, land, water and energy sources are being rapidly depleted. These developments globally have resulted in an acute demand for land, resulting in on-going controversial large-scale land acquisitions on the African continent by foreign investors seeking alternative investment options, as well as biofuel and food production (Deininger&Byerlee 2011). These new challenges and opportunities require Africa to have greater foresight and a science strategy for managing the anticipated global changes in agriculture and food systems.

The above trends indicate an overall growth in global demand for food of some 70 percent by 2050 (FAO 2009). Future increases in agricultural production will have to come from both intensification of existing land in the form of yield increases and higher cropping intensities and from expansion into new land (in limited areas of the world). In this case, science will be critical raising yields sustainably, identifying domains and technologies for sustainable expansion, and in addressing the related social equity issues.

Climate change has the potential to irreversibly damage agriculture's natural resource base, with alarming consequences for food security. Climate change could also significantly limit economic development in those developing countries that depend to a very high degree on agriculture. Climate change can lead to the spreading of a range of diseases and pests that have hitherto been contained or at manageable levels. Many countries in Africa will experience extreme weather events (droughts, floods, etc.)(SEI 2008, UNCTAD, 2013).

Meeting the challenge of food security and broader development objectives while mitigating and adapting to climate change requires political commitment to invest in science and technology, to prioritise climate resilience and adaptation, and increased productivity; in agriculture.

Implications for Africa

These mega trends have opened new market opportunities, increased the potential availability of foreign capital and technology, while creating new competitive pressures on African agriculture, especially the new global demand for land in Africa. Among the most important changes over the past 20 years in the global context in which African agricultural development occurs are the following: new market opportunities for African farmers to export high-value markets; emergence of sophisticated supply chains for agricultural products destined for regional export markets and high-end domestic markets..In addition, biotechnology offers the scope for much more rapid conventional breeding and transgenic engineering; the information revolution has greatly expanded the scientific opportunities, reduced isolation, and improved market information; and the emergence of growing economic powers such as China, India and Brazil has increased the demand for agricultural raw materials, such as cotton and cashews.

2.3 The productivity challenge

The African productivity improvement challenge has become more urgent than ever in view of the foregoing challenges. In addition to becoming more productive, African agriculture must become more competitive and profitable. It must be linked to consumers through efficient markets, and it must be capable of responding to market opportunities and requirements in terms of the products demanded, the quantities required and ever-higher specifications and quality standards. In addition, it needs to be an agriculture that helps reduce the vulnerabilities of poor rural people to risks and shocks and one that does not diminish, but rather helps to protect or renew, the natural resource base. Finally, it must help underpin rural transformation by contributing to poverty reduction, food and nutrition security, and broad economic development.

All these point to the need to invest more in science for sustainable intensification, foresight activities and capabilities and which can adapt to and help mitigate climate change impacts. Science must enable farmers to make more efficient use of fertilizers, pesticides, land and water. Approaches used must not cause further pollution, must be environmentally sustainable, preserving or enhancing soil fertility and protecting biodiversity and help make farming systems more resilient to shocks and stresses.

These trends too have implications for the science agenda in terms of building better local supply chains, instituting food safety regulation mechanisms, and addressing, in the longer term, changes in the consumption patterns of Africans as they increasingly embrace less sustainable diets. Moreover, as modern agricultural value chains grow in Africa and become more complex, greater attention will need to be paid to the broader value chain.

Impact of ICT Innovations

ICT can play a crucial role in benefiting the resource-constrained farmers with up-to- date knowledge and information on agricultural technologies, best practices, markets, price trends, and weather conditions. Experiences in fast developing economies indicate that rapid development of ICT has significantly facilitated the flow of data and information among farmers and decision-makers alike. In Africa, M-PESA Kenya is the leading mobile phone-based financial transaction scheme that benefitted millions of the country's citizenry, including those in remote farming and pastoralist villages (CTA 2014, World Bank 2011: 36 – 38). Several African countries, in collaboration with their technical and financial partners and the private sector, have instituted web-based portals including off-line versions that contain research outputs, information on improved agricultural practices; market related information, extension packages for a wide range of crops and livestock as well as on agricultural risk management (see, for example, World Bank 2011: 133 – 136; 267 - 280).

Given the heterogeneity in farming systems, transformation in African agriculture must be pursued using diverse approaches. Systems solutions must be employed. Continent-wide strategies which provide an overall framework must be adapted to fit the local context. The Science Agenda acknowledges this reality.

Section II

The Science Agenda for transforming agriculture in Africa

3. A vision for a science-driven transformation of Africa's agriculture

3.1 Introduction

Investment in science for agriculture is expected to yield the technological solutions and products that will increase productivity of labour, land, water and other natural resources available to producers. The potential for agriculture to grow faster and contribute more effectively to widely shared development in Africa is greater now than at any time since the 1960s. This is due to new opportunities arising from the changing socio-economic and political contexts both within Africa and globally (see, for example, World Bank 2009, Nwanze 2013). The renewed belief by African leaders in agriculture as a precursor to broader social and economic transformation, and evidence of successes in African agriculture all serve as the basis for learning and a foundation for more widespread and sustained agricultural growth in the continent.

Since the late 1990s several African countries have succeeded in sustaining a rapid rate of agricultural growth, although this is yet to reach the 6 per cent average annual growth rate that NEPAD estimated as necessary to meet the Millennium Development Goal of cutting poverty in half by 2015. In the preceding decades, especially during the 1975 – 1995 period, Africa underinvested in agriculture and some of the damage will take time to repair (see, for example, Benin et al 2010, Benin & Yu 2012).

The Science Agenda is expected to be Africa's collective commitment to rehabilitation as well as a call for new investment into science and technology as a means of accelerating growth in agriculture.

3.2 How science will transform agriculture in the next decade

Given the huge heterogeneity of Africa, including the complex nature of the African systems of crop and livestock production, no single Asian-style green revolution is likely to drive the required growth. Rather, Africa will need to develop a series of differentiated agricultural revolutions suited to its varied ecological niches, farming systems and market opportunities (IAC, 2004). Yet, it is essential that the critical factors that militated against the realisation of large-scale green revolution in Africa be addressed.

The Five "I"s of African agricultural transformation

The available evidence points to the importance of the five 'i's in agricultural transformation: strengthening of *institutions*, including investment in agricultural research and development; availability and affordability of improved *inputs*; expansion of high quality rural *infrastructure*; *incentives* for producers to enhance their uptake of technology, including an optimally functional market system; and adequate and timely supply of *information* to support production and marketing decisions (Synthesised from Swanson et al 1997 & World Bank 2008). All these factors require investment in people and investment into capacity of key institutions. Although technology, infrastructure and people are all important for transformation, the primary force for broad based transformation and change is in people and their capacity to change their situation.

Recent international experience among emerging economies bears out the 5 "i"s (see Annex 4): In particular, Brazil's agricultural success story is largely built on the effective functioning of its Agricultural Research Corporation (Embrapa). In China, incentives for farmers to meet market demands were supported by public investment for infrastructure and small-farmer oriented agricultural research and education, all as part of a broad, co-ordinated agricultural transformation agenda. Effective linkage between research and extension helped Korea to achieve self-sufficiency in rice with its Green Revolution in a short period of time. In Thailand, agricultural success has been achieved primarily through private initiative, with the state playing a strategic role in setting an investment climate, investing in roads and research, and supporting agricultural credit to overcome market failures.

In order for science to transform agriculture and help Africa anticipate and respond to emerging challenges, each nation must reach a consensus with respect to addressing, with sufficient political, policy and resource backing, the key determinants of success as discussed in the five 'i's above.

3.3 Demystifying science

Science is indispensable as a long-term part of Africa's transformation process. For agriculture in Africa to be more productive, competitive, sustainable, and inclusive, scientific solutions need to be pursued through an integrated approach that takes cognisance of the fragility of

African environments, its rich biodiversity and the complexity of the agricultural production systems. Moreover, this role of science is even greater in the long run as new and more complex challenges and opportunities face the agriculture, food and nutrition, as well as the associated natural resources sectors. This calls for science to be valued better by Africa's ordinary citizens. Science can longer be a mysterious activity, understood and appreciated by a few.

Scientists, policy makers and politicians alike need to deploy a vision of science-driven agricultural transformation to African society at large. This to a degree requires a mind-set change on the part of leaders and scientists, who have to believe more in the ordinary people and farmers as the main source of transformation. Socialising and de-mystifying science, in of itself, should be regarded as a scientific endeavour.

As the world of science is being increasingly de-mystified, knowledge and skills can be acquired more quickly and from non-conventional forms of research, education, extension and training. These boundaries are getting thinner as the business sector in particular makes in-roads into knowledge, educational and extension activities previously thought to be the preserve of the public sector. The pluralism that is growing in the broad community of science, innovation and technology now makes it imperative for national and regional systems of research and innovation in Africa to seek for lower cost and more effective ways of doing business while achieving even greater impact.

The imperatives of institutional reform

The Science Agenda requires systemic capacity at national and regional levels to address researchable issues and challenges in the short, medium and longer term. Management, governance, and institutional reforms need to be driven by a problem-solving culture, deeper and broader understanding of producers' circumstances, challenges and opportunities, as well as a greater understanding of the innovation environment as a whole, especially the interface and nexus between various public and private investments and capabilities spanning science, technology and innovation, education, human and institutional capacities. Science for agriculture in Africa now requires greater levels of organizational and team learning, ability to learn fast, integrate and co-create new knowledge, as hallmarks of an innovation system that will continue to be relevant.

Africa's educational, research and extension systems have to integrate in order to excel at science and achieve greater efficiency, relevance and effectiveness. All this may require a fresh look at governance and management issues at all levels given that the required transformation

Box 2: A people-centred Science Agenda

This Science Agenda is premised on the belief that people largely drive change, and therefore science will make greater difference the more it transforms the situation through people, as the people themselves transform. Informing and educating society to bring about and sustain the desired changes, requires agricultural scientists to integrate knowledge with other non-agricultural disciplines, and vice versa, and offer learning and knowledge activities and options, not only in the schooling and educational system, but also publicly and socially through use of mass and social media.

in an innovation system is increasingly a space for new-age leadership that is constrained by neither tradition nor traditional knowledge boundaries. The leadership required is one with a deeper stewardship mentality, always looking for lower cost and more effective ways of putting up teams, focusing on problems and opportunities, and generating greater financial and economic returns to public and private investors in science.

3.4 Vision of the Science Agenda

The growing population world-wide is increasingly conscious of what its eat, and people are looking for healthier, safer and more nutritious foods, and these are generally more costly to produce. In addition, the need to protect the environment also means that increasing production has to be achieved on less land, with less water, chemicals and waste, and generating lesser GHGs for sustainability.

The Science Agenda is an instrument for mobilising the physical, human, institutional financial and policy resources required to achieve these multiple objectives. Its vision is that:

"By 2030 Africa ensures its food and nutrition security; becomes a recognised global scientific player in agriculture and food systems and the world's breadbasket"`

The vision of the Science Agenda is based on the conviction that science for agriculture in Africa is too important to be outsourced to external actors. African countries must build the basic science capacity to participate in the transformation of African agriculture. This will entail making domestic investments in science for agriculture, commensurate with the size and economic status of each country.

The S3A is a framework for establishing Africa as a player, contributor and beneficiary of global science for agriculture. It is underpinned by principles of solidarity among African scientists, support for action at the national, sub-regional and continental levels, and open collaboration horizontally among scientists and vertically with regional and global centres of excellence.

In the short- to the-medium-term the Science Agenda should be aligned with and be pursued to advance CAADP's targets under the Sustaining the CAADP Momentum strategy. This is predicated on the realisation that CAADP is the single most important programmatic and partnership development framework that the AU institutions and Member States have embraced for the renewal of agriculture on the continent. It should be appreciated that the first decade of CAADP (2003-13) confirmed that science and technology are at the heart of all four pillars of CAADP.

Following a recent strategic review of CAADP (NEPAD Agency 2012), leading the 'Sustaining CAADP Momentum' strategy into the next decade, the issue of a science agenda for agriculture in Africa is addressed within the rubric of *'Knowledge and Learning Support'* that targets the spectrum of players across the agricultural value chains. Overall, the outcome-level priorities of CAADP in the next decade to which the Science Agenda will have to contribute are:

- increased agriculture production and productivity;

- better functioning agriculture markets, increased market access and trade;
- increased availability and access to food and access to productive safety nets; and
- Improved management of natural resources for sustainable agriculture production

In the light of current global dynamics and internal changes in Africa, now is the opportune time for African governments collectively to commit themselves to the bold step of building on the successes of CAADP by deciding on the additional policy and financial interventions to spur new investments. In particular, building on and scaling up the gains made thus far on the continent and learning from the examples of countries such as Brazil, China, Thailand and South Korea, it can be envisaged that an African agricultural sector will emerge where increased productivity, competitiveness, enhanced food security and greater sustainability of food systems will be the reality. Such a drive towards new and increased investment in science in African agriculture must involve all relevant parties working within a common, agreed-upon agenda that addresses the role of science in meeting long-term development goals.

3.5 Goals and main actions

Strategic goals

The main strategic goal is to increase public and private sector investment into agriculture R&D and at least double the volume of investment by 2030. Moreover Africa should be significantly reducing its dependence on donor funding for research during the same period.

Other complementary strategic goals include:

- Build capacity at the national level to critical mass and ensure implementation in higher agriculture education
- Promoting solidarity among African countries in building shared science capacities, growing some national centers into regional Centers of Excellence, sharing technologies across countries and regions including sharing information, facilities and staff.
- Mainstreaming the visibility of science at the community level, and improve the working capacity of young researchers.
- Generate data and knowledge that informs the policy process, and strengthen the legislative processes to promote better policies and budgets for agriculture and related R&D.
- CGIAR systems reforms need to contribute to STI and continue to improve on alignment with CAADP.
- Establish an Agricultural Research and Development fund in each country, and at regional and continental level.

Short-term goal: Increase domestic public and private sector spending and create the enabling environment for sustainable application of science for agriculture.

Medium term goal: Build basic science capacity at national and regional levels with special attention to the youth and women.

Long-term goal: Double current level of Agricultural Total Factor Productivity (ATFP) by 2025 through application of science for agriculture.

Actions for short-term goal:

1. Adopt the Science Agenda for Agriculture in Africa as the principal vehicle and framework for operationalizing the AR4D component of *Sustaining the CAADP Momentum.*
2. Develop and implement country and regional specific strategies and operational plans for implementing the Science Agenda for Agriculture in Africa within the frame of National Agriculture Food Security Investment Plans (NAFSIPs) and regional investment plans.
3. Establish an African Science for Agriculture Transformation Fund (ASATF), in consultation with key African financial institutions (e.g. the African Development Bank (AfDB) and the International Fund for Agricultural Development (IFAD)), a funding mechanism for science, technology and innovation to mobilize additional resources for purposes of up-scaling successful agricultural innovations in Africa.
4. Increase national budgetary allocations for science and innovation for agriculture.
5. Set up Chairs in universities as vehicles for attracting investment from the private sector.
6. Promote the adoption of IAR4D through the development of functional innovation platforms at country level.

Actions for medium term goal:

1. Mobilize collective action to take advantage of science and technology in resolving common problems across member states and building the basic science capacities.
2. Develop and mainstream a framework for human capital formation in science, technology and agri-prenuership in schools, colleges, vocational institutions and universities.
3. Support regional mobility programmes.

Actions for long-term goal:

1. Develop appropriate technologies, policies and institutional innovations for increasing total factor productivity
2. Promote access to and use of factors of production including new varieties and breeds and inputs by end users.

Main assumptions over the next 2-5 years:

- African political leaders, that is Ministers of Agriculture, and the Heads of State support and approve the S3A and adopt its implementation in 2014 and pave way for accelerated implementation as aligned to CAADP.
- Implementation of the Science Agenda to deliver result 2.1 of the Sustaining CAADP Momentum Results Framework based on its targets/assumptions.
- Curriculum reforms active for universities and technical agricultural education so as to make curricula more relevant
- Agricultural R&D more attractive to the youth

4. Science Agenda themes

4.1 Introduction

The focus of this chapter is on the range of science and technology opportunities available to increase agricultural productivity, competitiveness, wealth creation, resilience and sustainability, and thus contribute to enhanced food and nutritional security in Africa. The thematic areas discussed here are illustrative of science and technology opportunities in Africa, rather than being an exhaustive list of priorities. Specific priorities will be determined at the national, regional and continental level in response to demand.

The thematic areas are grouped into four categories: ***sustainable productivity in major farming systems; food systems and value chains, agricultural biodiversity and natural resource management, and responses to mega trends and challenges for agriculture in Africa.*** Furthermore, the Science Agenda is underpinned by three cross cutting themes, where the application of modern science will play a major role in Africa's agricultural transformation:

- ***Sustainable intensification***, as an organising framework for enhancing productivity, at all scales of production.
- The potential for ***modern genetics and genomics*** to give better understanding of gene function, leading to more specific targeting of genetic improvement in agriculturally important species of crops, livestock, fish and trees;
- ***Foresight capabilities***, including strategic planning, modelling, and analysis of 'critical technologies', as a means of systematic analysis and interpretation of data and perspectives to better understand trends and future challenges.

4.2 Sustainable productivity in major farming systems

This research theme is about enhancing food availability and fibre productivity. While better management practices can reduce the existing yield gaps, productivity gains necessary to meet future food demand (under conditions of constrained resources and with potentially adverse impacts from climate change) require developing new crop varieties and livestock breeds that have higher and sustained productivity levels that would also meet the challenges of tomorrow. The focus here will be on breeding and genetics for major crops and livestock, vaccine and diagnostics development for livestock diseases, and better management policies and practices for fish to increase the yield potential and provide solutions for major production constraints.

Transforming production systems

The complexity and importance of farming systems in the African context highlights the critical importance of adopting a systems-led approach. Scientific research must embrace a broad agenda, spanning biophysical, policy and social elements of key production systems. Combined with research on natural resources at the systems level, this thematic area stresses the integration of research advances on specific commodities (crops, livestock, etc.) within production systems.

This thematic area also focuses on natural and social science research to examine impacts, particularly interaction effects, of component technologies to increase systems-level productivity and sustainability. Research within the systems context will contribute to improved stability of food production, incomes, and farmer resilience. Key opportunities include research on soil fertility, water and nutrient policy and use, aquaculture and fisheries policy and management, producer safety nets, conservation agriculture, input and output markets, and trade.

By incorporating the latest individual technologies into real farming systems, extension specialists and farmers can gain a better appreciation of the potential impact of the new technology in real farm situations and thereby speed up the technology transfer and adoption process. By building models of the farm system, researchers can also predict potential impacts of new technologies within the system.

Crop improvement and crop protection

Constraints to crop production: The availability of water, fertile soils and plant nutrition are major factors to crop production, with their relative importance varying across agro-ecological regions. Significant losses in crop yields occur due to pests, diseases and weed competition. The impact of climate change will further exacerbate the stresses on crop plants, 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.

Two broad strategies are critical in ensuring that crop productivity is enhanced with efficient resource use while limiting environmental degradation. The initial strategy is to apply existing knowledge in order to change sub-optimal crop and soil management practices and achieve advances in crop productivity. The second strategy requires: (1) the development of integrated soil–crop systems management (ISSM), which will address key constraints with existing crop varieties; and (2) the production of new crop varieties that offer higher yields but use less water, fertilizer or other inputs and are more resistant to drought, heat, submersion, and pests and diseases.

Customer focussed plant breeding*:* One factor in increasing agricultural productivity is genetic improvement through the breeding, dissemination and adoption of higher yielding, more nutritious, and environmentally adapted crop varieties, for staple foods, higher value cash crops and under utilised crops. Improving ***crop productivity*** will come through accelerating plant breeding (often based on marker assisted selection), to develop new varieties that meet market demands and market drivers. Market drivers are defined as the major factors that can influence the uptake of output products by farmers and their value chains. They include economic, biological, agronomic, environmental, public policy and trade considerations, as well as social and cultural factors.

Currently, less than 35% of new plant varieties available in Africa are adopted by farmers, in contrast to over 80% adoption in South America and over 60% in Asia (Byerlee&Bernstein 2013). This suggests that greater effort is needed on determining customer needs and preferences and market demands for new plant varieties, as well as ensuring adequate availability of seed supplies and other inputs necessary for crop production.

Demand can originate from producers, processors, consumers and policy makers. In the realm of food crops, this demand-led approach impinges on public sector plant breeding and crop improvement programs. A successful example of developing new crop varieties that meet market demand is the development of new rice varieties well adapted to African conditions.

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). Other African countries have genetically modified crops with useful traits (e.g. drought tolerant maize) under field trial.

The advent of new biotechnologies, such as genotyping and marker assisted selection, accelerates plant breeding, and enables new crop varieties with desirable traits to be bred more quickly, for example halving the time taken to develop new cereal varieties. The wider application of these new breeding strategies, when combined with more customer focussed design of new crop varieties, will lead to increased crop productivity, for both food security and income generation.

Horticultural and tree crops: Fruits and vegetables are increasingly important for local consumption, as consumer preferences change to include more nutritious foods in their diets; as well as being high value products for export markets. Some traditional Africa green leafy vegetables have been subject to little genetic improvement, and their productivity could be improved through genetic improvement for yield and nutritional content. Tree crops, such as tea and coffee, are the subject of long standing breeding programs, usually managed by industry-funded research institutes. Ethiopia, as the centre of origin of coffee, has valuable genetic resources, and the world's best quality coffee.

Crop protection: Diseases, pests and weeds continue to cause substantial crop losses, both before and after harvest. There are also new diseases emerging, such as Ug99 rust in wheat, Xanthomonas bacterial blight of banana, *enset* (*Enseteventricosum)*and plantain, amongst many others. There is the threat of pests, diseases and invasive weeds spreading into new areas as a result of climate induced changes in the environmental conditions in which pests and pathogens flourish. Aflatoxins in foods are the result of fungal contamination in certain crops (e.g. maize and groundnuts). This is both an acute and chronic health issue in Africa. In addition, Aflatoxin contamination in animal feed can lead to decreased animal productivity and cross contamination of milk and eat coming from livestock fed on contaminated feeds. Aflatoxins also impact on trade.

Science can contribute new solutions for crop protection, such as: marker-assisted breeding for disease resistance (e.g. new wheat varieties with resistance to the Ug99 rust); and the development of genetically modified crops with novel genes for resistance introduced into locally adapted varieties (e.g. Xanthomonas bacterial blight resistance gene introduced into highland banana for eastern and central Africa). There are also biological control approaches, which have been introduced successfully in West and Central Africa by the International Institute of Tropical Agriculture (IITA) for the control of cassava mealy bug and cassava green mite. A biological control approach is also on the verge of commercialization for the control of Aflatoxins in maize, as well as the development of maize varieties resistant to invasion by the fungi that produce the Aflatoxins.

Biological control is also being used for the control of invasive weed species such as water hyacinth on Lake Victoria. Integrated Pest Management (IPM) is being introduced for the improved pest control and the consequent reduction of pesticide use on cotton and horticultural crops in West Africa, through a regional FAO program.

An innovative approach to plant disease management is through "*Plantwise*" plant diseases clinics, which is delivering science -based advice for disease control directly to farmers in remote areas, using the best of modern diagnostics with new information and communications technologies (ICTs). Plant disease clinics are held regularly in markets, schools and farming communities, where field diagnostics by plant health doctors are supported by access to remote diagnostics, through data bases and remote microscopy. This initiative is described further in Box 3.

Livestock: Improving livestock production and productivity

Livestock production: Livestock constitutes a substantial component of African agricultural production, contributing about 30% of agricultural GDP in sub-Saharan Africa (SSA). Livestock contribute to food security and nutrition through the provision of animal sourced foods (meat, milk and eggs), a source of income and capital assets, as well as being a source of draught power and manure for farming. Around 10% of the population of SSA is primarily dependent on livestock, while another 58 per cent is partially dependent on livestock. Nearly 60% of the

Box 3. "Plantwise": An innovative management systems for plant pests and diseases

Plantwise is an innovative global partnership that aims to improve food security through strengthened national systems of plant health and extension. *Plantwise* connects farmers to the information they need for better pest and disease control, enabling them to lose less, grow more and improve crop quality. The impact of plant pests and diseases on these crops can be catastrophic, destroying farmers' livelihoods and threatening the food security of their households and their communities. In some areas, up to 70% of food is lost before it can be consumed.

The *Plantwise* approach to crop protection is based on three inter-linked components:

1. The spearhead is a growing network of locally-owned and run plant clinics, readily accessible to farmers in locations such as market-places, and staffed by trained plant doctors who give advice on any problem and any crop, guided by the principles of integrated pest management (IPM). Farmers are given a diagnosis and recommendations on how to manage problems. Clinics are funded and delivered by local organizations, primarily existing extension providers but also involving an alliance of other relevant public and private stakeholders. For example, in Africa, there are several Plant wise clinics operating in African countries, including DRC, Ghana and Kenya, amongst others.
2. The clinics are the starting point for developing and reinforcing the links that help create a functioning plant health system. Better communication and coordination between public/private actors in the areas of extension, research, regulation and input supply enable them to become more effective, delivering concrete benefits to farmers. The vast majority of farmers accessing *Plantwise* advice put the available knowledge to work in their fields, achieving substantial increases in yields, quality and income, while reducing production costs.
3. A free, open access online knowledge bank of locally relevant, comprehensive plant health information about the problems facing farmers and of use for everyone from plant doctors to scientific researchers as well as a platform for collaboration and information sharing between plant health stakeholders. It contains factsheets, distribution maps and treatment advice on over 100 crops and 2500 associated plant pests. For more information: www.cabi.org

value of edible livestock products is generated by cattle in the form of meat and milk, while small ruminants (meat and milk) and poultry (meat and eggs) generate around 20% each (AU-IBAR 2009).

Livestock productivity: The constraints to increasing livestock production are in the areas of nutrition, health and genetics and these are the priority thematic areas for livestock research in Africa. In the future, production will be affected increasingly by competition for natural resources, particularly land and water; competition between crops for food and feed; and by the need to operate in a carbon-constrained economy. Improving *livestock productivity* will come through developing *better breeds, better health and better feeds for priority livestock species in Africa*.

Better breeds: There has been limited successful use of genetics to improve the productivity of livestock systems in the developing world. In contrast, genetic improvement has been the cornerstone of steadily increasing productivity gains in livestock systems in industrial countries (e.g. for productivity gains in dairy cattle). This lack of attention to animal genetic improvement in the developing world contrasts with the critical role of genetics in boosting the productivity of staple food crops over the past several decades.

Livestock keepers in Africa could benefit more from better breeds. There is a need for improved breeding methods, dissemination and adoption of improved livestock breeds across Africa, in order to transform livestock productivity, in cattle, sheep, goats, pigs and chickens. Recent scientific developments make a new approach to the utilization and conservation of animal genetic resources timely. For example, new approaches to animal genetic improvement are possible through new discoveries in biosciences (e.g. genomics, embryo cloning, embryo transfer and other reproductive technologies, *in-vitro* conservation technologies for animal genetic resources and marker assisted selection techniques to identify traits for breeding). These biological approaches have synergies with new information and communication technologies, using mobile phone technology and remote sensing data to guide breeding and selection programs.

Better health: In sub Saharan Africa, animal diseases cause estimated annual losses in excess of US$ 4 billion, representing about a quarter of the total value of animal production. The impact of animal diseases arises from direct losses due to mortality and its indirect effects through reduced growth rates, low fertility and decreased work output that result from morbidity.

For the future, the infectious disease threat will remain diverse and dynamic. Climate change is likely to add to the continuous threat of the emergence of new diseases and the re-emergence of previously minor diseases. Future disease trends are likely to be affected by disease surveillance and control technologies. Effective control measures exist for many infectious diseases, and impacts on future disease trends depend on the appropriate implementation of these measures. There have been significant developments in the technology that can be brought to bear against disease, including DNA fingerprinting for surveillance, polymerase chain reaction (PCR) tests for diagnostics and understanding resistance, genome sequencing and antiviral drugs (Perry & Sones 2009).

Vaccines are also important in the protection of animals and in the control and potential eradication of diseases. The development of a thermo tolerant vaccine against rinderpest was a critical component in the successful eradication of rinderpest from cattle in Africa. An analogous approach of developing a thermo tolerant vaccine is being pursued for the control of a viral disease (Peste des petites ruminants –PPR) in sheep and goats. Epidemiology and better understanding of interactions with social behaviour is a developing field that can contribute to better diseases control and prevention (for example in the management of African swine fever in pigs.

Better feeds: Poor nutrition is one of the major production constraints in smallholder livestock in both pastoral and crop/livestock systems in Africa (Thornton 2010). The quality and availability of feed resources can be improved through the conservation and use of better quality forages, the use of multi-purpose trees, dual purpose, and food/feed crops with more nutritious crop residues (e.g. cow peas, and strategic feed supplementation especially in more intensive livestock systems). Advances in nutrition and related sciences offer prospects for improving the efficiency and sustainability of livestock production. For example, improving grass quality through traditional breeding or manipulating the bacterial flora of ruminant digestive systems can increase productivity and reduce the release of methane by ruminant livestock.

Addressing the nutritional constraints faced by livestock in extensive rangeland systems is difficult. While there is potential to improve livestock productivity in arid and semi-arid lands (ASALs), practical solutions requires integrated application of several technologies, including dissemination of information from early warning systems and drought prediction. This advance information enables livestock keepers to better manage the complex interactions amongst herd size, feed availability and rainfall (NRC 2009). For example, the index based livestock insurance (IBLI) scheme developed by 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.

Aquatic systems and inland fisheries

Expanding aquatic systems for fish production has high potential for both domestic supply and high-value export in several African countries. Aquaculture, in particular, has the potential to grow in intensity in many parts of Africa which possess adequate inland freshwater resources or coastal zones which could be exploited for marine aquaculture.

At present, aquaculture production in Africa represents a very small share of global production (FAO 2012), and the projected growth in aquaculture production for Africa is very small compared to the fast-growing regions of Asia and Latin America (OECD-FAO 2012, World Bank 2013). But these forward-looking projections cannot fully capture the incredibly dynamic nature of aquaculture markets – which saw some countries like China go from zero production to being world-leading exporters of valuable species of farmed tilapia (World Bank 2013). As such, they might be seriously underestimating the potential transformation of aquatic systems that are possible in Africa. For example, countries such as Cote d' Ivoire, Egypt, Kenya and Malawi are expanding their aquaculture systems.

A science agenda for African aquaculture should to explore ways in which farming systems innovations that incorporate aqua culture can be brought to bear in Africa. Among the critical components of aquaculture intensification is that of feed and disease management, which are the areas in which the most important gains in efficiency have been made in the more advanced systems of Europe, Asia and the Americas. Research is needed to find suitable plant protein substitutes to fishmeal, which remains a highly-demanded and increasingly costly input to aquaculture production (Delgado et al 2003).

Inland fisheries production and productivity issues are also important in the inland lakes e.g. the Lake Victoria fisheries supports 1 million artisanal fisher persons, nets about $0.5 billion to the three countries in Foreign exchange and has a very strong regional Fisheries Research Organization supported by the three countries. The same applies to Lakes Malawi/Nyasa; Tanganyika; Kariba; Chad; etc.

Another science and policy-related area is that of sustaining ocean capture fisheries (coastal artisanal fisheries). There are two threats facing coastal fisheries. One is embodied in the warming effects of climate change on ocean temperature, which causes the viability of some fish species to decrease (FAO 2009; Cheung et al. 2010). The advent of large foreign-owned trawlers fishing in African waters has accelerated the demise of small-scale artisanal coastal fishing in a number of regions. A social effect of this decline has been the need for coastal fishermen to find alternative sources of income. Science and policy research is needed to provide guidelines to governments to sustain ocean fish populations in their waters for the benefit of coastal fishing communities; and policy research is required to better regulate large-scale fishing activities in African waters.

Agroforestry and forestry

Even though trees are conventionally not explicitly seen in farming systems, 46% of the agricultural area globally has more than 10% tree canopy cover (Zomer et al. 2009) and it is estimated that agroforestry is practiced by 1.2 billion people worldwide. Agroforestry systems may range from open scattered tree systems such as Sahelian parklands to dense and highly diverse home gardens which mimic tropical rainforests like the Southern Cameroonian cocoa agro-forests, or trees planted in hedges or on field boundaries. By associating trees with crops and/or livestock on the same farm, farmers ensure the production of a wide diversity of products including food, fodder, fuel, medicine, timber and other products which are key to their livelihood security and flexibility as well as income stability.

When the complementarity between trees and crops is managed effectively, agroforestry allows increased agro-ecological sustainability through higher resource efficiency and soil nutrient accumulation. Agroforestry systems also provide services of national and global importance such as protection from flood damage and carbon sequestration. Yet because the ways trees contribute to people's lives are diverse and difficult to measure, their role is not always recognized in development programs and policies. R&D attention is needed in the areas of germplasm supply systems, market of agroforestry products, governance and tenure, credit, incentives such as payments for environmental services, information, promotion in policies and inter-sectorial policy coordination.

With regard to forestry, there are numerous products and services derived from forests including timber, non-timber products such as: honey, Gum, Acacia, Shear butter, Palm oil, Mushroom, Medicinal plants (*Prunus africana, Gnetumafricanum*); and ecosystem services such as regulation of water regimes, the maintenance of soil quality, limiting soil erosion, modulating climate; and being key components of biodiversity both in themselves and as a habitat for other species.

There are several substantive forestry policy issues requiring research, such as the conservation of forest areas, when there is competition for land use amongst retaining natural forest cover, versus opening up of forest areas to allow the expansion of small scale and new large scale farming (including through concessions on land made available to national and foreign investors), versus mining in forest areas.

Several aspects of forestry require increased research attention. These include : sustainable forest management and management of forest based industries such as saw milling and charcoal making which will significantly increase productivity, employment and eventually reduce degradation through conservation.

4.3 Agricultural mechanization

Contextually appropriate mechanization in African agriculture

According to the FAO, in 1961, SSA had 2.4, 3.3 and 5.6 times more tractors in use than in Brazil, India and the People's Republic of China respectively. By 2000 the reverse was the case, and India, the People's Republic of China, and Brazil had respectively 6.9, 4.4, and 3.7 more tractors in use than in the entire SSA region (including South Africa). Similarly in 1961, SSA had approximately 3.4 times more tractors in use than in Thailand; however, by 2000 Thailand had the same number as in SSA. Further, the tractors in use in SSA in 2000 were concentrated in a few countries, 70 percent being in South Africa and Nigeria. Also, primary land preparation in SSA was estimated in 2000 to rely completely on human muscle power on about 80% of the cultivated land, with draught animals and tractors being used on only 15% and 5%, respectively (compared to Asia where land preparation on over 60% of the cultivated land is done by tractors) (FAO, 2008).

The failure of many public sector tractor hire programs of 1970s to 1980s significantly influenced policy decisions on agricultural mechanization in Africa during the last two decades of the 20th century. This should not be used as a reason to under rate the varied benefits that mechanization brings especially in the 21st century where African farmers have to be globally competitive. Mechanization must however be contextually appropriate. Policy must recognize that one size does not fit all and farm households use or benefit in different ways from mechanization. The success of mechanization in Asia was largely because of long-term steadfast implementation of enabling technical and economic policies and programs. According to the FAO, four main policy lessons for mechanization in SSA can be gleaned from the Asian and African experiences over the past four decades.

First, attention should be placed on increasing the profitability of investments in mechanization by encouraging commercial agriculture and focusing investments and support necessary to increase the profitability of farm and non-farm enterprises. A critical question in this respect is whether there are entrepreneurs/farmers ready to invest in machinery and implements for use on their farms as well as for providing mechanization services to the small-scale farmers who are unable to marshal such levels of capital investments.

Second, mechanization should be viewed strategically within a longer-term time frame. Despite the array of studies demonstrating that mechanization is often not profitable, larger-scale farmers in South Asia pushed ahead with their change to tractors. Also in Asia, policy-makers in general regarded the short-term impact of mechanization as less relevant and important, and took a more strategic longer-term perspective, viewing mechanization as part of a broad-based economic development strategy aimed at economic growth and agro-industrialization. Short-term social costs were at times ignored in favour of probable increases in labour demands following intensification. The result was a dramatic transformation of agriculture in Asia over a 40-year period.

Third, mechanization is a complex and dynamic process that cannot be appraised only from the standpoint of factor substitution or net contribution to production. Where mechanization has taken place worldwide, there have been fundamental and interlinked changes in the structure of agricultural sectors, in the nature and performance of agricultural support services, and in the livelihood strategies of farmers and agro-processors. These changes do not necessarily take place simultaneously nor impact on all people in the same way.

Fourth, while mechanization has been actively promoted by political leaders and governments in Africa and Asia, its successful development has not depended on governments being directly involved in offering mechanization services. Instead, where mechanization has been successfully implemented, essential mechanization supply systems and support services have developed in response to economic demand – in most cases, starting with support services targeting medium- and larger-scale farmers.

The use of mechanization is not simple substitution of tractors for labour with rising labour costs. It requires a system, providing servicing and spare parts, access to fuel, and markets for the increased product. A key question is whether African countries can realistically achieve agricultural development and transformation with agricultural sectors that rely to the extent they currently do on human muscle power and hand tools.

Trends in mechanization worldwide clearly show that there are strong correlations between economic growth and mechanization – those countries that have achieved unprecedented economic growth over the past three decades and have succeeded in solving their food problems have also advanced to higher levels of mechanization in their agriculture. Countries that have stagnated economically with significant numbers of their citizens steeped deeper in poverty have also lagged behind in agricultural mechanization.

Many African experts and policy-makers are able to see the progress in mechanization in Asia over the past four decades especially given the impetus of globalization and information flows. African leaders understand the importance of mechanization in the future vision of the region; efforts to accelerate mechanization will require substantial long-term political and financial commitments while grappling with the technical problems. The S3A must therefore address those factors which have constrained the use of mechanization inputs in African agriculture from a technical; policy and environmental perspectives. Policy makers should consider support for the mechanization and intensification of smallholder agriculture as much as focusing on large scale land use programs.

4.4 Food systems and value chains

Food and nutritional security

Food security “*exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”* ((World Food Summit 1996). Food security depends on four integrated components: (1) physical availability of food, i.e. increasing ***production*** and improving ***productivity;*** (2) enabling ***access*** to food; (3) better ***use*** of food, including reducing post-harvest losses and improving the nutritional quality of food; and (4) **stability** of food production, access and use over time.

Nutritional security: Diets are diversified, as incomes increase, with increasing demand for more nutritious foods such as fruits and vegetables and animal sourced products. Traditional African crops such as green leafy vegetables have a strong demand and high nutritional value. Supply of traditional vegetables cannot meet current demand in either the informal markets or in supermarkets. Some examples of the applications of science towards improving nutrition security include the genetic improvement of nutritious foods, such as African vegetables (e.g. Amaranth). Some of these traditional crops have been subjected to little genetic improvement so rapid gains in productivity can be made. Also, nutritional content and micronutrient levels in crops are highly dependent on what is present in the soil. Depleted soils lead to depleted nutritional value in harvested crops.

Diet evolution in urban areas often means excess consumption of calories leading to overweight and the related health problems. Applying science to food supply implies going beyond agriculture to tackle these issues increasing in urban areas, including the science of human behavior.

4.5 Post-harvest handling, food processing, safety and storage

Post-harvest losses in Africa range from 20 to 60%, across various countries and for various commodities. Such losses could be reduced through more efficient post-harvest processing, handling and storage systems. With increasing urbanization in Africa during the 21st century, much larger quantities of food produced in the rural areas will have to be moved to towns and cities, to meet the needs of growing urban populations. Moving such large amounts of food and agricultural products will require increased use of science and technologies embodied in the handling, processing and storage of food.

Increased processing of agricultural products into finished products opens new opportunities in domestic, regional and international markets. There are a number of constraints to developing large-scale agro-processing industries in Africa, including limited R&D capacity in post-harvest handling and processing. There is also a lack of suitable equipment. Improvements in post-harvest technologies, including sorting, grading, packaging, cooling and storing, are needed to develop a sound food processing industry. The bulk of processed food in domestic markets is produced by myriads of micro enterprises in the informal sector. There is a need to improve processing technologies to increase incomes, generate more employment and assist in increasing raw material supplies from primary agricultural production. Technical improvements will be particularly rewarding in such areas as root and tuber processing, grain milling, dehydrating fruits and vegetables.

Transforming traditional food crops into processed foods with better shelf-stability and food safety, and which meet consumer demands for taste, eating patterns and convenience in handling and preparation is a technological challenge for the development of the food-processing sub-system. Research and development should focus on modifying processing technologies and introducing design concepts for technologies especially where activities are prototypes or replicates of processes already developed and tested in other countries.

Improving food storage can prevent much of the loss in quantity and quality of the harvest. Integrated pest management approaches have potential for controlling post-harvest storage losses, such as in maize. Food quality and safety is also strongly related to storage practices, as has been shown with Aflatoxin contamination in maize. Improved feed storage is necessary also to improve livestock production. High-quality storage and processing technologies and facilities are also important to generate new export opportunities for African produce, especially with regards to meeting the international food safety standards required in export markets. The private sector plays an important role in developing and using postharvest handling and processing technologies worldwide.

Food safety: Food safety and quality management are becoming increasingly important at both the national and international levels. Access to export markets may be limited where producers are not able to comply with international food safety requirements (for example FAO/WHO Codex) and those of importing countries. The growth of large supermarkets is also driving new standards in food safety and quality in Africa. At the national level, improvements in food safety and consumer health require food safety and consumer health policies, institutional systems, effective food law and enforcement, and education of food producers, caterers and staff in food safety standards and best practices.

Considering national food production systems, it is recommended that food safety should be considered using a food safety management systems approach, for example hazard analysis and critical control point (HACCP) and as part of this, Good Agricultural Practice and Good Manufacturing Practice. It is important to identify the main food safety hazards, where they occur in the food production and marketing chain and their potential risk to consumer health. A multi-disciplinary approach to hazard identification, based on risk assessment, is necessary. This should include collection of data on occurrence of food hazards (for example, pathogens), and the conditions and handling practices that lead to their presence in food systems.

4.6 Agricultural biodiversity and natural resource management

Conservation and enhancement of agricultural biodiversity

Africa has a rich treasure trove of biodiversity in flora and fauna. The preservation and utilization of Africa's rich biodiversity will require a strengthening of local, national and sub-regional policies on agro-biodiversity conservation and use. Policy support is vital to halt genetic erosion; without it, national programs will continue to lack the finances and capacity to support conservation and use initiatives.

In some instances, well-structured private-public sector partnerships can provide a means of exploiting this potential and creating niche markets (e.g. medicinal plants). Increased investments in national and regional gene banks for plants, animals and microbes will be required to fully realize this promise. Tools need to be developed to determine the value and function of the different components of agro-biodiversity to farmers and other sectors of society if it is to be conserved and sustainably used. Conservation and utilization need to become mutually reinforcing so as to create an economic stake in conservation.

Information on agro-biodiversity needs to be more widely known and readily available in different formats for different audiences and users, especially in areas rich in the biodiversity of under-utilized crops.

Both *in situ* and *ex situ* conservation strategies should be pursued. For example, community-managed agro-biodiversity sanctuaries may be established for sorghum and millets in the Rift Valley in East Africa.

Future needs include: (i)development of early warning systems and indicators for monitoring genetic erosion and loss of biodiversity; (ii) mapping of the distribution and endowment of agro-biodiversity resources in Africa using GIS and other related technologies; and (iii) *In situ* conservation strategies as well as *ex situ* gene banks and bio repositories as part of a comprehensive scientific scheme for the long term conservation and characterization of plant, animal and microbial species in Africa.

Most African countries are signatories to several international treaties and conventions on biodiversity and genetic resources but there are gaps in national policies to implement treaties. Policies on agro-biodiversity are needed for the dual purposes of domesticating international treaties and safeguarding national biological heritage.

Land and water resources, irrigation and integrated natural resource management

Degradation of land and water and changing land use patterns in rural areas are becoming increasingly widespread, and this poses a definite threat to national and individual food security in many parts of Africa. Agro-ecological systems are resilient, but subject to a collapse when degraded beyond a certain threshold.

Renewable natural resources such as land, water, forests and fisheries are generally undervalued and overexploited but are an integral part of rural livelihoods, at community, national and trans-boundary levels. New ways of using natural resources can have unintended adverse effects; e.g. the multiplication of individual tapping in the groundwater table in some irrigated areas, which can lead to salinity problems. Climate change will bring increased pressure on natural resources, for example by affecting eco-systems and contributing to carbon emissions through increased deforestation. It will also bring opportunities, for instance through global carbon markets and off-setting schemes and valuing environmental services.

It will be necessary to expand research into the wider issues of renewable natural resources and their sustainable use, as well as the potential for renewable energy sources (e.g. solar power and wind energy). Research should also look at assessing the value and long- term impacts of loss of natural capital to provide evidence for long-term decision making. Research must respond to the challenges through development of technologies and innovations to address sustainable natural resource management. This will include technologies to address conservation agriculture principles relating to soil organic matter decline, soil erosion and degradation, nutrient depletion, loss of biodiversity, prevention of invasive weeds, maintenance of water quality, optimization of water use efficiency under both irrigated and rain-fed conditions, capturing and storing rainwater (rainwater harvesting) and restoration or creation of new balances in biotic communities.

GIS-based technologies, natural resource inventories and adequate characterization and monitoring are considered essential. Science can help find ways to empower farmers' organizations and foster their collective awareness of problems in natural resource management and ways to overcome them, including through the use of indigenous knowledge.

Water management is becoming an increasingly important issue, including with the expansion of irrigation schemes (e.g. on the Niger River in West Africa). Environmental science can help underpin the choice of suitable location and sustainable management of dams and irrigation schemes.

4.7 Responses to major mega trends and emerging challenges for agriculture in Africa

The main mega trends affecting African agriculture are outlined in section 2.2. They include population growth, urbanisation and climate change. The discussion on mega trends here dwells on climate change.

Climate change, variability, adaptation and mitigation

Adapting to climate change is an increasingly important external driver of change in Africa. Climate change will impact on agriculture and food security and must be mainstreamed into research, technology development and management strategies for all agricultural and natural resource management related activities. Agriculture and food production will need to adapt to a changing world with a higher likelihood of extreme and volatile weather events, as well as contribute towards reducing greenhouse gas emissions. Agriculture is a key element in combating the challenge of climate change. This will need investments in science and innovation systems to ensure that science and technology efforts meet the needs of the people living in complex, diverse and risk-prone settings in Africa.

Changes in precipitation, river flow patterns and groundwater availability due to climate change are highly uncertain, and yet are of paramount importance for food security of millions of rural people in Africa. Appropriate measures in agricultural water management can greatly reduce their vulnerability by reducing water-related risks and creating buffers against often unforeseen changes in precipitation and water availability. A further issue is the need to undertake research to provide farmers with information and forecasts on changing weather patterns and likelihood of drought or floods. This applies to existing climatic variability as well as future variability, which is likely to increase due to climate change.

Research should be carried out on high carbon fixing land use systems, specially the role of soil organic carbon in simultaneously meeting climate change targets and promoting more productive agriculture suitable for rural poor, including in agro-pastoral systems. Another example where science can contribute towards adaptation strategies is by developing more resilient crop varieties and animal breeds that are able to withstand higher temperatures and are adapted to less rainfall. Developing effective means to control plant and animal diseases as they spread into new areas as a result of climate change is another challenge to which science can contribute solutions. Early warning systems are also becoming available through the use of satellite technology and geographic information systems (GIS).

Responses to policy and institutional shifts

Policy research is required to improve the evidence base for policymakers, including on markets, regional integration, international trade and price volatility. Smallholder farmers experience a range of market-related constraints in attempting to boost their production to enhance their incomes. Such constraints include poor access to market information, imbalances in available information between various actors in the market and poorly organised input markets. The research objectives here would be to broaden market opportunities for smallholders by using modern ICT to provide timely market and price information to small holders; identifying new niche value-added marketing opportunities; and improving input delivery systems (IAC 2004). Research also needs to focus on developing a strategic understanding of the macro-economic environment and on value chain co-ordination, relating this to micro-economic decisions required by farmers.

The rapid trend for food marketing value chains to seek greater efficiency at wholesale as well as at retail levels, and the rise of supermarkets in many countries of Africa, require research on enhancing farmers' assets for greater market participation. Inclusive transformation of agriculture will require greater understanding of land and labour markets, services markets, the role, function, representation and governance of farmer organisations, and increasing competitiveness of small farms. Agricultural growth will leave winners and losers. Policy research should seek to find ways to mitigate negative impacts on smaller producers, including the role of agriculture in social protection in rural areas.

There is also a need for technology policy research, in understanding the benefits and risks associated with the introduction of new technologies, including biotechnology. These findings can help guide the development of science based regulatory systems, including biosafety regulations, to ensure the safe and effective use of modern technologies in agriculture in Africa. Understanding the political economy of countries and what drives the adoption or non-adoption of evidence based policies in the agricultural sector is also an important area for research.

Responses to changes in livelihoods of rural communities

Despite the preponderance of smallholder agriculture in Africa, the rural population is becoming less agrarian. This trend is accelerating as a result of urbanization, population growth, environmental degradation, and land subdivision. The latter two make it difficult for large numbers of smallholder farmers to rely only on subsistence agriculture as a source of food and income for their families. Increasing employment opportunities in rural areas, including non-farm employment, is one of the policy challenges facing most African governments. The policy priority is to create more jobs in both agriculture and the rural non-farm economy, especially to address youth unemployment in rural areas.

The basic ingredients of a dynamic rural non-farm economy are a rapidly growing agricultural sector and a good investment climate. Linking the local economy to broader markets by reducing transaction costs, investing in infrastructure, and providing business services and market intelligence are critical. Much socio-economic and policy research has been carried out on coping strategies and diversification of livelihoods in rural areas. However, there is a lack of clearly documented and synthesised information on what policies work where and why in order to inform coherent rural development policies. Additional research is needed in this area to develop policy options for government and identify future investment opportunities for public and private investors. An emerging policy research area is in relation to social safety nets, in terms of which approaches are most suitable in different countries and within countries.

Gender

A key reason for the failure to realise the potential of African agriculture is that rural women, who constitute about half of the players in smallholder food production (see Box 4), continue to be unsupported by agricultural policy and development interventions (AGRA 2013). This is due in large measure to gender norms and underlying cultural factors that stress female subordination and male dominance over access to and control of productive resources (Manyireand Apekey, 2013). These norms and cultural factors also impact on all aspects of the science agenda, including agricultural education, extension and research

Mangeni*et al.*(2010) identified a series of gender issues in agricultural education and training, which were considered as limiting access to, and progression in the type of education that girls and women opt for, resulting in low uptake of, and attainment in, sciences in general and agriculture in particular among girls. Similarly, women are under-represented in extension services and evidence demonstrates that the development and dissemination of agricultural innovations rarely take gender-specific characteristics and requirements into account (Manyire andApekey, 2013).

In a ten country sample study Beintema and Di Mercantini (2009) found that the participation of African female professionals in R&D institutions contracted with advancement into senior positions with proportion of female professionals sharply falling at senior level posts. Programs such as AWARD (African Women in Agricultural Research and Development) supported by Bill and Melinda Gates Foundation (BMGF) are contributing towards addressing these gaps by mentoring new generations of women professionals (www.award.org).

Box 4 : Gender in agriculture – facts and figures

According to the FAO:

- Women comprise, on average, up to 50 percent of the agricultural labour force in Sub-Saharan Africa.
- About two thirds of poor livestock keepers, totalling approximately 400 million people, are women.
- Average male wages are higher than average female wages, and women tend to have more part-time and seasonal employment.
- The yield gap between men and women averages around 20–30 percent and most research finds that the gap is due to differences in resource use.
- Closing the gender gap in agriculture could reduce the number of the world's hungry people by 12 to 17 percent.

Source: FAO. "Men and Women in agriculture: closing the gap." http://www.fao.org/sofa/gender/policy-recommendations/en/

Relevance in agricultural innovation demands that the complementary insights of the female researcher and extension service provider are utilised. Both technology innovations and agricultural policies can then be aligned to the needs and interests of Africa's predominantly female smallholders and rural entrepreneurs.

Accordingly, the implementation of the Science Agenda must focus on mainstreaming gender issues to:

- ensure that women as well as men are active participants in the process of research planning and research management, receiving the training and skills they need,
- evaluate impacts of all research on both women and men and adjust programs to ensure that both benefit,
- measure progress through changes in incomes of both women and men in rural areas,
- ensure that women, as agricultural producers, have access to assets, inputs and technologies,
- ensure that the technologies developed respond to women's needs and roles,
- fund new research to develop and share best practices for integrating gender research
- Advance women's leadership in science and technology through proactive recruitment, mentoring, and targeted research support.).

4.8 Cross cutting themes

Sustainable intensification

Sustainable intensification is presented as a "new paradigm" for global agriculture (The Montpellier Panel, 2013).The Montpellier Panel report describes the sustainable intensification challenge as follows: *"This pathway strives to utilize the existing land to produce greater yields, better nutrition and higher net incomes while reducing over-reliance on pesticides and fertilizers and lowering emissions of harmful greenhouse gasses. It also has to do this in a way that is both efficient and resilient and contributes to the stock of natural environmental capital. None of the components of this paradigm are new. They comprise techniques of ecological and genetic intensification within enabling environments created by processes of socio-economic intensification. What is new is the way in which they are combined as a framework to find appropriate solutions to Africa's food and nutrition crisis".*

The approach of sustainable agriculture is pragmatic and recognises that African farmers need to use more inorganic fertilizer but they also need to strike the right balance between managing soil organic matter, fertility and moisture content and the use of such fertilizers. The same principle can be applied to the judicious use of herbicides through precision farming techniques. Water management (for scarcity and floods) is a critical part of the approach and water, nutrients and soil structure are synergistic.

There are three components of sustainable intensification: ecological, genetic and socio-economic:

- *Ecological intensification* relies on highly productive intercropping that relies on reducing competition and increasing mutual benefits between crops by Integrated Pest Management (IPM), which depends on natural enemies replacing pesticides and by conservation farming using no-till to encourage the build-up of organic matter and active biology in the soil
- *Genetic Intensification* has occurred through conventional breeding since the first bread wheats were hybridized from wild wheat and wild grass and improved through human selection. More recently, cell and tissue culture and marker assisted selection (MAS) and genetic engineering have further intensified the process, leading to higher performing plant varieties and animal breeds.
- *Socio-economic intensification* results from development of innovative and sustainable institutions on the farm, in the community and across regions. The process includes all the elements of sustainable livelihoods including building social capital, and human capital and, of course, the physical capital in land.

Sustainable intensification is not a substitute paradigm for external input agriculture practiced by large scale farmers applying the techniques of conservation agriculture. It is an accessible approach for the 80% of small farmers with limited access to external inputs, and it represents a very large diversity of intensification pathways depending on local context and farmers' strategy.

The challenge is if it will successfully create opportunities for young "future farmers" and scientists to generate new knowledge and new opportunities for producing surpluses and earning income from their existing small land holdings. Table 1 shows the primary outputs for sustainable intensification as detailed by the Montpellier Panel, complemented by its contribution towards biodiversity and ecosystem services

Biosciences, information and communications technologies

Biosciences, genetics and genomics

New developments in biosciences offer scientific opportunities to improve agricultural productivity in Africa. These opportunities were recognized by AU/NEPAD, when it established the Africa Biosciences Initiative (ABI) in 2004. An important part of this initiative was the establishment of "centres for excellence" in biosciences to serve the various regions of Africa. One such centre for excellence is the *Biosciences eastern and central Africa (BecA)* shared research platform, located at ILRI in Nairobi (the BecA-ILRI Hub). The hub has several science facilities that are available to and used by the African scientific community and their international partners in the areas of:

- Bioinformatics
- Genomics

Table 1: The Outputs of sustainable intensification

Production	Income	Nutrition	Biodiversity and Ecosystem Services
Definition: Total amount or yields of food per unit output	**Definition**; amount of net income generated per unit input	**Definition**: Human consumption of nutrients per unit input	**Definition:** Maintaining the stock of natural environmental capital
Resulting from:	**Resulting from**	**Resulting from:**	**Resulting from:**
• Improved high yielding, drought and pest resistant germplasm or livestock • Better crop cultivation or livestock husbandry • More effective inputs of water • Synergies between crops and livestock	• Fair and efficient output markets • Greater market and price information • Shifts from low value to high value crops or livestock • Diversification of income generating activities, including • Adjustment of the farm or household enterprise • Exploiting new market opportunities • Increasing non-farm income	• New varieties of staple crops or breeds of livestock with improved nutritive value • Diversification of production towards higher overall nutritive value.	• Reduced reliance on pesticides and fertilizers • Decrease of pollution (chemicals in air and soil) • Increased biological activity in soil • Ecosystem services at work.

- Genotyping and sequencing (as an aid for marker assisted selection of plants and animals)
- Nutritional analysis and Aflatoxin detection platform
- Tissue culture and plant transformation
- Rapid diagnostics, for animal and plant diseases

Biosciences based innovations: When developing a new science strategy for agriculture in Africa, it is timely to consider the achievements of the African and international scientists who have used the shared biosciences research platform to generate new knowledge of potential impact on African agriculture. One lens through which to assess the success of the regional biosciences platforms is to identify biosciences based innovations emerging from research conducted that are likely to lead to economic and/or social benefits for food and nutritional security and income generation for small scale producers in African agriculture. These innovations include disease resistant banana, new diagnostics and vaccines for livestock diseases, amongst others (http://hub.africabiosciences.org).

Information and communications technologies

The challenge in the use of new information and communications technologies in agriculture is to use the new ICT platforms now available in Africa (e.g. through widespread adoption of mobile phones) to make science and technology information available in useful and usable form to a wide range of end users across Africa, including those in remote rural communities. This will entail the interpretation, packaging and dissemination of the information in appropriate and usable forms. Modern information communication technologies (ICTs) and innovations based on the internet, digital satellite television and cellular telephones are required to facilitate access to information. This same technology can be utilized for obtaining information such as crop areas and crop yield estimation for agricultural statistics, national collections of pests and diseases and use of Global Positioning technologies, data loggers and other portable and fixed point ICT devices for the collection of data on natural resources.

An example of science innovation is in the potential use of modern ICTs to aid selection of improved progeny from livestock breeding programs in Africa. There is need for new systems to collect data on animals to drive selection programs for targeted livestock species and production systems. Modern technology can assist with this through low cost sensing for improved phenotyping and reproductive status monitoring in livestock systems.

There are two complementary approaches to address the challenge of providing data on livestock management for immediate use by farmers and to guide rational breeding strategies. One approach is '*crowd-sensing'* using mobile phone technology to allow farmers to submit a minimal set of health and productivity data. Another is the use of 'clouds' of low cost sensors conveying a minimal set of data about an animal. These two strategies can be combined for capturing phenotypic, reproductive and productivity data that can be used by researchers to develop improved breeding and management strategies, for short- term gains through better management (e.g. disease control); and long-term gains through introducing improved genetics from well-targeted animal breeding programs that address productivity constraints.

Another example is the use of geographic information systems, spatial modelling and scenario planning. The spatialization of data, combined with remotely sensed imagery using GIS technology, provides a powerful tool for informed decision making. Spatial technologies used in a modelling environment allow simulation far wider than when using only non-spatially referenced data. Applications include agricultural statistics with sample frames, climate change scenarios, forecasts and advisories and natural resource inventories and monitoring.

Foresight capabilities

Given the rapidly-changing global environment, and the environmental and socio-economic pressures that are exerting themselves across the African landscape, there is a need for taking a forward-looking perspective in order to plan and prepare for future challenges as well as to prioritize critical investments. There are pressures that will come from outside Africa and that will be felt through markets or the changing global environment – such as increasing volume of trade and demand for agricultural and non-agricultural goods that Africa produces and/or requires, or through a changing climate that comes as a result of cumulative and collective global carbon emissions. Some pressures for Africa's natural resources will come through concessions that are directly negotiated with African governments. Other pressures will result from Africa's own internal socio-economic growth and evolution, and will be felt through overall population growth, land use, urbanization and the evolution of consumption patterns in response to rising incomes and changing lifestyles.

Given the uncertainty over how fast and strong some of these changes might take place, and the dependence of their evolution upon local, national and regional governance and policy action within Africa, there is a need to adopt a forward-looking perspective. Such a perspective should systematically and comprehensively account for these driving forces and their critical interactions with policy, so that it can describe (qualitatively and/or quantitatively) their ultimate effect upon the physical and socio-economic landscape of Africa. Foresight provides this kind of an approach, and also creates a means for various analysts and stakeholders to interact closely and constructively, so that their collective expertise, knowledge and intuition can be harnessed in an effective way.

Essentially, foresight is built on the conviction that we can create our own desired futures. It requires that we become proactive, brave, and strategic. Our goal must not be simply to undertake technology foresight, but rather to create a new future-oriented culture in policy making and implementation. With the aid of this approach, African countries will be enabled to identify weak signals, provide early warning and promote learning to allow for effective policy making and implementation in a rapidly changing and complex world.

Foresight is a participatory process. It seeks to organize actors and institutions. It can also facilitate a shared understanding of challenges, opportunities and driving forces of change. As a mobilizing force it can facilitate collective actions. The participation of stakeholders in the thinking and planning process will allow African countries to realign innovation efforts with real world challenge and opportunities. The critical challenge, however, is to integrate foresight into governance decision and policy making processes and implementation.

A number of key factors need to be understood in developing a Foresight capacity in Africa:

- Foresight has to be viewed as a long-term undertaking and as a process to transform the culture of governance and policy making/implementation in Africa.
- The process must focus on the future and as such it must be used to investigate future possibilities (scenarios) and to build shared visions. It must involve activities such as horizon scanning with the aim of identifying and analyzing trends, weak signals and ensuring early warning as well as developing effective strategic responses.
- Successful Foresight depends on political leadership and championing without control.
- Societal ownership of the process is critical and all stakeholders, such as policy makers, researchers, firms, and social groups must be engaged and enlisted in the processes.
- The process cannot be left to chance and efforts must be made to build necessary institutional structures (whether in Planning or other areas) to coordinate and serve as the foresight secretariat.
- Foresight has to become an intrinsic process of governance and policy making in African countries.

Section III

Towards realising the vision and making it happen

5. Strengthening institutional systems of science for agriculture in Africa

The current institutional set up for agricultural research in Africa was established through the recommendations of the *SPAAR/FARA 2000 Vision for Agricultural Research in Africa.* These recommendations included the establishment of a strong apex Forum for Agricultural Research in Africa (FARA) at the continental level; strengthening of the sub-regional organizations (SROs); and establishment of strong national systems embracing the National Agricultural Research Organizations (NAROs), faculties of agricultural sciences in universities and the technology transfer agencies. These recommendations were implemented from 2001 when the three SROs signed the agreement to establish the Secretariat of FARA in Accra, Ghana. The secretariat was established in 2002 with the appointment of the first Executive Secretary of FARA.

Since then FARA has grown into a strong continental organization for agricultural research and has spearheaded many initiatives including this one of developing a science agenda for agriculture in Africa as well as others for strengthening the institutional base at continental, sub regional and national levels. This institutional framework established over the past decade offers a good base for implementation of the science agenda for agriculture in Africa.

This chapter describes the essential institutional elements for implementing the science agenda, at the national, regional, continental and global level; and the cross cutting issues of human resources, including gender issues; sustainable financing; and an enabling policy environment that are essential for science to flourish. Open systems are in a constant state of flux; FARA has been effective in developing the S3A and could provide flexible leadership in facilitating its movement through the AUC processes.

5.1 Ensuring capacity at the national level

Sustaining a basic science capacity at the national level

Effective national systems are the building blocks for regional, continental and global partnerships in science for transformation of African agriculture. Each country will necessarily have its own strategy that defines its needs for science and agricultural research in transforming its food and agricultural sector. It will, therefore, require a capacity to: 1) identify the agricultural potential of its natural resources, particularly soils and water; 2) diagnose emerging disease and pest risks, and organize a response to such threats, in conjunction with regional and global partners; 3) be a knowledgeable borrower of new technologies from the regional and global stock of knowledge. Well-structured and well-resourced national systems have a wide array of potential partners and are attractive to new funding from national treasuries and the private sector as well as from donors.

Moreover, in order to facilitate uptake and utilisation of technologies, each country needs to put in place a well thought out long-term strategy for professional, technical and vocational education aimed at enhancing the skills and expertise of its professional and technical human resources; agricultural producers and agri-business actors.

The scale at which a country's system functions is limited by its size and available resources. Therefore a country's strategy will reflect its sustainable scale of operation and the different investment trade-offs it will make between accessing global knowledge, generating its own technology, and adapting research results from regional networks. As part of further refining the contents of this strategic framework document, specific studies need to be undertaken to provide pointers for a basic minimum capacity that countries at different stages of development as well as of different sizes need to establish.

Weaknesses to be addressed in strengthening the national systems of science for agriculture include the absence of effective linkages between research, education, and advisory services. In countries that have a federal structure of government, linking state level research systems with national structures compounds the challenge. Several African countries as well as many of the emerging economies addressed this challenge through establishing national agricultural research councils, or a national agricultural consultative forum that creates the necessary policy coherence with respect to the generation and utilisation of demand-driven technologies and the promotion of innovations.

The S3A recognises the utility of an innovation systems approach in diagnosing constraints in internal flows of information, coordination, resources and people. Policy should facilitate flexible collaboration across ministries ("governance"), geographic boundaries ("location") and organizations ("structures"). Increased collaboration between universities and national research institutes could be facilitated by joint appointments, compatible promotion streams, freedom of movement back and forth between academia and research institutes, similar access to consulting jobs, and collaboration in research projects.

Integrating higher agricultural education with research and extension:

Building the research, policy, service delivery and private sector capacities that will underlie the transformation especially of small-holder-farmers in Africa will depend critically on developing the human capital that is essential for effective and efficient agricultural institutions. Africa needs to train and retain high calibre agricultural researchers with postgraduate degrees, who are essential for the development of robust programs and institutions in national agricultural research, higher agricultural education, agricultural policy and leadership across the agricultural sector.

The cohort of agricultural scientists that were trained at PhD level in the 1980s and 1990s are retiring (or close to) and there is a missing generation of postgraduate scientists, due among other reasons to: structural adjustment programs implemented in the 1990s which froze hiring of new staff; the increasing cost of higher degree training in industrial countries; declining number of scholarships; and the inadequate capacity of African universities to fill the gap. This missing generation of agricultural PhDs is set against the expanding demand which has occurred over the past two decades for postgraduate scholars owing to increasing numbers of universities, international agricultural research institutes, international NGOs, and an emergent private sector, all requiring human capital capable of mixing disciplinary depth and practical experience (see, for example, Flaherty 2011,Beintema and Stads 2011

Regardless of the increasing number of both private and public universities over the last decade, universities have for the most part, first degrees, and postgraduate degree programs remain a lower priority in this competitive environment. Postgraduate training, particularly in agriculture, is constrained by a limited pool of PhD trained staff, limited research funding, an expanding curriculum, and the need to cater to an increasing array of skill sets demanded by a differentiating labour market.

The demand for higher education is unlimited and governments are politically pressed to satisfy it. However, with limited resources, governments need to be strategic in determining where their priorities for public investments lie. Key considerations with regard to enabling the higher educational sector become an integral part of the national system for science for agriculture include the following:

- Higher agricultural educational plans become a required part of the Agricultural Investment Plans of CAADP Compact Reviews and updates.
- In addition to strengthening of instruction in traditional agricultural science disciplines (e.g., agronomy, animal husbandry etc.) emphasis should also be on imparting practical and entrepreneurial skills. There is also a need of increasing the focus on crafting multi-disciplinary approaches including the ability of appreciating the imperatives of disciplinary integration in the work environments.
- New agricultural challenges require new science and new curricula in higher education. e.g. Bio-sciences; Climate Change etc.
- Curricula must prepare graduates with the knowledge and experience to develop and manage policies, to work with producers and in agribusiness as well as in donor and NGO agencies.

Over the past three decades the extension and advisory services have undergone tremendous changes from being dominated by public sector agencies in the 1980s to being dominated by the NGOs in the 1990s and early 2000s to the current situation where one could say there is confusion, with public sector agencies, NGOs; Farmers Organizations and the private sector all competing in an uncoordinated manner for the farmer's attention (Maatman et al 2011). There is certainly a need for better coordination and new institutional architecture for the extension and advisory services and this should be one of the top priorities in reforms necessary at the national level if the implementation of the science agenda is to succeed.

As the lead agencies steering the agricultural transformation agenda, Ministries of Agriculture should be supported in retaining a core scientific capacity including for advisory services and ability to solicit the required expertise from other ministries and agencies. Moreover, in addition to addressing the efficiency of the different elements constituting the Science Agenda, "Science for agriculture" should be championed by a multi-sectoral coalition of ministries composed of ministries of scientific research, education and vocational training, agriculture, as well as economic development and planning following a 'whole of government approach'.

Furthermore, a mechanism for identifying and building support for shared priorities of these Ministries could be established. Such shared interest comes about where Ministries overlap in mandate, organization, resources, and planning. Finally, the shared strategic framework of these Ministries should seek financial support from science as well as development ministries in partner (developed) countries to ensure the science component is not lost in the current shift to the development end of the research-development continuum.

5.2 Enhancing regional collaboration

Sub-regional cooperation

Regional collaboration exploits natural comparative advantages through networks; allows specialization (whether acquired or natural); and facilitates attainment of economies of scale - particularly in the use of expensive laboratory equipment and data bases that are beyond the reach of individual countries. Regional collaboration is most effective when it addresses common problems that a country could not address on its own and when benefits are perceived to be shared fairly. It is important to build on the experience and expertise of Africa-based regional and sub-regional research coordination mechanisms which have been established over the past three decades.

The key regional actors in agricultural research are the sub-regional organizations (SROs). The evolution of the SROs in the 1990s was informed by the *frameworks for action* (FFAs) developed by the SPAAR. Most recently, through World Bank financed agricultural productivity programs in eastern, west and southern Africa (in conjunction with respective SROs), country loans have been used to support regional activities, with different countries taking responsibility for establishing a centre for excellence, on a particular commodity, and agreeing to share results with neighbouring countries (e.g. Kenya on smallholder dairying; Tanzania on rice; Ghana on roots and tubers; Burkina Faso on cotton) (see websites of African agricultural productivity projects: www.eaapp.org, http://waapp.coraf.org/index.php/en)ican). The SROs have been important in articulating the views of NARS in the CGIAR and the Global Forum.

The principal challenge of the SROs in the future is to institutionalize national funding for both their core capacity and work, and recognize the importance of increasing their support to the NARS, to reduce possibility of the research agenda being driven by the ebbs and flows of outside support. With collective support by their governments, SROs will be able to concentrate on scientific collaboration and strengthening of the NARS than on projects. The S3A needs to build on the strength of sub-regional collaboration efforts to advance collective action in technology generation and use.

Regional (continental) collaboration:

It is well-known that FARA has taken leadership for the development of the Framework for African Agricultural Productivity (FAAP) as CAADP's Pillar IV technical arm of AU-NEPAD. FARA is taking the lead in developing the S3A, and is expected to play a critical role in overseeing the implementation of the Agenda through formulating alliances and partnerships with a range of African and Africa-based science and technology organizations.

At the continental level, there are several Pan-African organizations that promote continent-wide actions in relation to science and agriculture, and which can play important roles in supporting the implementation of the Science Agenda and in its effective coordination at the continental level. Of particular note, in this regard, is the role that some of the more prominent AU specialised Technical Agencies – including AU/IBAR and AU/PANVAC - are playing in animal husbandry and veterinary technology development, transfer and popularisation among AU member states.

Other regional centres for excellence, such as *Biosciences eastern and central Africa* (BecA)–ILRI Hub, offer to scientists in Africa, shared research advanced facilities that are beyond the reach of individual countries. . Thus African scientists can accelerate their research through access to these facilities and mentorship. Research can be done within a much shorter period than would ordinarily be required in most national facilities. Also university faculty collaborating with other scientists at the regional centre of excellence improve their own teaching and research guidance to students. International scientists, who work on problems endemic to Africa, can do their analysis with local researchers in situ.

Regional centres of excellence also provide opportunities to strengthen cooperation between NARS and international partners such as CGIAR and ARIs. Critical scientific mass can be built around dynamic portfolios of research projects, including capacity building, thus generating well balanced long term partnerships

Regional centres for excellence play some role in sharing facilities to achieve economies of scale but this is often not enough for financial and institutional sustainability. The commitment of the host country and/or host institution to maintain the resource as a regional public good is fundamental. As such the business model needs careful consideration and regional funding from member states may be part of the solution for sustaining regional centres for excellence.

The need to integrate the knowledge institutions: research, higher education and extension at the national level are also recognized at the regional level. With the growing numbers of universities, and established capacity in some natural “lead” universities, Africa is developing innovative approaches to regional collaboration. Regional university consortia, such as RUFORUM, have a role in raising standards across the region, generating economies of scale in use of training facilities, pioneering collaboration with new partners, and sharing scarce resources through offering regional post graduate degree programmes

The Science Agenda highlights the importance that policy makers and research managers should attach to the emergence of a more integrated system of research and higher education at the regional level.

The role of the RECs

The architecture surrounding science for agriculture in Africa is in a state of evolution: CAADP has introduced a new strategy; the CGIAR is in a process of reform that moves it closer to CAADP in a way that highlights cooperation and not competition, all three sub-Saharan Africa sub-regional organizations have new leaders. FARA, the apex organization is spearheading the development of the Science Agenda.

The RECs have a particularly important role to play in creating the regional environment for the Science Agenda and putting in place support to planning at the national level, sub-regional mobility and opening of trade and collaboration. All the RECs have been quite active in supporting member countries in developing the country CAADP compacts and are therefore going to play a key role in the coordination of the implementation of the Science Agenda in their respective sub regions. As with economic exchange, scientific mobility and economies of scale in capacity building may begin first at the sub-regional level before taking off at the continental level.

5.3 Global partnerships in science

Science is a global enterprise; the most productive countries scientifically are those most strongly networked globally. There is a virtuous cycle in which building capacity to network and participation in networks is a means of achieving further capacity development. New ideas, access to new technology and competition for funds all raise the quality of science and the productivity of scientists.

From the point of view of science in Africa, it is expected that the S3A will strengthen the framework for collaboration with global partners while, at the national level, an established program of cross-ministerial scientific priorities will facilitate access by external partners to the differing capacities found in universities and research institutes. This may help strengthen links between university staff, national institute researchers and other actors in the national innovation system.

CGIAR: The CGIAR has been one of the key partners of the NARS and their SROs over the last four decades. The recent reform of the CGIAR with its new CGIAR Research Programs (CRPs) targeting collaboration on specific themes is expected to improve alignment with CAADP. The CRPs are expected to increase collaboration and reduce transaction costs for NARS in collaborating with the CGIAR, as the CRPs will enable access to packages of global knowledge and expertise targeted at specific regions and/or farming systems. The CRPs are uniquely placed to facilitate multi-level and multi-stakeholder collaboration – including capacity strengthening at national level - and align themselves with NARS partners.

Advanced Research Institutes: Africa has had long-standing collaboration with Advanced Research Institutes (ARIs) in developed countries especially those from Europe and North America. Africa is also beginning to collaborate with a new array of bilateral partners, with advanced research institutes of their own through agreements with – among others - Brazil, China, India and Argentina bringing specialized scientific and eco-system specific expertise. These ARIs have been providing technical support to national institutions in Africa especially for capacity building – with some having been working in Africa for over five decades.

It is well known that each bilateral donor (and hence each ARI)– be it traditional or new - has a list of priority countries that makes scientific and development cooperation attractive to its own constituents. This list of preferred countries reflects many criteria beyond the expected payoff from science and research. Moreover, each donor country has its preferred mode of interaction - through its universities, technical agencies or contractors – in providing support to its priority countries.

Multilateral programs are also not immune to selection bias. Experience has shown that donor support to enhancement of Africa's agricultural research and scientific capacity has tended to focus on a relatively small number of countries – often in a duplicative manner. In the absence of conscious regional measures to spread benefits, such approaches do not enhance the capacity of several neglected national systems and are thus inimical to the advancement of the Science Agenda. The need for better coordination and alignment of these ARI efforts with the support provided by the CGIAR system to Africa needs to be factored in the emerging institutional framework for the implementation of the science agenda.

6. Sustainable financing of the Science Agenda

6.1 Introduction

The Science Agenda will help guide the evolution of the institutions needed to implement it. This may involve some new mandates and missions and even consolidation and merger/separation of some units to make implementation serve national needs while linking better to sub-regional and continental opportunities. At this stage of conception the S3A is not an institution-restructuring guideline, nor should it be.

The Science Agenda should involve several national commitments that require adherence by national Governments. These include, for example, 1) fulfil their commitment to their national Science Agenda targets and plans; 2) participate in intra-African mobility and knowledge sharing schemes; and 3) provide a policy environment that keeps the science for agriculture system an open one.

The S3A system so-described is one that will encourage financial and technical partners, bilateral and multilateral agencies, and African partners to maintain and expand support. The policies, plans and supportive institutions that create incentives for national scientists are the same ones that create incentives for partners to align around Africa's plans. An arrangement like the independent review of agricultural investment plans for CAADP Compacts could be used to ensure that accountability and reward are linked.

The S3A is an agenda for all of Africa and it calls for elaboration of financing measures at the national, sub-regional and continental levels. While commitment begins at the national level, recent innovations in financing regional research programs and centres of excellence are leading to an increased share of regional research programs being funded by donors through regional organizations and national governments through their national systems.

Sustainable financing of the Science Agenda is the responsibility of all. Scientists must provide convincing evidence of the social impact of their work; national governments must provide adequate funding and create an enabling policy environment for farmers and other actors along the value chains and socially responsive corporations to make investments that are inclusive of smallholders. Foreign alignment with Africa's agenda will depend on agreement on desired outcomes and measures of achievement. Technical and development partners need to prove to their constituents and, more important, convince them that the investments are worthwhile and well monitored at the national, sub-regional and continental levels. Thus achieving sustainable funding of the science agenda will require enhanced efforts at all levels of operation and decision-making.

There are two principal lessons on sustainable financing that have emerged during the preparation of the S3A, from the technical discussion paper, discussions at the 6th African Agricultural Science Week (AASW) and the e-consultation. These are:

i) National commitment is the key that unlocks other support.

Once a country has defined its optimal scale and scope of its system, it must make a strong commitment to sustain it from domestic resources, supplemented by but not dependent on, external support.

For agricultural research, the Agricultural Research Intensity Ratio (ARI) has served to highlight the scientific component of the commitment to agriculture. It is the ratio of Agricultural Research Expenditure (ARE) to Agricultural Gross Domestic Product (AGDP). It is a rough measure of how much is being invested to sustain or grow the base. Various proposals have put the ratio around 1 per cent, a target that most countries find difficult to attain. Designating a single ratio for agricultural research expenditure for the whole continent may serve as a notional tool to galvanise political leaders to strive towards increasing investment in science

Raising the national commitment requires a careful public finance analysis of "how to do it" and "how fast it can be done" without discouraging the initiative or touching off an inflation in the cost of doing science as demand outstrips supply of scientists. Any tax or subsidy must consider "allocative" efficiency (how it may distort real costs as independent producers alter their effort and allocation of resources), "distributive efficiency" (whether it succeeds in reallocating benefits towards targeted stakeholders) and "fiscal efficiency" (whether the cost of collection and administration is low relative to fiscal revenues from it). Countries should welcome public expenditure reviews as an opportunity to rebalance their fiscal system when needed.

The critical opportunity for governments to generate the resources for investment is in the profits generated in the growing non-agricultural sector during times of expansion. Fiscal regimes need to modernize. As growth shrinks the relative size of the agricultural sector, tax revenue can be generated from the growing non-agricultural sector and used for support to science that raises agricultural productivity. Fiscal adjustments are part of the strategy for raising support to science.

At any rate, a single ratio cannot serve as a criterion for measuring a country's commitment to science without a good understanding of the country's strategy for accessing and using knowledge and the relative urgency and pay-off to alternative investment in infrastructure, education, extension, credit or direct support to farmers. Moreover, an agrarian country is likely to have a low tax base (given the preponderance of smallholder subsistence agriculture) and a large problem (a large share of low productivity agriculture in the economy). Countries with the greatest need for science investment for agriculture may be severely constrained by their limited fiscal capacity.

In general, African countries have been increasing investment in agricultural research but this has not alleviated the growing divide in capacity between the countries that have generously invested in agricultural research and scientific assessment and those that are progressively falling behind. There is need for an African scientific solidarity mechanism that depends on intra-African funding In support of disadvantaged countries.

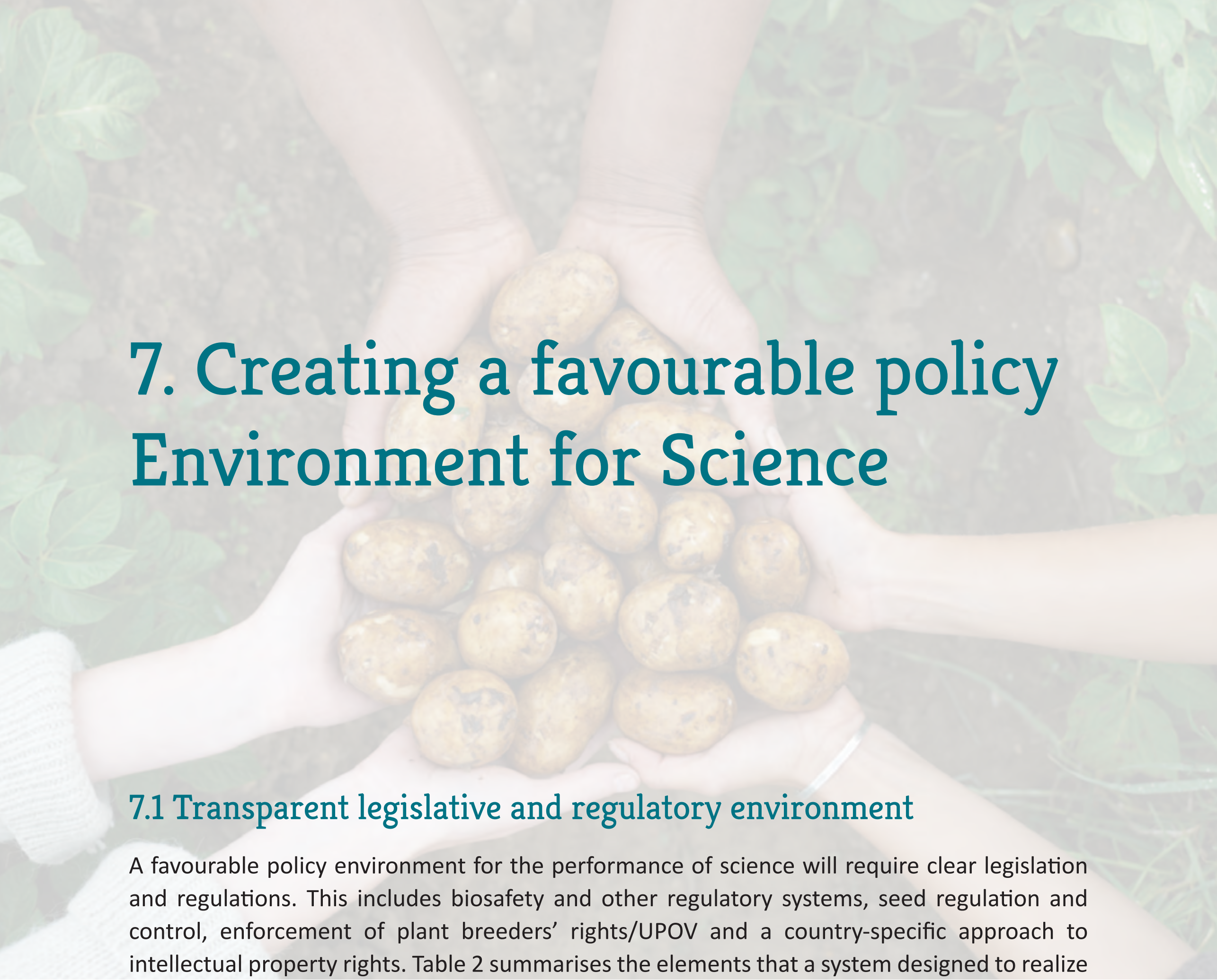
ii) Mobilizing revenues from Africa's growing economies.

The S3A will not materialise without a major effort to secure financing from domestic sources. One of its priorities is ensuring that rising revenues from the growing economies in Africa are invested into the development of agriculture. Specific activities include:

- Building capacity of farmers' associations, finance institutions, and agribusiness agencies to work together
- Encouraging governments to offer tax incentives and make preferential procurement choices for companies that source from small farmers
- Developing inclusive financial models that combine incentives, reduce debt risk and promote longer term agribusiness models

Not all innovation comes from within the "agricultural" sector. The tremendous impact that ICT technologies have had on lowering the barriers to communication and information access for millions of Africans across the continent, can also be seen through better market information that producers and middle-merchants can use to increase their marketing margins or improve the integration of agricultural markets. The interaction of banks, insurance companies and mobile phone companies, has underwritten the successful experiment with index-based crop and livestock insurance in East Africa and insurance-for-work in West Africa.

Corporate social responsibility has been demonstrated in various philanthropic activities, often in terms of local health or nutrition. There are large fortunes in Africa that could potentially endow a science foundation or similar body. What is required is an appropriate fiscal regime that provides an incentive for philanthropy and a convincing case to potential private donors, professionally presented.



7. Creating a favourable policy Environment for Science

7.1 Transparent legislative and regulatory environment

A favourable 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 and a country-specific approach to intellectual property rights. Table 2 summarises the elements that a system designed to realize a transformational science agenda for agriculture in Africa should embody.

7.2 Managing the science-policy interface

Strengthening the science-policy interface requires that scientists become excellent communicators. There is a science of science communication that can be developed to support the Science Agenda.

"We should be as scientific about communication as we are about the science we communicate" (Sackler Colloquium)

The science of managing the science-policy interface merges into the art of politics. However, there are clear lessons that come from the literature and experiences of policy advocacy.

i. The messages must be "credible, salient and legitimate". In short, they must be perceived as a) scientifically rigorous, and unbiased; b) important and relevant; and c) delivered by an acceptable source that is perceived as fair and respectful of beliefs.

ii. Policymakers want "rigorous and, in some cases, sensible proxy indicators to help in understanding risk and causal relationships and general support in making decisions in uncertain contexts" -all in under two pages.

iii. "Boundary spanning partners" or "intermediaries" may be used to interpret the scientific cause in the language of policy makers. These may include farmers and producer organizations, associations of agribusiness and traders. Boundary spanning organizations may provide effective forums, serve as brokers and act as capacity builders.

iv. The Agriculture Committees of Parliaments (national assemblies) are politically astute allies for agricultural interests but underutilized by science.

v. Governments may create an autonomous higher scientific body that establishes consensus on scientific issues to feed into the policy process. They may also control the flow of scientific requests and adjudicate disputes. Their effectiveness is often determined, however, by the degree of their independence and their real power

vi. Communication is a continuous process so that scientists keep up with a changing political landscape. Particularly difficult is communicating the ways that the science agenda can serve the poor and providing information that keeps technical and financial partners aligned around the African agenda.

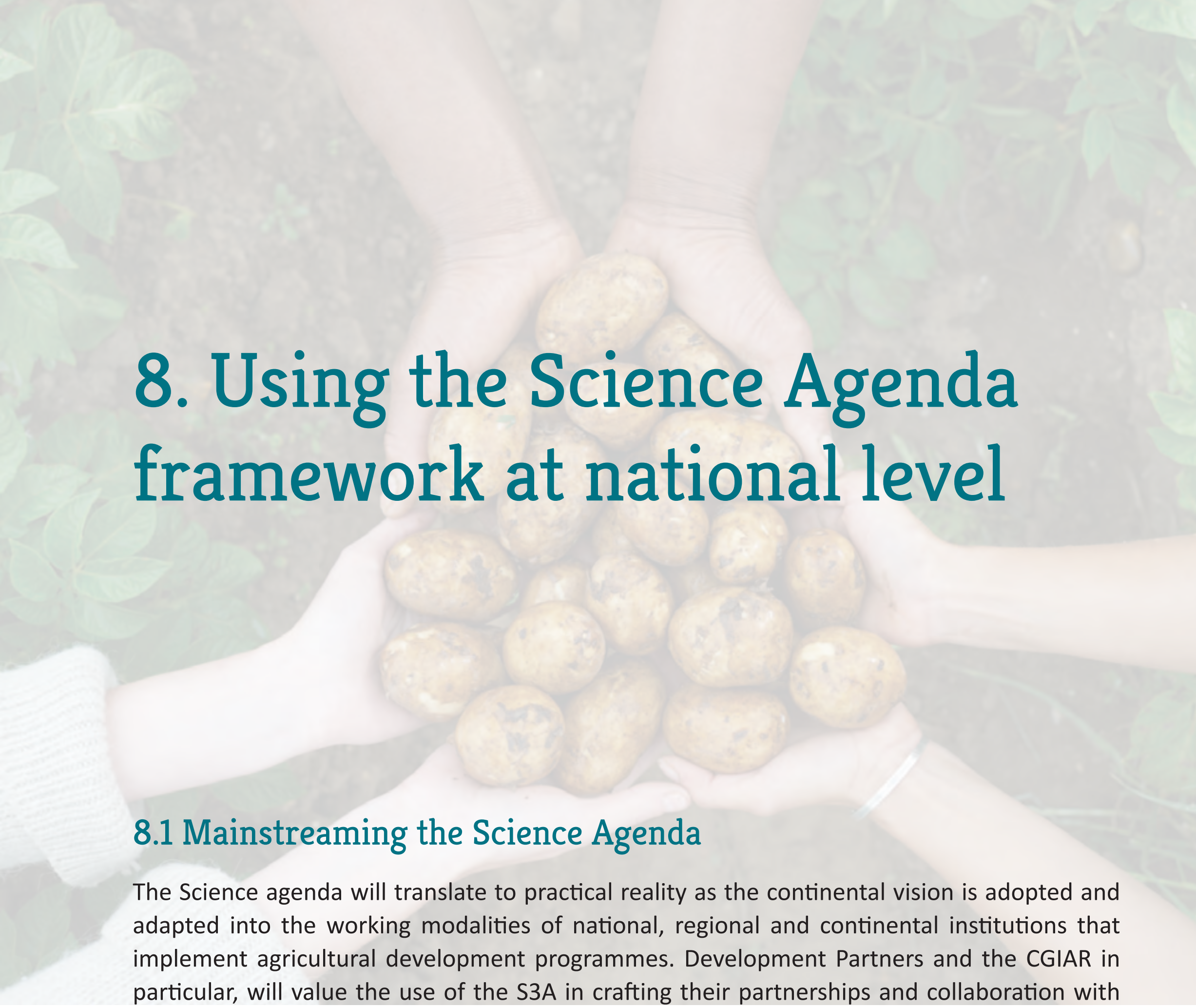
7.3 Strong commitment to women and youth

It is not just that gender equity is the right thing to aim for but it is necessary for both transformation at the farm level and for productive science. At the farm level, if women had the same access to productive resources as men, they could increase farm yields by 20-30% (FAO, 2011). As science in support of agriculture moves from the field to the lab, women are playing an increasing role in both basic and applied science of importance to farmers of all classes. A country cannot ignore the potential of 50% of its population when training and using its science capacity. Women will continue to expand their proportion in the scientific disciplines; the human resource and policy environments must ensure equity in their advancement. The attraction of the best young people to scientific pursuits, to field-oriented agriculture, and to technical support skills for servicing farm equipment is a demographic plus, if educational policies stimulate orientation in these directions.

Table 2. A system built around the Science Agenda for Agriculture in Africa

System Elements	A System to Realize a Transformational Science Agenda for Agriculture in Africa
Goals	1. Science that contributes to sustainably transforming agriculture for economic growth in Africa 2. Science that anticipates and responds to emerging threats and challenges 3. African institutions that take responsibility for defining and implementing goals 4. All African countries have a sufficient capacity to access the benefits of science 5. Scientists and leaders are connected within the continent and globally.

System Elements	A System to Realize a Transformational Science Agenda for Agriculture in Africa
Components	1. A policy making and policy supporting apex (AUC, NEPAD Agency, RECs, FARA) 2. Scientists in NAROs, Universities, and Extension services 3. Farmers and their organizations, and agribusiness 4. African regional organizations, international agricultural research centres and global advanced research institutes (ARIs) 5. Sub-regional research organizations (SROs) 6. Regional forums and platforms with research, training, and service functions; (AFAAS; PANAAC; PANGOC etc.) 7. Private sector entities active in research and development at national, regional and global levels 8. Policy and decision-makers connected across the levels
Means of Coordination	1. Defined multi-sectorial programs at national level with shared cross ministerial priorities 2. Sub-regional strategies defining the African agenda and CAADP 3. MOUs between AUC/NEPAD (CAADP)and Consortium of CGIAR Centres 4. African initiatives at national, regional and international involving innovations; financing mechanisms 5. Africa-wide "Scientific Mobility "Program, including mobilizing the diaspora. \through national and regional initiatives
Resources	1. Enhanced national commitment to Science for Agriculture in Africa 2. Innovative financing mechanisms such as Solidarity Fund for Science in Agriculture in Africa financed by, among others, African Governments. 3. African philanthropy, domestic private sector, international private foundations, bilateral donors, multilateral programs of donors, and development banks.
Environment for S3A	1. The increased interest in agriculture among governments and donors 2. A growing emphasis on the development end of the research-development continuum 3. The need to make strong case for a "sufficient science capacity" in every country 4. A heightened attention to showing causality in research impact pathways 5. A growing potential for growth in government revenues from taxes and royalties on extractive industries and growth of non-agricultural sectors. 6. Climate change and continued volatility in international markets that need to be understood and mitigated



8. Using the Science Agenda framework at national level

8.1 Mainstreaming the Science Agenda

The Science agenda will translate to practical reality as the continental vision is adopted and adapted into the working modalities of national, regional and continental institutions that implement agricultural development programmes. Development Partners and the CGIAR in particular, will value the use of the S3A in crafting their partnerships and collaboration with African institutions. The initial set of work-streams will therefore be driven by the SROs, FARA, RECs, and NEPAD Agency.

Guided by the Sustaining CAADP Momentum strategic outcomes and strategies, regional and continental entities, and development partners at that level, need to weave the S3A into support programmes to national CAADP investment plans. In turn these support activities will focus on ways of infusing the Science Agenda into national programmes and priorities.

The S3A is both a vision of Africa as a player in global scientific collaboration and a framework for building open systems with multiple interactions at the national, regional, continental and global levels. The vision is attainable if the resulting S3A systems receive commitment by top policy makers, ensure credibility of their scientific and education institutions, communicate their results in a professional way and connect openly for the free flow of ideas, people and resources.

> While strongly adopting a systems perspective for understanding the environment within which science for agriculture is effective, the Science Agenda must not be understood as a framework responsible for all aspects of the agricultural transformation of Africa. Instead, the Science Agenda must be seen as one that has a distinctive focus on creating the capacity and connections for effective science for agriculture.

8.2 Strengthening African ownership and leadership of the Science Agenda

The vision of the Science Agenda and the measures that need to be in place to realise the Agenda are noble yet lofty. To start with, African scientists and science administrators have to literally go behind closed doors and figure out how to stop the culture of outsourcing the thinking that goes into crafting science agendas, policies and development models. As Africans embolden themselves to own the problem analysis role, and as science leaders deepen the problem analyses and bring better quality evidence (both qualitative understanding of issues and quantitative measurement of the same), then Africans are better able to craft scientific initiatives, policies and development models that Africans own intellectually and practically.

These are the own-narratives that Africans have to write in all the aspects of *why, what* and *how* the Science Agenda will be rolled out so that its goals and vision will be realized. This is the most important start that Africa could give to the Science for agricultural development in Africa. This task cannot be out-sourced or delegated, if African leaders are to take responsibility for the role of science in society, and if Africans are to envision, create and work towards their own destiny.

African leadership at all levels, therefore, must invest in enhancing collective thinking capacity, and to therefore take responsibility for establishing institutions and processes capable of envisioning, conceptualizing, strategizing and crafting scientific and developmental models, policies and solutions for the continent. Integrating and socializing the sciences so that science is part and parcel of transforming agriculture and society at large in Africa requires that the agricultural science fraternity think and operate more broadly and openly than has been the case hitherto.

8.3 Building systemic capabilities at all levels is key to implementing the Science Agenda

It is clear from Chapter 5 that Africa does have the institutions in place at national, regional and continental levels. Partnerships with international research institutions have also matured over time. The challenge in realizing the Science Agenda vision, therefore, lies in strengthening the capacity of these institutions and more especially in rebuilding the sharing, collaborative and learning capabilities. Doing research does not in itself necessarily lead to innovation, rather scientists in teams and individually, as well as science administrators in Africa have to refresh their capacity for innovation by actively and consciously seeking breakthrough across ‘technical’, ‘infrastructural’ and ‘institutional’ innovations.

The Science Agenda is therefore about how to do research more innovatively than hitherto. Most challenges in the search for agricultural productivity and competitiveness require the capacity for simultaneous solutions across technical, infrastructural and institutional bottlenecks. Innovation therefore becomes largely a function of the capacity of research teams to learn faster and deeper across disciplinary, subject matter and sectoral boundaries, and this often requires sharing and/or collaboration across stakeholder groups.

It is this capacity for behavioural change and working in more practical and creative ways on the part of national and sub-regional organisations that is likely to lead to greater impact. Doing research that- besides technical breakthroughs -also actively seeks for institutional and infrastructural breakthroughs is part of the Science Agenda approach that should bring farmers, producers, and rural entrepreneurs closer to science, as the processes of science becomes more appealing to rural society. It is then the role of leadership to continually translate the body of science and technology work into different work-streams as follows:

- ***Problem solving and adaptive research:*** science that seeks farm-level, or production, processing, and marketing solutions that improve productivity, profitability and competitiveness of produce/products or services as well those than enhance resilience; this category of science is needs-driven and closest to producers and entrepreneurs; often requires more multi-stakeholder and inter-disciplinary collaboration; solutions may require combinations of technical, institutional and infrastructural innovations.
- ***Strategic, subject matter and disciplinary research:*** science that seeks higher order technical solutions, methods or knowledge that can be applied across several needs. This is research often carried out in laboratories as well as on controlled experiments in laboratories and field conditions. Strategic knowledge is for wider application across say a cropping or livestock system, farming system, or challenges shared across such, and so on.
- ***Basic and fundamental research:*** science that seeks deeper knowledge on principles of basic sciences and constitute building blocks of disciplinary and subject matter knowledge such as in biology, biochemistry, physics, economics, psychology and so on.

8.4 African solidarity in science

Promoting African solidarity in science is also the major vehicle to ensuring that no country is left behind, and that each country has a minimum capacity to address the needs of the agriculture, food, nutrition and natural resources sectors. Identifying and agreeing on important challenges and opportunities at national and regional levels, and then owning these collectively and collaboratively requires sharing of information and facilities to a greater extent than at present. Two or more countries sharing staff, facilities and information in addressing a common need is an example of new ways of collaboration envisaged by the Science Agenda.

Solidarity for Science" is a commitment by African countries to a new approach to science and agricultural transformation characterized by openness to new knowledge, regional collaboration, shared benefits of discovery, and significant increases in academic and scientific mobility. Sharing the broad science agenda at national and regional levels across these science work-streams and priorities allows for growing the various 'solidarity' and 'collaborative' programmes. Sharing information and facilities across scientists, institutions and national programs is more effective when organized around a common challenge or goal.

Collaboration and solidarity in science, if built on the principles of this science agenda, will deepen the quality of regional programmes by shifting emphasis from the establishment of regional research programmes and networks—to emphasis on national systems engaging each other on the basis of:

- Building capacity and strengthening existing institutions across the board as discussed in Chapter 5
- Crafting more effective modalities of collaboration and solidarity in the next 5 years at national and regional levels
- Planning for the various work-streams necessary for deploying the Science Agenda vision ahead of the AU Summit in June 2014 and beyond
- Mobilizing the key stakeholders at all levels to embrace the Science Agenda and developing practical ways towards implementation and realizing the vision.

Collaboration between countries and regions requires country and SRO joint efforts in establishing and/or strengthening collaboration and knowledge platforms. The question to answer is what is needed to incentivize the SROs and continental/regional agricultural organizations to participate and prioritize the Science Agenda and align this with existing mandates. The African Peer Review Mechanism (APRM) could also be relevant here as countries enjoy learning together as well as healthy forms of competition that are typical of African values and culture. Good examples now exist in Africa on sharing facilities and services for science. Examples of sharing of existing facilities include BecA at ILRI Nairobi, Maize Lethal Necrosis Lab and the maize double haploid (DH) facility for Africa – both established by CIMMYT in partnership with the Kenyan Agricultural Research Institute (KARI)

8.5 Collective action and solidarity across stakeholder groups in implementing S&T on CAADP programmes

Stakeholders across the board who are important in deciding priorities include, among others: a) organized farmer groups at national, regional and continental levels; b) education and training institutions including institutions that train farmers; c) extension services; d) NGOs that support farmers in various ways; e) private sector especially those based on inclusive business models; f) various government entities across various sectors involved in agriculture and rural development; and g) the various governmental and non-governmental institutions doing science for agriculture in Africa.

At initial stages of implementing strategies and approaches in this agenda, the AUC, NEPAD Agency, Sub-Regional Organisations (SROs), FARA and the CGIAR have a major catalytic role to play in getting the ideas in the Science Agenda translated to coherent and coordinated action. The main task is to partner and support national agricultural research and innovation systems in embracing the agenda and its vision.

In the next 5 to 10 years, the most practical and effective way is to roll out the Science Agenda as part of the CAADP Country Processes that include the implementation of the National

Investment Plans for Agriculture and Food Security. African countries have broadly embarked on the CAADP agenda, and it follows therefore that the Science Agenda has to initially focus on delivering the CAADP vision. The science agenda will find a more conducive policy environment if promoted as part of the knowledge support agenda for sustaining the CAADP momentum.

8.6 The "African Science for Agricultural Transformation Initiative" (ASATI)

The "African Science for Agricultural Transformation Initiative" (ASATI) is an idea that supports various activities such as information and resource sharing and providing incentives for all national systems in Africa to strengthen their science base. This Initiative needs development based on deeper needs and problem analysis. ASATI would be a solidarity fund for science and a means to demonstrate long-term commitment to building science capacity in all countries of Africa. No country has built a Science and Technology capacity by short-term projects alone – science needs to be mainstreamed as an essential part of an agriculture-led social and economic transformation in Africa.

Potential ASATI activities include:

Science honours: While scientists are generally motivated by their work, public recognition of accomplishment through an "African Food Prize" or "African Prize for Scientific Breakthrough" encourages not only the scientist but creates a role model for students that can help attract top students into agriculturally-related research;

Increasing scientist mobility: A functioning innovation system works through the flow of ideas, resources, and people. International experience broadens perspectives and helps deepen knowledge. Governments have it within their fiscal powers to set up tax legislation, fiscal exemptions for visiting scientists, and other measures that encourage intra-African mobility. Regional university exchanges and scientific visitors can be stimulated by appropriate measures at low cost to tax authorities of recipient countries.

Increasing mobility will first require some attempt to understand and evaluate credentials. Experience will eventually lead to harmonized standards and rigor of peer review for publication and evaluation of performance. Ethical procedures in research must be scrupulously observed if intra-African mobility is to be enhanced. In one West African study, almost 60% of peer-reviewed publications were with non-African partners. For some this could be seen as a positive measure of the strength of globalization but others view it as continued dependence. Intra-African mobility will change this ratio.

Engaging the African diaspora. Intuitively, the contribution that the African diaspora can make to African science is enormous. Africans account for 15% of the world's population but (by residence) produce only 1.5% of peer reviewed publications. Members of the diaspora may be engaged as practitioners to fill gaps in skills; as partners in research, and as scientific leaders. However, to attract them requires careful planning: 1) in mapping their numbers, 2) creating awareness, 3) ensuring meaningful participation and 4) preparing the infrastructure for their welcome. Such planning is an activity that should be led by a supranational organization.

Other ideas include:

- Exchange programmes on information, facilities, staff and other resources
- A scholarship and staff development programme
- Technology sharing platforms
- Youth engagement and other social marketing activities

8.7 Promoting the Science Agenda

The entire science fraternity working on agriculture in Africa has an important task of promoting the Science Agenda across other stakeholders and across the continent. It is important to disaggregate the messages to target specific audiences especially the NARS, policy actors, NGOs and private sector. Some potential activities for various stakeholders include:

- Identifying appropriate channels for communication (mass media, electronic media, workshop and conferences) and taking advantage of them
- Science agenda website which should be linked to all partner websites
- Community based platforms discussing the agenda
- Filter the relevant/key messages in communication briefs and policy briefs.
- Use of African and non-African champions/ambassadors to sell the S3A and engage the highest levels of the political leadership to drive the process
- Leverage machinery of government to reach more target groups and partners

AUC and NEAPD Agency need to provide guidance as to how some of these activities could be planned as part of celebrating the 2014 AU Year of Agriculture and Food Security.

9. Conclusion and moving forward

9.1 Connecting Africa with the world

The S3A is a framework for consolidating Africa as a player, contributor and beneficiary of global science for agriculture. It is underpinned by principles of solidarity among African scientists, support for action at the national, sub-regional and continental levels, and open collaboration horizontally among scientists and vertically with regional centres of excellence, the CGIAR and advanced research institutes globally.

The S3A is built on the belief that Science is a lever for agricultural transformation in Africa and that Science contributes towards making agriculture in Africa more productive, competitive, resilient, sustainable, and inclusive. To that end, the Framework calls on governments to maintain a basic science capacity in all countries of Africa.

Short term research projects have their place in development, but cannot be the path for realizing the vision of the Science Agenda. Moreover, science needs to be responsive to future challenges such as climate change and changing demographics, the changing needs of farmers, producers, consumers and agribusiness entrepreneurs.

Visionary science leaders, especially at the national level, must champion S3A through accelerated sharing of knowledge and research facilities, within and amongst countries. Strong national institutions are the building blocks of effective regional collaborations. Africa needs more world-class

scientific institutes at national and regional levels that are strong and effective in sharing knowledge and facilities. African leaders need to put in place the necessary agreements, fiscal accords and financial support to maximize scientific and academic mobility within Africa itself. Africa should achieve such solidarity through various means, including commitment to establishing an Africa Science for Agricultural Transformation Initiative including a Fund that supports various solidarity activities that strengthen all countries.

Africa will earn its place by seizing the moment. Now is the time to increase investments in science for agriculture in Africa, when countries have the means and opportunities to invest, and gain returns. Africa shall strengthen its role as a player in global science for agriculture by giving strong direction to the science agenda, and minimising the outsourcing of science policy and agenda setting to international researchers and investors, public and private.

Africa has earned its place at the table. Its increasing disposition and capacity to plan and integrate activities across the continent has brought together partners that can align with its agendas. Global players must adjust their mandates to align with Africa's needs and there is need to create mechanisms and plans that respect African agendas.

Africa has always earned its place as a welcoming place for regional and international exchanges. Capacity, collaboration and continued partnership will be the hallmarks of advancing further. Partnerships will therefore adhere to the S3A principles of: mutual respect; mutual benefit; and mutual accountability.

9.2 Towards implementation of the Science Agenda

1. Preparation of a 5-Year Implementation Strategy and Plan as follow up to the AU/NEPAD process
    - **a. Implementation of S3A at continental and regional levels**
        - i. Identify common challenges, opportunities, targets at regional levels in collaboration with AUC/NEPAD, SROs, CGIAR and other stakeholders in line with Regional CAADP Compacts and process
        - ii. Complete needs assessment and capacity development plans for regional and entities and their support of national systems
        - iii. Plan for the establishment of more 'shared science facilities' at regional and continental levels
        - iv. Examine and expand successful existing facilities such as: BecA at ILRI Nairobi; and the Maize Lethal Necrosis Lab and the maize double haploid (DH) facility for Africa – both established by CIMMYT in partnership with the Kenyan Agricultural Research Institute (KARI)
        - v. Identify need and plan for new shared scientific facilities
    - **b. Supporting and strengthen National CAADP National Agriculture Investment Plan (NAIP) Implementation**
        - i. Develop a S3A 'country implementation guidelines' aligned to and driven by the country CAADP NAIPs
        - ii. Working with all stakeholder groups to actualise the NAIPs

iii. Formulate approaches and develop capacities and procedures to work on challenges and opportunities for improving agricultural productivity, competitiveness, resilience and job creation in ways that yield simultaneous solutions across technical, infrastructural and institutional bottlenecks and innovations.

c. Craft a S3A Results Framework derived from (a) and (b) above

2. Design and plan to establish an "African Science for Agricultural Transformation Initiative" (ASATI): a Fund for promoting African solidarity in science
   a. ASATI is a vehicle to ensure that no country is left behind, and that each country has a minimum capacity to address the needs of agriculture.
   b. Strengthening systemic capabilities at all levels more especially in rebuilding the sharing, collaborative and learning capabilities, including how to be innovative in doing science
   c. Examples of working models
      i. Two or more countries sharing staff, facilities and information in addressing a common need
      ii. SROs joint efforts in establishing and/or strengthening collaboration, knowledge and technology sharing platforms.
      iii. Science honours: eg"African Food Prize"
      iv. Increasing scientist mobility and exchange programmes
      v. Scholarship fund for staff development
   d. Promoting technology platforms especially for smallholder farmers
3. Mainstreaming and promoting the Science Agenda
   a. Strengthening African ownership and leadership of the Science Agenda
   b. Social marketing the S3A so that farmers, producers, and rural entrepreneurs come closer to science, as the processes of science become more appealing to rural society.
   c. Identifying appropriate channels for communication (mass media, electronic media, workshop and conferences) and utilise them
   d. Develop popular messages in communication and policy briefs.
   e. Use of African and non-African champions/ambassadors to sell the S3A

Annexes

Annex 1: Agriculture in Africa – Key statistics

Agriculture as share of GDP: **30 – 40 per cent**

Employment in agriculture as share of total workforce: **60 per cent Sub Saharan Africa (SSA)**

Female employment in agriculture as share of total rural workforce: **50 per cent (SSA)**

Contribution of agriculture to the income of the rural workforce: **50 per cent**.

Agricultural export earnings as share of total export earnings: **40 per cent.**

Agricultural produce lost to poor post-harvest management system: **30 – 40 per cent of total production**

Average food import bill per year in the 2000s: **USD 20 billion**

Annual growth rate of agricultural GDP (in real terms), 2002 – 2007: **5.5 per cent**

Irrigated land as a proportion of potential: **7 per cent** (East and South-East Asia: 29%; South Asia: 41%)

Use of fertiliser per hectare: (Sub-Saharan Africa) **13 kg** - i.e., 7 per cent of the average for East Asia; (North Africa) **73 kg**- i.e., 38 per cent of the average for East Asia

Farm power sources in percentages - **SSA** (Other Developing Regions): **Hand, 65** (25); **Animal, 25** (25), **Engine, 10** (50)

Annex 2: Developing the Science Agenda – The process

The S3A is one of four strategic thrusts of knowledge and knowledge support under the 'CAADP sustaining the momentum'. Its development began as one of the five work streams of the *Dublin Process,* which aimed at improving alignment of the CGIAR to the CAADP agenda. Under the championship of IFAD's President, and an Oversight Group of African stakeholders, the S3A has become an African-led initiative to reaffirm the role of Science for Agriculture in Africa. Of particular importance in this respect is two meetings that were held in Accra, Ghana during the first quarter of 2013, which helped define work plan and methodology for the formulation of the Science Agenda. The outcomes of these meetings, which were also endorsed by subsequent meetings in Rome (March 2013) and in Dublin (April 2013), came to be known as the *Accra Consensus on the Development of the Science Agenda for Agriculture in Africa*.

The whole process for the formulation of the Agenda is Africa-owned and Africa-led. It is endorsed by the AUC and the NEPAD Agency. It is led by an Oversight Group (OG) reporting to the FARA Board. Furthermore, an Expert Panel (EP) composed predominantly of African professionals was entrusted with drafting the Science Agenda as well as implementing a process of broad stakeholder consultation. In this regard, the EP produced a *Discussion Paper* that laid out the issues that a S3A needs to explore and which was circulated to all relevant stakeholders for further inputs. FARA presented a progress report to the Sixth African Agricultural Science Week held in July 2013 in Accra. The Discussion Paper served as a background reference document for an e-consultation process undertaken in August 2013. The outcomes of these processes and the results of a small number of focused commissioned studies on critical topics of relevance to the S3A discourse served as source materials for developing the present document: *"Science Agenda for Agriculture in Africa- Connecting Science: A science agenda for transforming agriculture in Africa "*.

FARA Secretariat submitted the draft Science Agenda document to the FARA Board for endorsement. This document was also presented at pertinent CAADP, SRO and other agricultural science fora to solicit additional inputs and enhance buy-in.

In April 2014, the FARA Secretariat formally submitted the edited version of the S3A document to the AU Commission on behalf of the African community of stakeholders. Key recommendations of this strategic framework document will be deliberated by AU high-level organs, including the Conference of African Ministers of Agriculture in April 2014. This conference will be preceded by a technical meeting of senior agricultural experts from all AU Member States. This will set the stage for the adoption of the Science Agenda through Summit-level Decisions by African Heads of State in July 2014 as part of the celebration of the AU's Year of Agriculture and Food Security.

The process and methodology to develop and ratify the Science Agenda recognises the necessity of linking the technical strategy with effective political buy-in and accelerated implementation. The goal is effective institutionalization of the Agenda within the AU and regional and sub-regional bodies.

Annex 3. Summary characteristics of the 14 major sub-Saharan farming systems

Farming Systems	Defining characteristics	Mean LGP	Market access	Main livelihood source	% Sub-Saharan rural poor <$1.25/day
Maize Mixed	Sub-humid and humid areas, dominated by maize with legumes	191	Medium	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work	19.9
Agro-Pastoral	Semi-arid areas, mixed sorghum/millet and livestock systems	129	Medium-high	Sorghum, pearl millet, pulses, sesame, cattle, sheep, goats, poultry, off-farm work	17.3
Highland Perennial	Moist highland areas with a dominant perennial crop either banana (often with coffee) or enset in Ethiopia	267	Medium-high	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work	15.0
Root and Tuber Crop	Lowlands, dominated by roots and tubers with no major tree crop,	271	Medium	Yams, cassava, legumes, off-farm work	10.9
Cereal-Root Crop Mixed	Two starchy staples alongside roots and tubers	186	Medium-high	Maize, sorghum, millet, cassava, yams, legumes, cattle, off-farm work	9.3
Highland Mixed	Above 1700 m; LGP, temperate cereals due to altitude	193	Medium	Wheat barley, teff, peas, lentils, broad beans, rape, potatoes, sheep, goats, live-stock, poultry, off-farm work	8.1
Humid Lowland Tree Crop	Where tree crops replaced forest; > 25% source of cash income; Oil palm has local market	292	High	Cocoa, coffee, oil palm, rubber, citrus, yams, cassava, maize, off-farm work	6.5
Pastoral	Household income from extensive livestock production	70	Medium	Cattle, camels, sheep, goats, remittances	4.5
Fish-Based	Proximity to sea or lake; fish is significant livelihood source	194	High	Fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work	3.5
Forest-Based	Humid lowland heavily forested areas	343	Low	Subsistence food crops including cassava, maize, beans, coco yam and taro, and off-farm work.	2.5
Irrigated	Large scale irrigation scheme; mappable; absence of rainfed agriculture	53	High	Rice, cotton, vegetables, rain fed crops, cattle, poultry	1.1
Perennial Mixed	High production intensity and commercial orientation	145	High	Deciduous fruits, tree plantations, sugarcane	0.9

Arid Pastoral and Oasis	Strong connection between oases and arid surroundings for water and livestock management	15	Very low	Date palms, cattle, small ruminants and off-farm work, with some scattered irrigated crops and vegetables	0.4
Urban-Based	Center or fringes of cities, high population density	Variable	High	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work	

* Measured by travel time (hours) to town of 20,000 inhabitants. Classes include: Very Low 15+; Low 9-15; Medium 7-9; Medium-High 4-7; High 0-4 hours

Annex 4: International case studies of science transforming agriculture

Brazil

Brazil has transformed from a food importer to one of the world's largest agricultural producers over the past several decades, catching up with developed countries that have historically dominated grain exports. The Brazilian Agricultural Research Corporation (Embrapa) was a key reason for this extraordinary growth, literally changing the landscape of Brazil to increase the cultivation of the cerrado, Brazil's savannah.

The country is notable for the science-based development of successful tropical agriculture. Until Brazilian agricultural researchers developed new crops and forage varieties with agricultural practices tailored for tropical agriculture to create a modern and strongly competitive agriculture in Brazil, it was believed that only temperate regions could effectively and efficiently feed the world. For instance, the research and entrepreneurial efforts made in Brazil to develop and cultivate soybean varieties for lower latitudes are capable of producing yields as high (and possibly higher) as those produced in temperate regions. In conjunction with this genetic effort, it was necessary to adopt new technologies, such as novel agricultural practices and modern innovations, including improved seeds, fertilizers, and agrochemicals, to change the farming environment into a highly productive one.

China

Smallholder agriculture drove China's agricultural revolution, which provided the basis for the country's dramatic economic transformation and poverty reduction in the last 30 years. Both the state and the market spurred on China's agricultural revolution. Public policies increased incentives for family farming, beginning with a pragmatic reform of land tenure arrangements. Rural industries and off-farm jobs were generated through special schemes for rural enterprises and employment creation. Progressive widening of regional and national markets led to more diversity and greater specialization within the agricultural sector. Incentives for farmers to meet market demands were supported by public investment for infrastructure and small-farmer oriented agricultural research and education, all as part of a broad, coordinated agenda to achieve medium and long-term objectives.

As a result, farm productivity rose rapidly. This, in turn, created economic surpluses that fuelled both rural and urban industries. With fertility rates held in check, per capita food production and consumption also rose quickly. Knowledge supported China's agricultural strategies and progressive diversification. Decision-making was evidence-based. China sought and absorbed agricultural know-how from other countries.

South Korea

The rapid development in Korean agricultural technologies include areas such as biotechnology, breeding, soil and nutrition management, agricultural mechanization, and post-harvest management. Strong support from international partners was critical to this development and includes technology transfer, provision of equipment, human capacity development, and improvement of technology development systems.

One of the most significant areas of international assistance was in the agricultural development system. In 1947, Korea adopted the Land Grant College system from USA, which established the National Agricultural Development Institute, responsible for agricultural research-extension-education. The strong bond between research and extension resulted in rapid transfer of agricultural technologies to farmers using the extension workers as catalysts. Because of this effective linkage between research and extension, Korea was able to achieve self-sufficiency in rice with its Green Revolution in a short period of time.

Thailand

From the mid-1980s, agriculture in Thailand began to transform rapidly. Job opportunities in manufacturing, urban services and rural non-farm economy attracted the labour force which drifted away from agricultures. At the same time, the land frontier was closing and it became harder to add new land. Consequently, agricultural growth slowed to about 2%–3% per year, although productivity increased notably. Given opportunities in both domestic and international markets, new activities emerged such as rubber, cassava, pineapples, and high value perishables for the fast-growing cities. Most farm households diversified their income sources, while some became more specialized in higher-value agricultural products sold into more sophisticated marketing chains. The rural non-farm economy rapidly grew to a point where it now provides around half of all rural jobs. Successful industrialization of the country s allowed direct and indirect net taxation of farming to be virtually eliminated.

In the early 1960s, more than 60% of the rural population lived in poverty. By the early 2000s that had been cut to only a little more than 10%. From 1988 to 2007, the number of households affected by food poverty declined from 2.55 million to 418 000. With more and cheaper staples, and reduced poverty, child malnutrition has also declined. The incidence of underweight young children fell from 17% in 1987 to 7% in 2006; while that of stunting was reduced from 25% to 16%. During the 1960s and 1970s, most of the improvements came from increasing farm incomes. Subsequently, incomes from rural non-farm jobs and remittances from migrants became important.

The Thai story is an example of a successful transition from an initial situation in which it was possible for agriculture to grow by putting underused factors of production to work, with only limited improvements in productivity, to a later stage where land and labor became increasingly scarce and growth could only continue through improved returns to these scarce inputs. Success has been achieved primarily through private initiative, with the state playing a strategic role in setting an investment climate, investing in roads and research, and also supporting agricultural credit to overcome market failures.

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Acronyms and abbreviations

ABI	Africa Biosciences Initiative
ASALs	Arid and Semi-Arid Lands
AFAAS	African Forum for Agricultural Advisory Services
ASARECA	Association for Strengthening Agriculture in eastern and central Africa
ANAFE	African Network for Agriculture, Agro forestry & Natural Resources Education
APRM	African Peer Review Mechanism
ASATI	African Science for Agricultural Transformation Initiative
AU	African Union
AUC	African Union Commission
AU-IBAR	African Union InterAfrican Bureau for Animal Resources
AU-PANVAC	African Union Pan African Veterinary Vaccine Centre
AWARD	African Women in Agricultural Research and Development
BeCA	Biosciences eastern and central Africa
BMGF	Bill and Melinda Gates Foundation
CAADP	Comprehensive African Agriculture Development Programme
CCARDESA	Centre for Agricultural Research, Development and Extension in Southern Africa
CGIAR	Consultative Group of International Agriculture Research
CIMMYT	International Maize and WheatImprovementCenter
CORAF	Conseil ouest et centre africain pour la recherche et le développement agricoles
CPA	Consolidated Plan of Action
CRPs	CGIAR Research Programmes
CSO	Civil Society Organisations
CTA	Technical Centre for Agricultural and Rural Cooperation (ACP-EU)
DNA	De-oxyribo Nucleic Acid
DP	Discussion Paper on S3A presented to African Agricultural Science Week
DRC	Democratic Republic of the Congo
EAAPP	East African Agricultural Productivity Programme
EMBRAPA	Brazilian Agricultural Research Corporation
EP	Expert Panel

FAAP	Framework for African Agricultural Productivity
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
FFA	Frame Work for Action
GCARD	Global Conference on Agricultural Research for Development
GDP	Gross Domestic Product
GHGS	Green House Gases
GIS	Geographic Information System
GM	Genetically Modified
HYVs	High Yielding Varieties
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAC	InterAcademy Council
IBLI	Index Based Livestock Insurance
ICT	Information Communication Technology
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute (ILRI*)*
IPM	Integrated Pest Management
ISSM	Institute for the Study of Security Markets
KARI	Kenyan Agricultural Research Institute
LGP	Length of Growing Period
MAS	Marker Assisted Selection (MAS
NARS	National Agricultural Research Systems
NEPAD	New Partnership for Africa's Development
NERICA	New Rice for Africa
NGO	Non-Governmental Organization
NPCA	NEPAD Planning and Coordinating Agency
OG	Oversight Group
OIE	Office International des Epizooties,

PAFO	Pan African Farmers Organisation
PANAAC	Pan African Agribusiness and Agro Industry Consortium
PANGOC	Pan African Non-Governmental Organizations Consortium on Agricultural Research
PCR	Polymerase Chain Reaction
PPR	Peste des Petites Ruminants
R&D	Research and Development
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
S3A	Science Agenda for Agriculture in Africa
SPAAR	Special Programme for African Agricultural Research
SROs	Sub-Regional Organizations
SSA	Sub-Saharan Africa
STISA	Science, Technology and Innovation Strategy for Africa
S&T	Science and Technology
STEP	Synthesis Team of the Expert Panel
TAEIs	Tertiary Agricultural Educational Institutions
TAG	Technical Advisory Group
TFP	Total Factor Productivity
UK	United Kingdom
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organisation
UPOV	International Union for the Protection of New Varieties of Plant
WAAPP	West African Agriculture Productivity Programme
WARDA	West Africa Rice Development Association,
WECARD	West and Central African Council for Agricultural Research and Development
WHO	World Health Organisation of the United Nations

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