BACKGROUND PAPER

Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat

Cereal Crops

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EXECUTIVE SUMMARY

Africa with its vast land area covering 3 billion ha has 1.3 billion ha of agricultural land out of which only 252 million ha (19.36 %) is arable (2011, FAO). Africa is the center of origin and also a major producer of several cereals like sorghum, pearl millet, finger millet, teff and African rice. Another major cereal, maize, has overtaken these traditional cereals while wheat is widely cultivated in North Africa and in Sudan and Ethiopia. Agriculture is the 'engine for growth' in Africa. With subsistence agriculture practiced by majority small holder farmers, yield gaps are high and poor soils, amongst other constraints add to the difficulties for sustainable farming and incomes. Cereals like Sorghum, Millets, Wheat, Maize and Rice are major staple foods of the most population. These cereals are grown over an area of 98.6 m ha producing 162 m tons (Table1).

Table 1: Area and production of selected cereal crops

Crop	Africa (2012)	
	Area (ha)	Production (t)
Maize	34,075,972	70,076,591
Millet	19,998,008	16,008,838
Rice, paddy	11,206,813	28,798,202
Sorghum	23,142,595	23,350,064
Wheat	10,224,952	24,704,201
Total	**98,226,080**	**162,422,507**

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Maize is a major staple food crop grown in diverse agro-ecological zones and farming systems, and consumed by people with varying food preferences and socio-economic backgrounds in sub-Saharan Africa (SSA). The central role of maize as a staple food in SSA is comparable to that of rice or wheat in Asia, with consumption rates being the highest in eastern and southern Africa (ESA). Of the 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet, 16 are in Africa. Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. An estimated 208 million people in SSA depend on maize as a source of food security and economic wellbeing. Maize occupies more than 33 million ha of SSA's estimated 200 million ha of cultivated land. Considering the low average maize grain yields that are still pervasive in farmers' fields, meeting the projected increase demand for maize grain in Africa presents a challenge.

Sorghum is the second most important cereal after maize with 22% of total cereal area, followed by millets (pearl and finger) with 19% of the total cereal land coverage. The continuing demand for these two crops is reflected in the trend for increasing area under sorghum and millets in Africa over the last fifty years. Unfortunately however, crop productivity has not kept pace with increasing demand, due mainly to a lag in crop improvement efforts in sorghum and millets, relative to other cereals, and the extreme environmental conditions and resource constrained, low-input farming systems where these crops are grown. Furthermore, in such dryland environments, the issues of climate variability, change and land degradation are acute with a lack of progress the result of neglect, remoteness

and weak national institutions. Despite these factors there is a strong case for stepping up the efforts towards development of technologies (germplasm improvement, agronomic management), markets and institutions to advance the case for sorghum and millets in the dryland tropics of Africa.

Rice has become a highly strategic and priority commodity for food security in Africa. Consumption is growing faster than that of any other major staple on the continent because of high population growth, rapid urbanization and changes in eating habits (Seck et al., 2013). It is the single most important source of dietary energy in West Africa and the third most important for Africa as a whole. Although local rice production increased rapidly after the 2007-2008 food crisis, a key problem facing the rice sector in Africa in general is that local production has never caught up with demand. The continent therefore continues to rely on importation to meet its increasing demand for rice.

Wheat is grown on around 10 million ha in Africa. It is a major staple crop for several countries and an imported commodity in all of Africa. In all African countries, wheat consumption steadily increased during the past 20 years as a result of growing population, changing food preferences and socioeconomic change associated with urbanization. African countries are the world's biggest wheat importer with more than 45 m t in 2013 at around 15 billion US$. Wheat imports account for 60% of African's wheat consumption and 80% of Sub-Saharan (SSA) countries. North African countries have the highest per capita wheat consumption and wheat provides up to 50% of daily calories and protein. In rapidly urbanizing sub-Saharan Africa, wheat consumption is expected to grow 38% by 2023 with imports already at 23 m tons of wheat in 2013 at a cost of $7.5 billion. Considering the growing importance wheat has for food security in Africa, African Union Heads of State endorsed their Agriculture Ministers' endorsement in January 2013, to add wheat to the list of strategic crops for Africa.

Cereal yields in Africa are lower than half the world average. The average fertilizer ($N + P_2O_5$) consumption is 16.24 kg/ha (2010, FAO) which is $1/6^{th}$ compared to the world consumption of 98.20 kg/ha. Increasing productivity of the small holder farmers, bridging the yield gaps by providing appropriate inputs along with improved technologies such as stress resistant and high yielding varieties will be a step towards agricultural transformation in Africa.

Africa faces a wide range of challenges in the production of the five major cereals considered in this Work Stream - rice, maize, millet, sorghum and wheat. Key among these challenges are:

1. ***The impact of climate change***: Global agriculture is facing the probable impact of global warming. Recent studies suggest that the production of major commodities has declined since 1980 due to global warming (Lobell et al. 2011). It is estimated that, given current warming trends in sub-Saharan Africa, the production of major cereals could decline by as large as 20% by mid--century (Schlenker and Lobell 2010). The poor who depend on agriculture for their livelihoods and are less able to adapt will be disproportionately affected (World Bank 2007). A recent study estimates the annual costs of adapting to climate change in the agricultural sector to be over USD 7 billion (Nelson et al. 2009).

2. ***Land degradation and persistent biotic and abiotic stresses***: In addition to inherently high climate variability, the looming threat of higher temperatures and more vicious droughts (arising from climate change) is a major concern. Further, high incidences of diseases, insect-pests, and parasitic plants, and sub-optimal soil nitrogen have also presented a continuous challenge to cereal productivity in SSA.

3. ***Rapid population growth across Africa and associated difficulty in meeting the projected demand for food***: The high population growth in Africa is giving rise to rapidly increasing demand for food. The UN's Human Development Indices suggest that the dryland areas in West and Central Africa (WCA) and East and Southern Africa (ESA) remain among the poorest and most food-insecure places in the world.

4. ***Poor mechanization***: The low level of mechanization in African agriculture has continued to serve as a huge impediment towards advancing cereal production, especially of wheat and rice which, in turn, results in the high cost of producing these crops.

5. ***Inadequate or weak policy environment***: Most government policies are inappropriate and inconsistent, and do not provide an enabling environment for the development of the cereal sector in Africa. This includes low funding of the national agricultural research and extension institutions, leading to ineffective technology development and diffusion mechanisms. Lack of investment in infrastructure such as roads, storage and market facilities handicaps the potential role of the private sector.

6. ***Dwindling financial resources for Research and Development***: There has been a steady decline in the level of financial support by the major donors to agricultural research, over the last 5 years. Many CGIAR centres have had to cut back their financial allocations to these cereals.

Good efforts are being made by the CGIAR Centres in collaboration with the national institutions and other key stakeholders to address these challenges and improve the productivity of maize, sorghum, millets, rice and wheat in Africa, to meet the increasing demands. The CGIAR Centres spearheading the development of these important cereals have put together strategies for re-invigorating the process of developing and disseminating the requisite technology that would increase the production and productivity of the cereals to meet the increasing demand in Africa. For example:

- ***Sorghum, Pearl millet and finger millet***: Additional support is required to enable the strengthening of the Crop Development Process, strengthen the seed production and delivery systems for improved varieties, empower farmers to enable them manage their natural resource base in a sustainable manner using integrated soil fertility and crop-livestock systems management (e.g livestock providing a better enterprise option for smallholder farmers), crop rotation (e.g. the important of cash crops like cotton in terms of residual P and N for the subsequent legume and cereal crops, respectively), minimum or conservation tillage systems, expedite the scaling out of new sorghum and millets technologies including products development, enable Farmers' access to production inputs and markets, and strengthen and sustain the technology delivery system.

- ***Maize***: Support is needed to scale-up and deliver improved multiple stress tolerant, nutrient-use efficient and nutritious maize varieties, Curb the spread and impact of MLN, strengthen the maize breeding pipeline for enhancing capacity of NARES and SMEs, sustainable intensification of maize-based agri-food systems, and develop better Aflasafe products, aflatoxin management systems and delivery mechanisms.

- ***Wheat***: Support is required to enable the generation of improved and sustainable wheat based technologies and innovations suitable for different agro-ecological zones of Africa, and enhance the sustainable dissemination, scaling-up and promotion of wheat based technologies and innovations along the value chain.

- ***Rice***: Additional support is required to support the establishment of efficient rice seed systems, Africa-wide dissemination of climate resilient rice varieties, dissemination of good agricultural practices (GAP) to close yield gaps, improving quality management along the value chain, and investment in rice production and processing infrastructure

Finally, a major requirement that cuts across all the five cereals is the need to strengthen the capacity of the National Agricultural Research Systems (NARS) in African countries.

Table 2 presents a summary of budgetary requirements for the work proposed for sorghum / millets, maize, wheat and rice in short, medium and long term basis.

Table 2: Summary of budget for implementing activities proposed for improving cereal crop production in Africa

Crops	**Budget in US$**			
	Short Term	**Medium Term**	**Long Term**	**Crop Totals**
Sorghum & Millets	40,387,487	42,642,400	73,929,600	156,959,487
Maize	130,120,000	-	-	130,120,000
Wheat	62,000,000	62,000,000	54,000,000	178,000,000
Rice	106,714,350	48,157,938	45,274,543	200,146,831
Term Totals	**339,221,837**	**152,800,338**	**173,204,143**	**665,226,318**

1. BACKGROUND

a) Sorghum and Millets

Africa is the center of origin and also a major producer of several cereals like sorghum, pearl millet, finger millet, teff and African rice. Agriculture is the 'engine for growth' in Africa. With subsistence agriculture practiced by majority of small holder farmers, yield gaps are high and poor soils, amongst other constraints add to the difficulties for sustainable farming and incomes. Cereals like Sorghum, Millets, Wheat, Maize and Rice are major staple foods of the most population. These cereals are grown over an area of 98.6 m ha producing 162 m tons. Sorghum is the second most important cereal after maize with 22% of total cereal area. Pearl millet is a climate hardy crop which is grown in harsh conditions, but as a subsistence crop. Harvested from an area of 20 m ha in the semi-arid regions of Africa pearl millet contributes 19% area to cereal production.

Cereal yields in Africa are lower than half the world average. The average fertilizer ($N + P_2O_5$) consumption is 16.24 kg/ha (FAOSTAT 2010) which is $1/6^{th}$ compared to the world consumption of 98.20 kg/ha. Increasing productivity of the small holder farmers, bridging the yield gaps by providing appropriate inputs along with improved technologies such as stress resistant and high yielding varieties and empowering farmers to better manage climate risk will be will be a huge step towards agricultural transformation in Africa.

The primary demand for sorghum and millets is for food in Africa, especially in the dryland regions where these are the principal crops. This continuing demand is reflected in the trend for increasing area under sorghum and millets in Africa over the last fifty years but crop productivity has not kept pace with this increasing demand. This is due to both a lag in crop improvement efforts in these crops and the extreme environmental conditions and the low-input agriculture under which these crops are grown. Thus it is immediately evident that crop improvement efforts combined with improved agronomic practices is a must for these crops in Africa, especially in view of the reducing arability of land. Interventions of the Bill and Melinda Gates Foundation-supported HOPE project (Harnessing Opportunities for Productivity Enhancements) for sorghum and millets (http://hope.icrisat.org) that started in 2009, have demonstrated that yield gains from as low as 17 to as high as 141 per cent for these crops are possible through the use of improved varieties and associated improved agronomic practices.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has the mandate for research and development of sorghum, pearl millet and finger millet, among other crops. A number of initiatives are currently ongoing that present good opportunity for the current process to tap from. Some of the key ongoing initiatives are:

1. Harnessing Opportunities for Productivity Enhancement (HOPE) of sorghum and millets in Sub-Saharan Africa Project, supported by the Bill and Melinda Gates Foundation, and implemented by ICRISAT in partnership with the national partners in 10 African countries. Phase 1 of this project (July 2009 to June 2015) covered Burkina Faso, Mali, Niger and Nigeria (in WCA) and Ethiopia, Eritrea, Kenya, South Sudan, Tanzania and Uganda in ESA. Phase 2 of the HOPE project, which is expected to commence in January 2016 and run for five years, will involve Burkina Faso, Mali and Nigeria (in WCA) and Ethiopia, Tanzania and Uganda (in ESA).
2. Enhancing the adoption of improved sorghum varieties for increased agricultural system productivity and food security in Nigeria, Supported by West Africa Agricultural Productivity Program (WAAPP), Nigeria Project

3. Agricultural Transformation Agenda Support Project Phase-1 (ATASP-1) outreach sorghum component supported by the African Development Bank through the Nigeria Federal Ministry of Agriculture.
4. Sorghum Transformation Value Chain (STVC) supported by Nigeria Federal Ministry of Agriculture and Rural Development
5. USAID funded Africa Rising project on large scale sustainable intensification in 5 countries of ESA and WCA including the dissemination of technologies for sorghum and millet based farming systems in Mali.

These initiatives have led to significant achievements with the release of high yielding improved sorghum and millet varieties adaptable across the target countries and agro-ecologies. The ATASP-1 outreach program that is implemented by IITA, ICRISAT and AfricaRice in partnership with several NAREs and private enterprises, intends to promote agribusiness, attract private sector investment in agriculture, reduce post-harvest losses, add value to local agricultural produces, develop rural infrastructure and enhance access of farmers to financial services and markets.

West Africa Agricultural Productivity Project (WAAPP) is expected to generate and disseminate improved technologies in the participating countries' target areas that are aligned with the region's top priorities, as identified by West and Central Africa Council for Agricultural Research (CORAF/WECARD).

A number of ICRISAT bilateral projects seek to generate new improved agricultural technologies, seed systems, value addition and capacity building of National partners. Similarly ICRISAT operates several CGIAR Center Research Projects (CRPs), with leadership in the sorghum and millets components of the CRP portfolio.

b) Maize

Maize is the most widely-grown staple food crop in sub-Saharan Africa (SSA) occupying more than 33 million ha each year (FAOSTAT, 2015). The crop covers nearly 17% of the estimated 200 million ha cultivated land in SSA, and is produced in diverse production environments and consumed by people with varying food preferences and socio-economic backgrounds. More than 300 million people in SSA depend on maize as source of food and livelihood (http://dtma.cimmyt.org/index.php/background). The top 20 countries, namely South Africa, Nigeria, Ethiopia, Tanzania, Malawi, Kenya, Zambia, Uganda, Ghana, Mozambique, Cameroon, Mali, Burkina Faso, Benin, DRC, Angola, Zimbabwe, Togo, and Cote d'Ivoire, account for 96% of the total maize production in SSA. (FAOSTAT, 2015).

The planted land of maize and grain production have increased significantly across regions in SSA since 1961 (FAOSTAT, 2015). Of the 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet, 16 are in Africa (Nuss and Tanumihardjo, 2011). Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. Regional average yields are as high as 1.7 t/ha in West Africa and 1.5 t/ha in East Africa, and 1.1 t/ha in Southern Africa (Smale et al., 2011). Even though some countries (e.g., Ethiopia with >3 t/ha) have made significant productivity gains, the average yield of maize in SSA (estimated at <1.8 t/ha) is still far below the global average yield of maize (~5 t/ha) and considerably below the 4.4-5.4 t/ha on-farm trial results of improved varieties under optimal inputs and improved management conditions undertaken by CIMMYT/IITA within SSA.

Several projects have been designed and implemented in SSA with funding from diverse donors to improve productivity at the farm level over the last ten years. The Drought Tolerant Maize for Africa (DTMA), the Improved Maize for African Soils (IMAS), the Improved Maize

for African Soils (IMAS), the Water Efficient Maize for Africa (WEMA), and the Nutritionally-enriched Maize for Ethiopia (NuME) are among the key projects in SSA, developing and deploying stress resilient and nutritionally enriched maize in SSA. These projects have made significant contributions in terms of improved variety releases and delivery of seed. More than 180 distinct drought tolerant (DT) maize varieties have been developed and released through DTMA, and nearly 52,000 metric tons (MT) of seed was produced and delivered across 13 target countries in SSA in 2014 alone. Partners working under IMAS project have released 11 nitrogen use efficient (NUE) maize hybrids, and produced 2,300 MT of seed in 2014.

Many DT and NUE varieties are being scaled-up in eastern, southern and West African countries, with significant present and potential impacts (Alene et al., 2009; Kostandini et al., 2015,). Similarly, under the Integrated Striga Management for Africa (ISMA) project, IITA, CIMMYT and partners in Kenya and Nigeria came together to develop and deploy Striga-tolerant improved maize varieties. Some of the projects have also developed improved crop management practices, including cereal-legume rotation to control Striga and to improve soil fertility (Kamara et al., 2008). Sustainable intensification of maize-legume cropping systems in eastern and southern Africa (SIMLESA) is another major project being implemented in SSA.

c) Wheat

In all African countries, wheat consumption has been steadily increasing during the past 20 years as a result of growing population, changing food preferences and a strong urbanization trend which has led to a growing 'food gap' in all regions, largely met by imports. In 2013 alone, African countries spent over $12 billion dollars to import more than 40 million metric tons of wheat, equating to about a third of the continent's food imports.

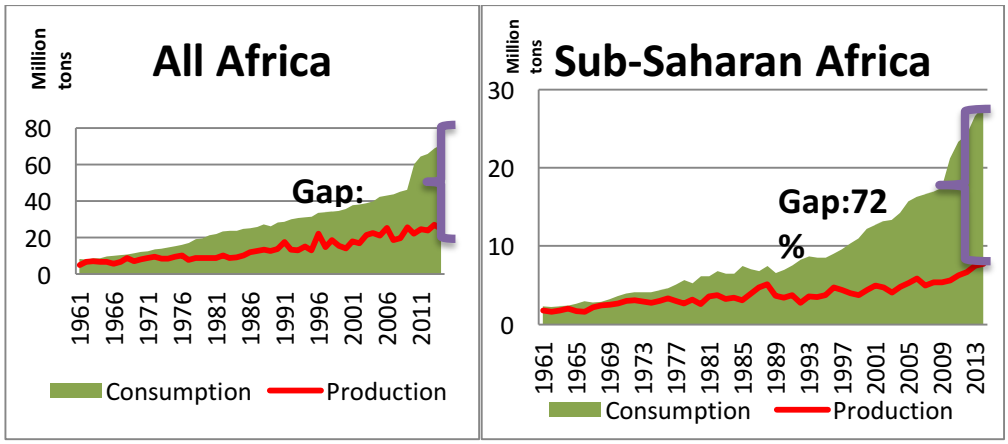
During 2010-2013, the average quantity of wheat import in SSA was about 17.5 Million metric tons per annum, which is close to 80% of the total domestic wheat consumption in these countries (USDA, 2014). Each year, less than 30% of wheat consumption in the region is covered from domestic production. In addition to the increasing trend in volume of wheat import in SSA, wheat prices (both producers' and world market prices) have increased substantially over the last half-decade. Domestic price volatility is very high. Both price and volume of wheat imports already impose substantial challenges to many SSA countries on their foreign currency reserve and annual trade balance. Thus, for SSA countries, it is essential and timely to look into the exiting wheat production and productivity potentials and exploit these potentials through putting proper policies, institutions and market arrangements in place and create incentives to all actors in the wheat value chain.

The average wheat productivity in SSA is 1.7 tons/ha (FAOSTAT, 2014), nearly 50% below the world average. The national average wheat productivity in SSA varies across countries. It ranges from 0.7 tons/ha in Burundi to 3.4 tons/ha in Mali. Yield data from experimental stations and crop models indicate a very high yield potential, among the highest reported for spring wheats. Therefore, the yield gap between yield potential and average farm yields is significant, often greater than 5-fold. This yield gap can be filled through use of improved technologies (improved varieties/seeds, agronomic practices, fertilizer and pesticides), and better institutional and market arrangements creating incentives to wheat producers and other actors involved in wheat marketing and processing.

The occurrence of UG 99 in Uganda in 1998 has led to the establishment of the Borlaug Global Rust Initiative in 2005 and several projects have since then since supported breeding of high yielding rust resistant varieties. Kenya and Ethiopia had been established as hubs for screening and more than 50 000 wheat accessions from programs around the world are annually evaluated

in Njoro, Kenya and Ethiopia. Identifying rust resistant wheat lines at these locations is of paramount importance to stop the spread of UG 99. Several rust resistant varieties were identified in Kenya and Ethiopia and are grown on large scale thanks to support from various donors for seed production (AfDB, BBSRC, BMGF, DFID, GIZ, USAID). The food crisis of 2008 and the socio-economic impacts it created worldwide resulted in an awakened attention on food security and the need for local production of staple food crops to minimize dependence on imports and meet the national needs for these crops. In 2010, AfDB initiated consultations among agriculturalists and specialists from its low-income Regional Member Countries (RMCs) and from CGIAR Centers working in Africa to address the need for food security in those countries. This has led to the launching of AfDB-funded project "Support to Agricultural Research for Development of Strategic Crops in Africa" (SRD-SC), involving CGIAR Centers and other international and regional research institutions (FARA, ASARECA, CORAF/WECARD), all working in partnership with national research institutions, farmers and other stakeholders. The wheat component builds on 3 hub-countries (Ethiopia, Nigeria, and Sudan) where a major R4D thrust is deployed and 9 'partner' countries (Eritrea, Mali, Mauritania, Niger, Kenya, Lesotho, Tanzania, Zambia, and Zimbabwe) benefitting from hub country results and adapting them to their local conditions.

Considering the growing importance wheat has for food security in Africa, African Union Heads of State endorsed their Agriculture Ministers' endorsement in January 2013, to add wheat to the list of strategic crops for Africa. Africa has the potential to become self-sufficient for wheat, through government commitment, appropriate policies and the contribution of female farmers and young people. This Wheat framework for Africa's Agricultural Transformation Agenda contributes to the goal of greatly reduce Africa's dependency on wheat import and on the long-term make Africa a wheat self-sufficient continent.



Widening gap between wheat production and consumption in Africa

d) Rice

Agriculture is the predominant economic sector in sub-Saharan Africa (SSA), with 70% of rural households depending on it as a source of their livelihood. Rice consumption is increasing faster than that of any other food staple in Africa at about 5.5% per year (2000–2010 average). This increase is driven by urbanization and related changes in eating habits, and population growth (Seck et al., 2012). Rice consumption was approximately 24 million tonnes (Mt) per year in SSA in 2012. With only about 60% of rice consumption being satisfied by domestic production, rice imports stand at 10–12 Mt. This is equivalent to one-third of the rice traded on the world market.

Demand for milled rice in SSA is expected to increase by 30 Mt by 2035, equivalent to an increase of 130% in rice consumption (Seck et al., 2012). With the exception of Egypt, nearly all African countries rely on the unreliable international rice market, where only 7% of the global production is traded. Africa accounts for one-third of global rice imports at a cost that surpassed US$ 5 billion in 2008. Africa can no longer afford to rely on the distorted global rice market, where major producing countries may restrict trade during periods of supply shortage. That was the case in the first quarter of 2008 when rice prices in international markets quadrupled in comparison to 2003 levels. SSA is highly vulnerable to global price shocks because 40% of rice consumed is imported. The "food riots" of 2008, with violent protests in countries such as Burkina Faso, Cameroon, Côte d'Ivoire, Mauritania and Senegal, are a testimony to Africa's vulnerability to international rice price volatility.

Current concerns are that rice prices may increase by 10 to 20 percent in 2015-2016, if the El Niño weather persists. Global ending stocks of rice are the lowest since 2007/08 and Thailand, a major rice exporter to Africa, is projected to reduce rice exports by 10% (Childs, 2015). Under this situation, if interventions are not made now, local markets in Africa may immediately experience severe shortage of rice in 2016 and this may be associated with socially unstable situations in rice growing areas, such as increases in poverty levels.

Rice consumption in Africa is expected to continue growing in the foreseeable future because of the continent's high population growth rate, rapid urbanization, and changes in employment patterns. The percentage of Africa's population living in cities is expected to grow to 48% by 2030. Faced with the threat of shortages in the supply of rice, the need to increase domestic production has become a top priority to contribute to food security in Africa. One of the main resolutions of the Abuja Food Security Summit, organized in 2006 by the African Union, conferred to rice the status of "region-wide strategic commodity." Whilst this confirms the important position of rice in the agricultural sector, it also creates opportunities for positioning it as an important commodity in the secondary and tertiary agricultural sectors. Rice is, therefore, a priority crop in the implementation of the New Partnership for Africa's Development/ Comprehensive Africa Agriculture Development Program (NEPAD/CAADP).

The 2008 rice crisis led to increased focus and investments in the rice sector. Nigeria, Ghana, Togo, Côte d'Ivoire, Gambia, Senegal and Burkina Faso plan to attain rice self-sufficiency in the medium to long term by increasing the level of public investment in the rice sector. For instance, Senegal launched a national program for rice self-sufficiency ("Programme national d'autosuffisance en riz") with the objective of increasing production from 215 000 tonnes in 2007 to 1.5 million tonnes of paddy in 2015. The Government of Mali embarked on an ambitious rice-promotion program entitled "Initiative riz," which aimed at increasing production by 50% in a single cropping season in 2009. The Federal Government of Nigeria embarked on the rice transformation agenda to boost Nigeria's rice production between 2011 and 2014. Similar rice-sector promotion programs were initiated in countries such as Ghana and Côte d'Ivoire. These align with the ECOWAS agricultural policy (ECOWAP) and 'Offensive Riz'.

Under the auspices of the Coalition for African Rice Development[1] (CARD), an initial group of 12 African countries (Cameroon, Ghana, Guinea, Kenya, Madagascar, Mali, Mozambique, Nigeria, Senegal, Sierra Leone, Tanzania and Uganda) have produced National Rice Development Strategies (NRDS) using a common outline developed by AfricaRice. At the country level, the NRDS were also aligned with existing policy documents for rice sector

[1]CARD is an initiative launched by JICA and AGRA. CARD aims to double Africa's rice production by 2018 as compared to 2008 levels. Current CARD steering committee members include Africa Rice Center, African Development Bank, AGRA, FAO, FARA, IFAD, IRRI, JICA, JIRCAS, NEPAD, and the World Bank.

development. A second group of CARD countries (Benin, Burkina Faso, Central African Republic, Côte d'Ivoire, DR Congo, Liberia, Rwanda, Gambia and Togo) will draw upon lessons learned from the first group of 12 countries.

It is our contention that the African continent will move from a food deficit to food surplus status when the problems in agriculture are considered as priority, and are seriously tackled through strong political will, positive changes in government's attitude and the involvement of the youth and women. This AfricaRice framework for Africa's Agricultural Transformation Agenda contributes to the (i) strategy and roadmap for implementing the Malabo Declaration on accelerated African Agricultural growth and transformation, (ii) the results framework for the refreshed strategy of the Comprehensive Africa Agriculture Productivity Program, and (iii) relevant sustainable development goals.

2. CHALLENGES

a) Sorghum and Millets

The environments in which sorghum and millets are cultivated face the toughest environmental challenges including:

- ***How to overcome the inherently low productivity and profitability of dryland agriculture and manage the high risks faced.*** Underlying root causes of these include low and irregular rainfalls, high temperatures, poor soils and inappropriate agronomic practices.
- ***Dealing with the global problems of climate change and land degradation.*** As environments that are currently considered favourable for agriculture become hotter and drier over time, dryland cereals will become increasingly suited for production in areas where other crops are now grown.
- ***The neglect and remoteness of the drylands*** that constrain the adoption of agronomic techniques and a greater role of market orientation and private enterprise in achieving development outcomes need to be addressed. Lack of investment in infrastructure such as roads, storage and market facilities handicap the potential role of the private sector. Modern digital technologies have the potential to meet these challenges and contribute to better communication and learning, and we will explore this.
- ***Rapid population growth across Africa***, including its dryland areas, is giving rise to rapidly increasing demand for food, education, and employment opportunities – particularly for youth. The UN's Human Development Indices suggest that the dryland areas in West and Central Africa (WCA) and East and Southern Africa (ESA) remain among the poorest and most food-insecure places in the world. Some 25% of all children die before the age of five from hunger-related causes, and those who survive are often affected by poor physical development and reduced mental acuity (both the result of malnutrition). About half of the people living in these areas survive on only US$1.25 per day or less.
- Poor farmers do not have access to the resources needed to invest in new ways of doing business. The large potential productivity gains that are biologically possible in these areas, as shown by decades of research across a wide range of dryland locations, remain beyond the reach of most farmers in Africa. The potential gains for sorghum and millets are as large as those derived from the Green Revolution in rice and wheat, and realizing even a modest portion of that potential would be transformative in the impoverished areas that are traditionally reserved for sorghum and millet production.
- ***The presence of counterfeit products*****,** such as seeds, fertilizers, or other agro-chemicals, is a major constraint to development of efficient agricultural inputs markets in much of Africa,

and distrust engendered by counterfeits contributes to low levels of adoption of such inputs, especially in riskier environments.

- ***Weak national institutions*:** In many African countries, the institutions charged with the responsibility of spearheading the development of agriculture (e.g. research, extension service or value chain operators) are weak and often starved of operation funds and human capacity needed to effectively carry out their mandates. Many national research institutions are poorly equipped, and lack the critical technical mass needed to implement the complex scientific procedures that modern science demands, leading to high staff turnover, as good national scientists seek better opportunities, quite often overseas. There is total dependence on donor funds for most operations.

ICRISAT and its national partners are working to mitigate some of these challenges, through various bilateral projects and initiatives. For example,

- Through the CGIAR Research Program (CRP) on Dryland Cereals, ICRISAT is spearheading the efforts to transform the livelihoods of the smallholder farmers living in the drylands of sub-Saharan Africa through the development of high yielding, stress-tolerant and nutritious varieties of sorghum, pearl millet and finger millet
- The HOPE for sorghum and millets project, involving ICRISAT and its national partners, is working to improve the productivity and profitability of the dryland cereals in smallholder farms, by developing and availing better production technologies (improved cultivars of sorghum, pearl millet and finger millet as well as better crop management practices), strengthening the seed systems and linking farmers to markets.
- ICRISAT, through its many bilateral projects, is at the forefront in efforts to strengthen the capacity of its national research partners, through short term and graduate training of the national scientific staff.
- The ongoing Sorghum Transformation Value Chain Project, of the Federal Ministry of Agriculture and Rural Development of Nigeria, seeks to increase sorghum production in the country by 2 million metric tons between 2011 and 2015, with the aim of improving nourishment and ensuring food and nutrition security through processing, and product development; and increase in productivity and profitability of sorghum through linking farmers with processors and markets.

b) Maize

- **Difficulty in meeting the projected maize demand with the current low on farm yields and high postharvest losses:** Considering the projected increase in annual maize demand in Africa reaching 52 million tons by 2020 (IFPRI, 2000), the current increase in yield gains averaging only 1% presents a challenge for countries to meet this demand. Yield gaps are pervasive in African smallholder farmers' fields, and are large for maize and other crops in all regions. If actions are not taken to close these yield gaps, smallholder farmers will not be able to benefit from the current yield gains offered by genetic improvement of maize. Similarly, inappropriate postharvest handling of grain leads to an estimated 20% avoidable losses in the postharvest stages. Saving half of this loss will make more efficient use of resources used for growing crops and add 10% more maize in African economy.
- **Impact of climate change and persistent biotic and abiotic stresses:** In addition to the high incidence of diseases, insect-pests, and parasitic plants, drought, high temperatures, and sub-optimal soil nitrogen have also presented a continuous challenge to maize productivity in SSA. Besides drought and poor soil fertility, biotic stresses such as Maize lethal necrosis (MLN), Maize Streak Virus (MSV), Turcicum Leaf blight (TLB), Gray leaf spot (GLS), southern leaf rust, blight, stalk borers, and the parasitic weed *Striga hermonthica*. Similarly, maize is particularly prone to contamination with aflatoxin which

is a serious impediment to improving health of African people and generating higher income. Country-specific biocontrol product (Aflasafe) has been or being developed in 11 countries, and several other nations have requested that such products are developed for their benefit. The need for reducing aflatoxin burden has been emphasized by the African Union through its agency Partnership for Aflatoxin Control in Africa (PACA).

- **Maize lethal necrosis (MLN) is threatening food security in eastern Africa:** Since 2011, MLN has emerged as a major threat to food security in the region. Kenya's loss was estimated at 0.3 million tons per year, or 23% of the average annual production estimated at US$ 110 million (US$ 365/ton). The situation is particularly critical as more than 95 per cent of the commercial maize varieties in eastern African seed market are vulnerable to MLN. This means that Kenya and neighboring countries (D.R. Congo, Ethiopia, Rwanda, Tanzania and Uganda) where the disease has been reported are on the verge of serious food insecurity, unless urgent and intensive actions are taken (Prasanna, 2015; Mahuku et al., 2015).
- **Barriers to adoption of improved maize varieties:** There are several major factors impeding adoption of improved climate-resilient maize varieties; these include: limited capacity of seed companies hampering product delivery at scale (especially in West and Central Africa), lack of adequate availability of improved seed, lack of awareness, unavailability of credit, and unaffordable seed price. The impact of these factors varied from country to country indicating that dissemination strategies will need to be further tailored (Tahirou et al., 2009; Fisher et al., 2015).
- **Lack of adequate integration of improved genetics with sustainable intensification practices in maize-based cropping systems:** Improved agronomic practices, soil fertility, water management and weed control, and enabling policies are key determinants of crop productivity. Maize yields need to be significantly boosted by scaling-up and scaling-out custom-made conservation agriculture practices.
- **Insufficient investment on enhancing genetic gains, improved agronomy and other technologies:** Some countries in SSA (e.g., Burkina Faso, Cameroon, Cote d'Ivoire, D.R.Congo, Togo, Senegal etc.) have faced serious challenges in developing, testing, release and deployment of new maize varieties and improved agronomic interventions due to insufficient R4D investment.

c) Wheat

- North African countries have the highest per capita wheat consumption and wheat provides up to 50% of daily calories and protein. Wheat is paramount for food security.
- In rapidly urbanizing sub-Saharan Africa, wheat consumption is expected to grow 38% by 2023; in SSA, consumer demand for wheat (Mason et al. 2012)[2] is growing faster, at 5.1% p.a.
- Rising food import bill: African countries are the world's biggest wheat importer with more than 45 m t in 2013 at around 15 billion US$. By 2020, 80% of wheat consumed in SSA will be imported, with 60% imports for Africa as a whole (OECD-FAO, 2015). Imports draw on Forex holdings. Food bills hide import subsidies from exporting and importing countries. This does not represent a fair market for African wheat producers.
- Compared to global average wheat productivity (i.e., 3.3 tons/ha), the average wheat productivity in SSA is 1.68 tons/ha (FAOSTAT, 2014; e.g. ca. 50% below the world average). But some of the world's highest spring wheat yields are obtained in Africa. Egypt

[2]Results suggest that the key drivers of rising wheat consumption in Sub-Saharan Africa are rising incomes, growing populations, women's participation in the labor force increasing at a faster rate than men's, and wheat food aid. Given population projections alone, wheat consumption in Sub-Saharan Africa is expected to increase at an even faster rate in the coming decades. »

averages 7t/ha, Ethiopian farmers have obtained more than 8t/ha, new varieties introduced through SARD-SC in Nigeria yield up to 7t/ha. However, the yield gap between on-farm and potential yield remains very high, often greater than 5 fold. Wheat-based systems productivity, production and wheat quality in most of Africa are much lower than the potential.

- New, on a global scale extremely aggressive and virulent stem and yellow rust races (e.g. Ug99) emerge rapidly in Eastern and Central Africa, threatening local, regional and global production.
- Mechanization: Number of tractors and draught animals has been stagnating in sub-Saharan Africa and SSA smallholder agriculture is increasingly relying on labor, i.e. human muscle power, while at the same time labor shortage becomes an issue. More than 50 per cent of the cropland in Eastern and Southern Africa is cultivated by hand. Tractors are only used on 20 to 25 per cent of the cropland, and on less than 10 per cent in Western and Central Africa. There is tremendous potential to introduce machinery that meets the demand of SSA small holder farmers.
- Many, especially small producers can't provide quality and quantities (e.g. stable yields) that African processors want to meet consumer demand. So they import.
- The wheat value chain from farmer to processor and consumer is not well developed.

Wheat import bills in Sub-Saharan African Countries are ballooning. With wheat consumption growing at 5.1% and wheat production increases at 2.2% p.a. the gap leads to a wheat import bill of more than 11 blln $ by 2030. SSA countries cannot rely on imports from top African wheat producers (Egypt, Ethiopia, Morocco, Algeria or Kenya), as they too import. Nigeria's wheat imports represent 1/5 of its total agricultural imports. For Ethiopia, it is even higher, at 40% (FAO, Deutsche Bank Research).

Depending on wheat imports exposes SSA to the fluctuations in global wheat prices which is translated into volatility in domestic wheat prices; in Sudan the domestic wheat price increased from April 2014 to August 2014 by 85% and from August 2013 to August 2014 by 238%; for Ethiopia, the changes were 30% and 75% respectively. Subsidizing imported wheat also will discourage domestic producers due to consequent lower prices. To develop policies that address these issues is a high priority.

d) Rice

The challenges facing the successful development of the African rice sector are huge and include the following:

- ***Choice of adequate production systems***: The focus of African production systems has been on rainfed agriculture to the detriment of irrigated agriculture. Africa has the potential to irrigate 20% of its arable land (only 4% is currently irrigated). The choice of a balanced approach to the use of rice production systems presents an opportunity to be exploited.
- ***Fragmented rice value chain:*** The rice value chain is highly fragmented from production to marketing. Production is basically driven by small holder farmers who have as a primary target self-consumption.
- ***Lack of adequate rice milling facilities*****:** The lack of rice milling facilities results in poor quality of the product, hence, poor competitiveness against imported rice.
- ***High production costs:*** High production costs in Africa reflect numerous production constraints. Yield levels are low due to a number of abiotic and biotic stresses – in part highlighting seed renewal constraints for farmers, who often use antiquated varieties.
- ***Low agricultural inputs:*** In Africa, rice farmers have little or no access to farm inputs such as fertilizer and seeds. On average, 13 kg of fertilizer are applied per hectare in Africa compared with about 100 kg in Asia and as against over 150 kg in developed countries.

The utilization of improved seeds is low in Africa (10% in Nigeria, and 25% in East Africa compared to 60% in Asia).

- ***Inefficient scaling up and out models*:** It is relatively ineffective in Africa and access to services is poor.
- ***Poor mechanization*:** The low level of mechanization in African agriculture has continued to serve as a huge impediment towards advancing the sector, given the high cost of land clearing. This in return results in the high cost of mechanization, which is a major disincentive for the expansion of cultivated areas. The use of mechanization from ploughing to harvesting, therefore poses great challenges to farmers across the continent. The number of tractors per 100 square kilometres in Nigeria is less than 10 in comparison to over 728 in the UK, 257 in the USA, 200 in India, 130 in Brazil, and 125 in the Philippines.
- ***Poor infrastructure*:** Most food products are unable to find their way to market due to weak market information, high transport costs, poor road infrastructure and networks.
- ***Lack of adequate human resources in the rice value chain*:** Most of the experienced rice scientists in the NARS programs in Africa are aging. Moreover, agricultural graduates are not in the Ministry of Agriculture, research institutions or on the farms. There is a need to increase the number and expertise of rice value chain actors including extension agents.
- ***Inadequate policy environment***: Most government policies are inappropriate and inconsistent, and do not provide an enabling environment for the development of the rice sector in Africa.

Despite these challenges, it is possible to transform the African rice sector into a competitive, income and employment generating sector.

3. OPPORTUNITIES

a) Sorghum and Millets

The drylands of Africa provide great opportunities for development and attainment of food security, but only if appropriate crops are grown, the right technologies are used and the appropriate institutions and policies are in place to create a conducive environment. The following factors we consider key drivers which are creating demands for agricultural outputs in the drylands:

- Rapid population growth across Africa is raising the demand for locally-grown foods, especially in the dryland regions where sorghum and millets are key cereals crops. Related to this is the fact that, while the majority of poor people are still located in rural areas, an increasing share of the population is migrating to urban areas in search of non-farm jobs. This is raising the demand for foods supplied through commercial markets rather than subsistence production.
- In recent years, the demand for sorghum and millets in Africa's crop/livestock systems has risen, creating new opportunities for these crops in the marketplace. As incomes rise across Africa, diets are changing and the demand for livestock products (meat, milk) is increasing. This growing demand is increasing the market value of dryland crop residues. Crop residues (stover) as well as grains are vital feed stocks for cattle, goats and chickens. Sorghum grain is a proven high-quality feed for cattle and poultry, but supplies are not reliable in quantity and quality for the livestock industry to be comfortable in investing in this additional feed resource. Pearl millet grain is also a valuable animal feed, comparable to maize for poultry, but with a higher protein content and a better-balanced amino acid profile, so that less protein concentrate is required in

a pearl millet-based feed ration. Overall, livestock provides a better enterprise option for smallholder farmers

- Also associated with growing affluence is an increasing demand in urban markets for value-added products. For example, the demand for finger millet porridge in Kenya far exceeds local supply. Kenyan processors regularly search for finger millet grains in neighbouring Tanzania and Uganda. Finger millet has high levels of iron and fiber and exceptionally high levels of calcium. It also has relatively lower energy content, making it ideal for weaning children, and for pregnant and nursing mothers. Finger millet is also being used in therapeutic feeding programs for diabetics and people who cannot tolerate gluten. This growing demand has stimulated increased investment by agro-processors supplying this and related products to supermarkets and other retail outlets.
- Another important opportunity for sorghum and millets derives from the persistently high price of fertilizer in most markets. Thus causing farmers to shift to these crops which can be produced more reliably with limited fertilizer inputs than other cereals. Cash crops like cotton can play an important role in the rotation in these systems in terms of residual Phosphorus (P) and Nitrogen (N) for the legume and cereal crops, respectively. We need to explore how the sorghum/millet systems can leverage the cash crops and their services.

ICRISAT is currently implementing a number of efforts that seek to utilize these opportunities. Some of these efforts aim at up-scaling improved technology for wider uptake by the farming communities. Examples include:

1. The Large-scale diffusion of technologies for sorghum and millet systems in Mali (DT_SMS), funded by USAID. The objectives of project are (a) to enhance farmers' knowledge of new sorghum and millet production technologies in selected FtF communities of Mopti and Sikasso regions, Mali, and (b) to facilitate farmers' access to sorghum and pearl millet production technologies in order to strengthen the sorghum and millet value chains in the FTF target areas. Key partners with ICRISAT in implementing this effort are the Aga Khan Foundation (AKF), the Catholic Relief Services (CRS), farmers' organizations and local NGOs in Mali.
2. Disseminating learning agenda on resilient-smart technologies to improve the adaptive capacity of smallholder farmers in the Mopti region, Mali, also funded by the USAID.
3. The Bill and Melinda Gates Foundation-funded Second phase of the HOPE for sorghum and Millets Project, expected to commence in January 2016, will emphasize on technology outreach and uptake as the key thrust, even as it maintains technology development efforts through breeding of improved cultivars and determination of better crop management options. The project will work to strengthen the seed systems by working with the national seed institutions (public and private) to streamline and enhance seed production and timely delivery to farm households. Public and private national partners will continue to be the main implementers of project activities. The research and technology development agenda will be led by the national agricultural research institutions in each implementing country. Local and International NGOs, and seed enterprises in each country have been mobilized to play critical parts in ensuring the delivery of improved sorghum pearl millet and finger millet technologies to farmers.

b) Maize

- **Productive stress-tolerant maize varieties and improved crop management practices:** Maize can make significant contribution to bridge the gap between food supply and demand in SSA because high yielding, stress tolerant and nutritious maize varieties adapted to the major agro-ecological zones are available for production and

delivery to farmers. These products can provide good opportunities for sustainable intensification of production to close the yield gap.

- **Nutritious maize varieties for alleviating protein and micronutrient malnutrition:** Maize is considered an ideal vehicle for provitamin-A enhancement and delivery in areas with limited access to supplements and fortified foods (Bouis et al., 2011). In partnership with the HarvestPlus Challenge Program IITA and CIMMYT have made significant progress in developing, testing, and release of provitamin. The production and deployment of nutritious maize cultivars can be expanded to other countries in SSA with similar production environments.
- **Existence of strong public-private partnerships for product delivery:** The presence of strong partnerships with the private sector and community-based seed producers as well as non-governmental organizations (NGOs) has created an excellent opportunity to deploy products adapted to SSA at much higher scale for greater impact at farm level.
- **Availability of new tools for enhancing genetic gains:** Continued and intensive application of novel and advanced tools and techniques, including precision phenotyping, doubled haploids (DH), molecular markers, and breeding informatics, are critical for increasing the rates of genetic gain in SSA through accelerated product development.
- **Increasing demand for maize grain by the poultry feed industry:** This will not only create huge demand for maize grain, but also enhanced use of provitamin A enriched maize as natural agent that imparts an attractive yellow color to poultry meat and eggs. Making aflatoxin-safe maize available also is crucial since the toxin kills birds, stunts growth and induces other harmful effects.
- **Dual-purpose maize:** The decline in farms size has seen livestock being edged out of the farm and the decline in the number of livestock units on the farm. The model of land set aside for crops and a different one for livestock feed only means more competition between food and feed. Dual-purpose maize can mitigate this as it ensures co-existence of crops and livestock on the farm (Grings et al., 2013). The development and availability of such maize varieties can promote diverse utilization of maize, increase income generating opportunities for farmers and processors, reduce the labor requirement of women at household level, and contribute to reduction of waste.
- **Developing better Aflasafe products, aflatoxin management systems and delivery mechanisms:** Until now, registered and registration-ready country-specific products are available in a handful of countries. More products are required for use in countries currently not having any. There is a need to develop regional products that can be used in several countries thereby expanding the market of such products to attract more private sector investment in technology dissemination and scale-up. Aflatoxin management requires an integrated approach and systems and mechanisms for its delivery needs to developed and implemented. Also required are aflasafe manufacturing plants in five countries to make the products available in the region.

c) Wheat

Sub-Saharan Africa has a tremendous scope and potential for increasing bread and durum (pasta) wheat productivity, whilst likely worst affected by climate change e.g. shortened growing seasons, erratic rainfall, increases in both day & night temperatures, new emerging diseases. Some of the highest spring wheat yields worldwide are obtained in African countries (Egypt, Ethiopia, Namibia, Zambia, Zimbabwe), but only by very few farmers. Modelling-based yield estimates in a CIMMYT/IFPRI Study in SSA, for rainfed and irrigated wheat farming systems identified countries with potential for wheat production. The results of the IFPRI-CIMMYT simulation analysis provide strong evidence for the economic

profitability and competitiveness of domestic wheat production for the selected SSA African countries. These preliminary results based on large grid data require follow up on detailed regional / local analysis. Opportunities include:

- Small and big farmers in specific African countries and agro-ecologies could produce more high quality wheat more profitably and sustainably. This becomes a source of stable cash-crop next to other farm (diversification)- and non-farm income, if value chains function better.
- Very fast growing consumer demand offers great potential for generating value addition, larger and more diverse wheat-based markets and more inter-regional trade (wheat and finished wheat products).
- Change national and regional policies to incentivize effective flow of agricultural research to farmers, to develop a wheat seed sector that promotes faster access to high quality seed and value addition along the wheat value chain in-country/region.
- Expand current projects activities (e.g. Durable Rust Resistant Wheat, funded by BMGF/DFID; SARD-SC/AfDB; Ethiopian Wheat/USAID and others) focusing on breeding resistant varieties and providing seed to farmers. Through a greatly expanded effort, most rust susceptible wheat varieties should be replaced in East and Central Africa. This would greatly reduce the rust inoculum and thereby the chances that new races emerge from mutations and also make a great contribution to regional and global food security, since these virulent races can and have travelled to other global bread baskets in N-Africa, Asia, Europe and Australia.
- Increase farm power through appropriate-scale mechanization, so farmers can deal with labor shortage, livestock-related trade-offs, drudgery for women farmers (Baudron et al, 2015).
- Improved wheat varieties with high yield, heat and drought tolerance, pest and disease resistance, adequate nutrition and processing characteristics, nitrogen use efficiency and in some regions acid soil tolerance
- Replace yellow and stem rust susceptible varieties to reduce risk of epidemics and at same time reduce probability that new races emerge through reduced inoculum.
- Seed system innovations (get the right seed to farmers faster).
- For all of the above, enhance sustainable scaling-up of technologies and innovations along the value chains through innovative platforms, exemplified by the SARD-SC project with continental coverage. They promote effective technology transfer by involving all stakeholders.
- Enable development of more efficient markets at national and regional levels. Consumer demand is there and predicted to grow even faster (Mason, 2012).
- Develop effective wheat value chain system, based on multi-stakeholder constraints and opportunities analyses.

d) Rice

There is a great potential for accelerating agricultural productivity to achieve the green revolution that Africa urgently needs. Africa has sufficient land and water resources to produce enough rice to feed its teaming population. The potential irrigable land in West Africa alone, estimated at about 8.9 million hectares of which less than 10% (920,000 hectares), is mostly utilized for rice and other crops. Irrigated rice production systems are considered the most promising because the highest rice yields per hectare are obtained under irrigation and in addition it offers the chance of two to three crops per year. The potential for expanding irrigation is large especially as we look beyond erratic rainfall in rainfed ecologies. Apart from Africa's natural resource endowment, its youthful population is regarded as a major human resource that will drive economic growth in the next decade. The prospects for

youth engagement in agricultural development in Africa are enormous. AfricaRice and its partners have adopted the rice sector development hubs that represent key rice growing environments and market opportunities across African countries. The rice hubs are made to work for resource poor smallholder using multi-stakeholder innovation platforms (IPs). The IPs in the hubs are linked to major national and regional rice development efforts to facilitate broader uptake of rice knowledge and technologies.

4. SUGGESTED ACTIONS / THE WAY FORWARD

a) Sorghum and Millets

Taking into account the challenges that face the production of sorghum and millets and the opportunities that exist for their development and expansion, it is envisaged that the following pragmatic approaches will have the potential for increasing productivity, creating impact and improving the livelihood of smallholder farmers:

- ***Strengthen the Crop Development Process***: Maintain and strengthen the development of new, well-adapted sorghum, pearl millet, and finger millet cultivars with high yield potential and the genetic capacity to withstand major biotic and abiotic stresses. There is need to continue the breeding efforts, and to seek to strengthen the NARS institutions in the use of modern breeding platforms and methodologies. The breeding research carried out as part of past and current efforts should enable NARES and ICRISAT breeding programs in WCA and ESA to provide appropriate gender-responsive cultivars that meet the needs of farmers and processors in targeted agro-ecologies. Implementation of these programs should lead to fundamental improvements in program efficiency by promoting improved operational practices and the uptake of modern breeding approaches, as well as much improved information management practices. Breeding plans should be developed and implemented based on the strengths and program gaps identified using the Foundation-sponsored Breeding Program Assessment Tool (BPAT). [**Partners**: ICRISAT and NARS institutions in each target country.]
- ***Strengthen seed production and delivery systems for improved varieties***: Improving the efficiency and effectiveness of seed production and delivery systems is critical for enabling the uptake of improved cultivars by smallholder farmers in WCA and ESA. This is the basis for increased productivity in the semi-arid areas of the target countries, it will lead to availability of nutritious food for a majority of the population especially for children under the age of five years. Increased systems efficiency will make improved seed more affordable, and greater effectiveness will help ensure that quality standards are met and maintained. In partnership with a functional private sector and community based farmers organizations, the seed of improved cultivars and associated inputs will be made available at outlets closer to farmers. [**Partners**: ICRISAT, NARS institutions in each target countries, Farmer Organizations and relevant NGOs, Seed companies and distributors, market operators.]
- ***Expedite the scaling out of new sorghum and millets technologies including products development***: This component should focus on raising awareness of new technologies, both with farmers and with those with mandate and/or incentive to provide farmers with access to technologies. Stimulated demand from farmers will create market opportunities for suppliers, particularly for improved seed and input services. Linkage should be formed with initiatives that are developing sustainable models of seed supply, such as AGRA's Program for African Seed Systems (PASS), which supports private seed companies and village-based agro-dealers. This linkage is essential to ensure that the demand for improved seed created by various initiatives will continue to be met in a sustainable manner. Scaling-out efforts should aim at making sorghum and millet growers in the target regions aware of

new technologies, while also allowing farmers to test new varieties and associated best management practices for themselves. They should also leverage current and emerging interest from those service providers (Community, NGO and private sector especial ally flour mills for composite with wheat)) looking to service the smallholder farming sector. Similarly it is important to develop sorghum and millet products for the urban market, since this will encourage commercialisation of the crops. [**Partners**: National research institutions, national extension service, farmer organizations, national and international Non-Governmental Organizations]

- ***Enabling Farmers' access to production inputs and markets***: A valid theory of change is that resource-poor smallholder farmers will adopt improved sorghum and millet technologies if they are relevant and made available, accessible and can be utilized, and that they have access to reliable markets to dispose of surplus production. Demand for productivity-enhancing inputs – seed and fertilizer – is largely derived from the product market. Existing use of improved inputs by smallholder farmers is limited both by inconsistent external demand on the output side, and lack of capacity to supply improved seed, fertilizer, finance, and know-how on the supply side. Efforts should be made to enable farmers to access both the inputs needed for production, and the markets for disposing of surplus farm produce.
- ***Strengthen and sustain the technology delivery system***: The agricultural extension services in many African countries are weak, at best, or non-existent. There have been many donor-inspired efforts to revamp agricultural extension in SSA, and the outcome has been discouraging, mainly because the national governments have been unable to match donor efforts in providing adequate resources and commitment to keep the system running beyond the lifetime of the donor funds. This lack of a strong, centrally- coordinated extension service has created a gap that many Farmer organizations and NGOS have tended to fill, to degrees that vary from country to country. There is need to formulate strong technology delivery programs and systems that ensure timely, accurate and location-specific information required by smallholder farmers for their decision-making process. Digital tools, such as the use of mobile phones and short text message (sms) are helping to bridge this gap in some countries. But a lot more still need to be done to read remote farmers.
- ***Mechanization: Adoption and use of small and medium scale Mechanization:*** The participatory evaluation and dissemination of machines and tools for mechanization of small and medium scale production and processing to increase productivity, reduce drudgery among women and youth will be given high priority. These operations will also be used to increase job and income generation among youths and women as well as increase quality of postharvest grains and products.
- ***Review of relevant agricultural policies***: In many countries in SSA, the policies governing many aspects that are central to agricultural production are in need of serious review. These include such critical aspects as seed certification, production and distribution, land ownership or tenure, gender relations and the rights of women to own property. Because some of these aspects have cultural roots, changing them is a slow long process which would need to go beyond mere changing the policies. But it is clear that efforts towards reforming such aspects are necessary and urgent.
- ***Restoring degraded soils and ensuring sustainability:*** In the Millet and sorghum based farming systems, soils are widely degraded and depleted of organic matter and plant nutrients. There is need to empower farmers to enable them manage their natural resource base in a sustainable manner using integrated soil fertility and crop-livestock systems management (e.g. livestock provides a better enterprise option for smallholder farmers), crop rotation (e.g. Cash crops like cotton can play an important role in the rotation in these systems in terms of residual Phosphorus (P) and Nitrogen (N) for the legume and

cereal crops, respectively) , minimum or conservation tillage systems. There is need for extension systems that enable farmers to continuously learn new ways of performing old tasks, as well as new tasks, to increase their production while sustaining the environment and their lands productive capacity**.**

- ***Understanding farm livelihoods and the potential impacts of interventions:*** Farm households are highly heterogeneous entities, with multiple constraints of labour, capital and access to resources and operating in highly climatically variable environments. The use of systems analysis, encompassing the biophysical and socio-economic makeup of farm households are methodologies that use redeployable computer based modelling tools that can capture some of these complexities. Such methodologies, applied participatively with farmers and stakeholders create robust intervention strategies which more effectively lead smallholders out of poverty.

b) Maize

- ***Objective 1: Scaling-up and delivering improved multiple stress tolerant, nutrient-use efficient and nutritious maize varieties*****:** The recently released multiple stress tolerant, nutrient-use efficient and nutritious maize varieties will be targeted for production, promotion and delivery to enhance adoption by maize farmers for sustainable intensification. IITA and CIMMYT, together with local knowledge and skills of a broad range of NARES, private sector, and community-based seed producers in SSA will be harnessed to catalyze improved seed production, widespread promotion and delivery of the maize varieties and hybrids.

- ***Objective 2: Curbing the spread and impact of MLN*** is a complex challenge and has to be effectively addressed as an immediate priority through several simultaneously-implemented strategies, including development and deployment of MLN tolerant/resistant germplasm, agronomic mitigation practices, crop rotations (especially with legumes), and preventing further spread of MLN-causing viruses (especially MCMV) through contaminated seed from the endemic to the non-endemic areas in Africa. This requires strong support from the policy makers and the Governments, coordinated and synergistic efforts of various institutions engaged in maize R&D, and greater commitment from all the players involved in the maize value chains in Africa.

- ***Objective 3: A stronger maize breeding pipeline for enhancing capacity of NARES and SMEs in SSA with improved climate-resilient varieties, and genetic gains in the farmers' fields*****:** Intensive efforts are required to increase genetic gains in terms of maize yields in the farmers' fields from the present rate of <1% to at least 2% in the next 6-7 years. This will require enhanced adoption of modern tools/techniques for reducing product development time, but also rapid replacement of several 15+ year-old, obsolete, climate-vulnerable maize varieties that are still grown in several countries in SSA. In addition, it is important to enhance capacity of NARES and SME seed companies in SSA to test, release, demonstrate and deliver improved stress resilient and nutritious maize varieties/hybrids to the smallholders.

- ***Objective 4: Developing and deploying maize with enhanced nutritional and end-use quality traits*****:** This activity willdevelope and deploying nutritious maize with high provitamin A, zinc, and essential amino acids, to attain greater impact on the nutritional status of the poor, especially pregnant women, nursing mothers and pre-school children.Also, a program to develop and deploy dual-purpose maize varieties will be

launched, so that the farmers can harvest significant grain yield but also equally significant yield of quality stoverto feed the livestock.

- ***Objective 5: Sustainable intensification of maize-based agri-food systems through climate-smart crop management practices and decision support tools*:** CIMMYT and IITA have developed and validated climate-smart agricultural (CSA) practices for sustainable intensification of maize-based systems in SSA. These improved crop management practices will be widely promoted. In addition, investment in developing and using decision support tools for deployment of technologies to appropriate target zones and in maize agronomy research will contribute to closing the maize yield gap at farm level.

- ***Objective 6: Developing better Aflasafe products, aflatoxin management systems and delivery mechanisms*:** Aflatoxin management system will integrate aflasafe, pre and postharvest management, awareness, training, market linkages, creation of testing facilities, advocacy and enhancing regulatory capacity.

- ***Objective 7: Capacity development and building a new generation of maize professionals in SSA*:** Strengthening the capacity of both research and development partners will be critical for further knowledge transfer, shared learning, innovations and sustainable impacts. In addition to research collaboration and technical backstopping, targeted capacity building activities will include post-graduate training, organization of both short- and long-term visiting scientist fellowships, refresher training worships from public and private sectors.

c) **Wheat**

- ***Component 1 - Generating improved and sustainable wheat based technologies and innovations suitable for different agro-ecological zones of Africa*:**
  - Improve wheat productivity and end use quality through breeding better varieties targeting irrigated and rain-fed wheat growing environments using latest technologies
  - Enhance and sustain wheat yields through better water/soil/crop integrated management and production packages
  - Promote suitable wheat based systems that safeguard the natural resources while providing resilience and adaptation to climate change and close the significant yield gap
  - Establish / continue to operate precision phenotyping platforms: Egypt (yield potential); Sudan and Morocco (heat); Morocco (drought); Tunisia (Septoria durum wheat); Ethiopia (stem rust durum and bread wheat; yellow rust bread wheat); Kenya; stem and yellow rust bread wheat)
  - Increase farm power through appropriate-scale mechanization, so farmers can deal with labor shortage, livestock-related trade-offs, drudgery for women farmers (Baudron et al, 2015).

- ***Component 2 - Enhancing sustainable dissemination, scaling-up and promotion of wheat based technologies and innovations along the value chain and with continental coverage*:**
  - Establish and operationalize innovative platforms (IP) for promoting effective technology transfer pathway through involving all stakeholders along the wheat value chain.
  - Disseminate and scaling up proven wheat technologies using developed through SARD-SC wheat project using IPproaches to new areas and countries of similar agro-

ecologies based on the findings of similarity studies for a wider impact with continental coverage.
  - Develop diverse and sustainable seed systems with the participation of various stakeholders to fast-track the production of quality seed, with affordable price and timely delivery at community level in target countries.
  - Develop an effective wheat value chain system to create market outlets for farmers and stakeholders by identifying constraints faced by a diversity of actors and by setting key strategic interventions for promoting wheat production, processing and marketing along the value chain.
  - Evaluate in detail potential (biology, value chain) for wheat production in non-traditional wheat growing regions / countries identified in CIMMYT/IFPRI large scale analysis.
  - Creating a favorable and enabling policy environment to encourage private sectors and to facilitate farmer access to credit, production inputs, machinery and wheat markets. Consequently, domestic wheat production can become more competitive by improving marketing efficiency and lowering transaction costs, and by designing policies, institutions and infrastructure to reduce the costs of acquiring inputs and marketing wheat.
  - Developing and expanding innovative small-scale agri-businesses within the established Innovation Platforms across all project intervention sites and countries for creating job opportunities, including women and youth in the rural areas.
  -
- ***Component 3 - Strengthening the capacities of project stakeholders***
  - Upgrading the capacity of value chain actors in R&D through need-based training and skill development.
  - Reinforce institutional research for development capacity through the development of research infrastructure and acquisition of key equipment strengthening research for development at national, regional and CG systems based in Africa.
  - Establishing and promoting continental and sub-regional networks to facilitate exchange of technologies, experience sharing, and for strengthening linkage and partnership.

All in all, realizing the full potential of wheat for food security in Africa requires developing suitable and target oriented varieties and technological packages; making affordable inputs available; building effective and sustainable wheat seed systems; making wheat extension systems more efficient and effective; increasing productivity among smallholders; establishing and strengthening the capacity of farmers and farmers organization; developing value chains for input supply, and output markets; fostering regional co-operation; putting in place appropriate policies that foster wheat industry; and political will to realize and harness Africa's wheat potential.

d) Rice

Agriculture is a business not a way of life. The African rice sector has the potential to become an engine for economic growth across the continent, contributing to eliminating extreme poverty and food insecurity. Good quality rice that can compete with imported rice requires a decent value chain approach using multi-stakeholder IPs. Africa must begin to transform the rice value chain segments as a business by growing the markets from "seed-to-table" or "farm-to-fork". This requires bold reform by adopting market-friendly policies, committing more resources and bank lending to the sector, and creating an enabling environment for private-sector participation.

Below are prioritized action plans to be implemented within the short-, medium- and long-term based on critical mass of personnel and the committed partnership of key stakeholders per country.

Short-Term (2016 – 2018)

I. Rice Seed Systems: Establishment of Efficient Rice Seed Systems in Africa

- Objective: Increase the availability of good quality seed of improved high-yielding rice varieties to farmers

Current Situation: Seeds are a vital input to enhancing the productivity of rice. It is estimated that the direct contribution of quality seeds to total crop production is about 15-20%. Despite several initiatives in seed sector development, the reality is that farmers are unable to access quality rice seed in SSA. All categories of seed production are mostly dependent on ad-hoc project funding. Many of the current seed producers and out-growers were not trained to produce quality seed because they were originally paddy producers and have limited knowledge of seed production, processing and storage. Farmers in many communities are yet to have access to seed of improved rice varieties. Most seeds planted by farmers come from informal sources including farmers' own crop, neighbors, and relatives, or from local markets. Most of the improved rice varieties have been in use for between one and two decades, with their foundation and certified seeds hardly rejuvenated. The impurity of certified seed threatens the sustainability of the rice value chain. As a result, the potential yield is yet to be fully achieved under the poor seed management system adopted by the farmers.

- Action Plan
  - Produce and promote large-scale use of certified seed of improved high-yielding rice varieties for use by smallholder farmers.
  - Capacity building for key stakeholders in the seed industry e.g. seed companies (small-to-medium seed enterprises), seed out-growers, etc.
  - Promote farmers' seed out-grower scheme to increase availability and accessibility to quality seed.
  - Strengthen seed certification systems.
  - Establish a seed development information system.
- Partnerships: AfricaRice, CBOs, farmer cooperatives, small-to-medium seed enterprises and private seed companies, NARES, and development partners such as JICA, CARD, CARI, USAID, and West Africa Agricultural Productivity Program (WAAPP).

II. Climate Change: Africa-wide Dissemination of Climate Resilient Rice Varieties

- Objective: Promote the use of flood and drought tolerant varieties by farmers and increased rice productivity in flood- and drought-afflicted countries.

Current Situation: The recent floods in the Sokoto watershed in Nigeria were reported to destroy rice fields with yields estimated at the value of US$225 million. To enable farmers adapt to rapidly changing environments such as flooding and erratic rainfall (drought), new climate resilient varieties are urgently needed in target domains including crop- and resource-management technologies, and institutional innovations such as insurance against crop failure. AfricaRice has developed flood tolerant varieties (WITA 4 Sub1 and NERICA L-19 Sub1) for use by farmers in Nigeria. These varieties can be disseminated to other flood afflicted countries outside Nigeria such as in Sierra Leone, Guinea, Liberia, etc.

- Action Plan
    - Fast track the release mechanisms of these varieties in Nigeria and other African countries.
    - Produce breeder and foundation seed and through private sector operators and famer entrepreneurs, facilitate the production of certified seed of the flood and drought tolerant varieties for drought and flood inflicted African countries
    - Disseminate information on flood and drought tolerant varieties (e.g. varietal characteristics, procurement sources, and seed renewal practices – including pamphlets and targeted media (rural radios).
- Partnerships: AfricaRice, Governments, ECOWAS, ECCAS, COMESA, NARS, SARD-SC, Syngenta Foundation, seed companies, etc.

III. Dissemination of good agricultural practices (GAP) to close yield gaps

- Objective: Increase rice yields at the farm level by 20%.
- Current Situation: Low rice yields at the farm levels are attributed to low use of agricultural inputs. There is, therefore, an urgent need to increase rice production rapidly by proposing appropriate interventions that will increase the efficiency with which farmers use inputs to grow rice, and in particular mineral fertilizer. AfricaRice has developed a crop management decision tool named Rice Advice, which is a software that helps farmers to increase the efficiency of mineral fertilizer use in irrigated and relatively favourable rainfed lowland areas.
- Action Plan
    - Promote the use of decision support tools such as Rice Advice and other multi-media tools to increase rice yields in farmers' fields.
    - Demonstrate new technologies and practices to increase crop yields at farm level.
    - Promote adoption and use of GAP and knowledge to improve rice management and their step-wise integration into farmers' practices.
    - Coordinate the formation and animation of rice producers' learning groups that constitute the nucleus of GAP learning and dissemination at farm level.
- Partnerships: AfricaRice, Governments, farmer organizations, farmers, etc.

IV. Mechanization: Adoption and use of Modern Mechanization and Labour Saving Devices

- Objective: Promote the use of modern and appropriate agricultural mechanization tools in order to minimize drudgery
- Current Situation: The low usage rate of farm machinery in Africa is partly responsible for low farm yields and the unattractiveness of rice farming to the youths. The desired level of mechanization has been difficult to attain due to the following problems: high cost of imported agricultural equipment, insufficient number of service providers, low level of equipment leasing services and inadequate supply of spare parts for the machinery.
- Action Plan
    - Support capacity building of Agricultural Equipment Hiring Enterprise (AEHE) centers equipped with tractors, planters, weeders, reapers, harvesters, threshers, and post-harvest equipment to facilitate farmers' access to mechanized services at designated demand driven rice production areas.
    - Demonstrate and carry out market exposure of these improved harvest and post-harvest rice-processing technologies in farming communities and with stakeholders.
    - Business management and enterprise development training for key stakeholders.

- Facilitate stakeholders' access to sources of credit (e.g. banks of industry and agriculture) though the innovation platforms (IPs).

- Partnerships: AfricaRice will work closely with HANIGHA Nigeria Ltd in Nigeria, AGRITECH in Senegal, recognized machinery manufacturing companies across the continent and regional economic communities (ECOWAS, UEMOA, COMESA, etc.) to promote local manufacture and dissemination of simple agricultural equipment in Africa.

V. Youths and Women Empowerment: Capacity Building for Youths and Women Agripreneurs

- Objective: Build the capacity of youths and women for employment with rice as the entry point.
- Current Situation: Africa has one of the highest unemployment rates of youths, who constitute about 60% of the population. The rice value chain presents a lot of business and enterprise development opportunities from input marketing through production and processing to marketing of finished rice. The different enterprises that could potentially engage the youths and contribute to reducing rural–urban drift range from production and commercialization and include but the following: seed production enterprises, paddy production enterprises, equipment operations and service provision enterprises, rice products diversification, rice processing enterprises, rice milling enterprises, rice equipment welding and fabrication enterprises, rural agro-inputs kiosk enterprises, rice threshing enterprises, and rice/paddy distribution enterprises.
- Action Plan
  - Capacity building for youths and women business entrepreneurs on agro-input and output market distribution and marketing.
  - Capacity building for youths and women business entrepreneurs on rice seed/paddy production, distribution and marketing.
  - Capacity building for youths and women entrepreneurs on rice products/diversification including bio-fortification.
  - Capacity building for youths and women business entrepreneurs on the fabrication and marketing of mechanical equipment such as weeders, planters, harvesters, threshers, and parboilers, etc.
- Partnerships: Agriculture Ministries, CBOs, development agencies such as JICA, CARI-GIZ, USAID as well as the development banks (Bank of Industry and Bank of Agriculture) and other agencies currently working in areas of job creation and entrepreneur development in Africa.

Medium-Term (2016 – 2020)

VI. Improve Quality Management along the Value Chain: Upgrade Facilities of Cottage Millers

- Objective: Upgrade the quality of African cottage milled rice to reach import quality standards within a 3-year period.
- Current Situation: The small cottage millers hold the key to closing the supply gap of imported quality rice if well supported with credit facilities. Current parboiling technology using petrol drums and tanks is already over 40 year's old technology in SSA with little or no improvement over time. It is poor parboiling techniques that introduce the characteristic odour into locally milled rice on one hand and degrade the physical appearance of final product due to dirty water contamination. AfricaRice and partners have developed an

efficient rice parboiling system branded the 'GEM parboiler' that meets the needs of women parboilers. The GEM parboiling facility can process high volumes of paddy resulting in up to 90% whole grain and zero impurities. This is progressively being scaled out through women parboilers in the innovation platforms (IPs) and private sector operators. However, weak capacity exists in grading, branding, labelling and packaging of milled rice products with the associated potential to improve pricing and marketing.

- Action Plan
  - Identification & sensitization of clusters of cottage millers in SSA countries for facility upgrading.
  - Capacity building on production of milled rice of acceptable quality (e.g. parboiling, milling, grading, branding, labeling, packaging and promotion of locally produced rice)
  - Scaling-up of best practices with improved dryers, parboiling, destoning, milling and grading equipment.
  - Facilitate market linkages between paddy producers and cottage millers, and miller to product markets.
  - Facilitate access to parboiling, de-stoning, milling equipment, grading machines and capacity building on their uses.
  - Business development trainings organized through multi-stakeholder innovation platfroms (IPs) on the above enterprises
- Partnerships: AfricaRice, Government Ministry of Agriculture, JICA, private sectors, integrated millers, and other development agencies currently working on improving the quality of rice from cottage millers.

VII. Policy Support: Promote Conducive Rice Policies for Smallholder Farmers and Agri-business Development

- Objective: Support favorable policies and create the political will that would sustain the growth and development of the rice sector both at the national and regional levels.
- Current Situation: Continuous policy dialogue, advocacy and engagement with governments and other partners at the national and regional levels (regional economic communities – RECs) is needed to facilitate the formulation and implementation of policies and frameworks on: enactment of policies bordering on new/emerging issues such as land and irrigation area expansion; release of food security stock; guaranteed minimum price support; subsidies on inputs such as seed and fertilizer; farm machinery and post-harvest equipment, etc.
- Action Plan
  - Collaborate with national and regional policy platforms to facilitate the formulation and implementation of national and regional rice policies and frameworks
  - Organize annual Round Table policy dialogues through national/regional rice policy platform in collaboration with development partners.
  - Initiate stakeholders' dialogue on the implementation of the current national/regional agricultural program and rice trade policy.
- Partnerships: AfricaRice, CARD, IFPRI, USAID, African Governments, CARI-GIZ, JICA, etc.

VIII. Market Opportunities: Farmers Access to Markets and Agri-business Development

- Objective: Create market opportunities for smallholder farmers and agri-business development.
- Current Situation: It is expected that after the production of rice, it should meet market demand. But this is not always the case in most SSA countries due to inefficient post-harvest, processing and value addition largely in use by key stakeholder; bad road; and lack of drying & storage facilities. In spite of the widespread economic reforms embarked upon by some governments in the past years and the emergence of a free market economy in some countries, the market is still fraught with grave imperfections.
- Action Plan
  - Identify appropriate opportunities to improve access to existing input/output markets and create new market linkages for domestic rice production and trade
  - Assess market opportunities for domestic rice and value-added products
  - Promote warehouse receipt systems for paddy storage
  - Build capacity of stakeholders in grading, branding labelling and packaging as well as promotion of milled rice products in national and regional markets
- Partnerships: AfricaRice, CARD, IFPRI, USAID, Governments, CARI-GIZ, JICA, etc.

IX. Investment in rice production and processing infrastructure

- Objective: Support major investments in rice production (irrigation) and processing infrastructure (integrated mills)
- Current Situation: With the uncertainties associated with weather, dependence on rainfed conditions as a means of boosting rice production in Africa cannot be assured. It is imperative that irrigated rice systems play a significant role in increasing production. There is therefore a need for governments to provide resources for rehabilitating existing schemes and develop new irrigation facilities for use by smallholder farmers. African governments also need to invest in integrated rice mills to support the cottage mills.
- Action Plan
  - Encourage governments and private sectors to invest in irrigation facilities
  - Encourage governments to rehabilitate faulty irrigation facilities
  - Provide enabling environment for private investors to invest in integrated rice mills
- Partnerships: Governments, private investors, etc.

5. ESTIMATED COSTS

a) Sorghum and Millets

i. Short Term (year 1-5)

Line Item	Budget in US$					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Breeders (2 in WCA and 2 in ESA)	632,000	642,000	647,000	652,000	662,000	3,235,000
Crop protection scientists (2 in WCA and 2 in ESA)	632,000	642,000	647,000	652,000	662,000	3,235,000
Agronomists (2 in WCA and 2 in ESA)	632,000	642,000	647,000	652,000	662,000	3,235,000
Economists (1 in WCA and 1 in ESA)	316,000	321,000	323,500	326,000	331,000	1,617,500
Social scientists (1 in WCA and 1 in ESA)	316,000	321,000	323,500	326,000	331,000	1,617,500
Seed Specialists (1 in WCA and 1 in ESA)	316,000	321,000	323,500	326,000	331,000	1,617,500
Communication Specialists (1 in WCA and 1 in ESA)	316,000	321,000	323,500	326,000	331,000	1,617,500
Project Manager	158,000	160,500	161,750	163,000	165,500	808,750
Research technicians (4 in WCA and 4 in ESA)	280,000	282,000	286,000	290,000	300,000	**1,438,000**
Field workers	100,000	120,000	130,000	150,000	180,000	**680,000**
Research support for NARS PhD students (10 in WCA and 10 in ESA @ $50,000)	250,000	250,000	250,000	250,000	-	**1,000,000**
Administration Assistants (1 for WCA and 1 for ESA)	60,000	62,000	65,000	67,600	69,000	**323,600**
Consultants	20,000	23,000	25,000	27,000	29,000	**124,000**
Motor vehicles (3 in WCA and 3 in ESA @$45,000)	270,000	-	-	-	-	**270,000**
Computers and accessories (10 for WCA and 10 for ESA @$3,000)	60,000	-	-	-	-	**60,000**
International travels	31,000	35,000	38,000	42,000	40,000	**186,000**
Local Travels	25,000	28,000	30,000	33,000	35,000	**151,000**
Office Supplies	20,000	10,000	12,000	14,000	16,000	**72,000**
Field Supplies	180,000	190,000	200,000	210,000	220,000	**1,000,000**
Laboratory supplies	60,000	65,000	70,000	73,000	76,000	**344,000**
Translation and publication services	30,000	30,000	30,000	40,000	45,000	**175,000**
Communication and IT services	10,000	12,000	12,000	14,000	15,000	**63,000**
Office space charges	10,000	12,000	14,000	16,000	18,000	**70,000**
Utilities	12,500	15,000	17,500	18,000	20,000	**83,000**
Vehicle running costs	100,000	110,000	120,000	130,000	200,000	**660,000**
Sub-grants to NARS (5 countries in WCA and 5 in ESA)	1,500,000	1,750,000	2,000,000	2,250,000	2,250,000	**9,750,000**
Total Direct Costs	**6,336,500**	**6,364,500**	**6,696,250**	**7,047,600**	**6,988,500**	**33,433,350**
Overhead of Direct Cost (15.8%)	1,001,167	1,005,591	1,058,008	1,113,521	1,104,183	5,282,469
Research Charges (3%)	190,095	190,935	200,888	211,428	209,655	1,003,001
CGIAR System Cost (2%)	126,730	127,290	133,925	140,952	139,770	668,667
GRAND TOTALS	**7,654,492**	**7,688,316**	**8,089,070**	**8,513,501**	**8,442,108**	**40,387,487**

ii. Medium and Long Term

Line Items	Budget in US$		
	Year 6 to 10	**Year 11 to 15**	**Total**
Scientific Staff	6,000,000	10,000,000	16,000,000
Research Support Staff	2,500,000	8,000,000	10,500,000
Field workers	1,000,000	3,000,000	4,000,000
Motor Vehicles & associated running costs	500,000	750,000	1,250,000
Computers, Communication & IT Support	300,000	450,000	750,000
Research support for NARS PhD students	2,500,000	5,000,000	7,500,000
Support for NARS Field and Laboratory Facilities	2,000,000	4,000,000	6,000,000
Support for NARS Research Operations	10,000,000	15,000,000	25,000,000
Farmer Empowerment	2,500,000	5,000,000	7,500,000
Strengthening grass-root seed and delivery institutions	3,000,000	5,000,000	8,000,000
Empowering the national technology delivery institutions	5,000,000	5,000,000	10,000,000
Total Direct Costs	35,300,000	61,200,000	96,500,000
Overhead of Direct Cost (15.8%)	5,577,400	9,669,600	15,247,000
Research Charges (3%)	1,059,000	1,836,000	2,895,000
CGIAR System Cost (2%)	706,000	1,224,000	1,930,000
GRAND TOTALS	**42,642,400**	**73,929,600**	**116,572,000**

b) Maize

The estimated budget for this initiative (as an additional investment to the existing) for a project duration of five years (2016-2020) is as follows:

Line Item	Budget (in million US$)					Total (in M US$)
	Year 1	Year 2	Year 3	Year 4	Year 5	
Personnel						
IITA and CIMMYT IRS	1.66	1.75	1.83	1.92	2.02	9.18
IITA and CIMMYT NRS / Admin. / Consultants	0.50	0.52	0.55	0.58	0.61	2.76
Sub-grants to NARES and SME partners	2.00	2.10	2.25	2.40	2.50	11.25
Equipment/Capex (including mechanization of breeding operations, phenotyping platforms)	0.60	0.63	0.66	0.70	0.72	3.31
Operational costs (Field/lab/office supplies)						
Objective 1: Scaling-up and deploying climate resilient maize	2.50	2.75	3.00	3.30	3.75	15.30
Objective 2: Curbing the spread and impact of MLN in SSA	0.45	0.48	0.50	0.52	0.55	2.50
Objective 3: Increasing genetic gains through a stronger breeding pipeline	2.00	2.20	2.40	2.60	2.80	12.00
Objective 4: Maize with enhanced nutritional quality and end-use traits	0.50	0.52	0.55	0.58	0.61	2.76
Objective 5: Sustainable intensification of maize-based systems	2.50	2.70	3.00	3.20	3.40	14.80
Objective 6: Developing better Aflasafe products, aflatoxin management systems and delivery mechanisms	2.78	2.89	3.04	3.19	3.35	15.25
Objective 7: Training and capacity development of NARES and SMEs	0.50	0.52	0.55	0.58	0.61	2.76
Foresight, technology targeting, gender, impact assessment, and M&E&L	1.50	1.70	2.00	2.20	2.40	9.80
Travel (local and international) & Country/Regional-level planning and review meetings	0.60	0.63	0.66	0.70	0.73	3.32
Communications and IT services	0.50	0.52	0.55	0.58	6.01	8.16
Subtotal	18.59	19.91	21.54	23.05	30.06	113.15
Indirect Costs (15%)	2.79	2.99	3.23	3.46	4.51	16.97
TOTAL	**21.38**	**22.90**	**24.77**	**26.51**	**34.57**	**130.12**

c) Wheat

Assumptions: AU member states would need to agree targets, associated with a cost/benefit analysis that would justify a certain range of investment, including their co-investment.

The estimated investments below are based on the high potential countries identified above and assume that ongoing investments (e.g. SARD-SC/Wheat, ASARECA-WHEAT) continue, e.g. SARD-SC/Wheat Phase 2 ($10M p.a., 6YRs), in conjunction with additional investments in research and scaling-out.

Phase II below is based on the assumption that national and international scaling-out partners would contribute additional investments.

Estimated costs to implement recommendations made by W4A strategy meeting, 2013

US$ Million	**Key partners**	**Short-term (2017-19) Engage 4-5 countries Discovery, validation; some scaling-out**	**Mid-term (2020 – 23) + 3-4 new countries Some discovery, validation, more scaling-out**	**Longterm (2024-26) +2-3 new countries Focus: Validation (adapt), scaling-out**
Foresight, M&E	IFPRI/CRP PIM, UNECA, select NARS	6	4	3
of which	personnel	70%	70%	60%
	Operation / travel	10%	10%	20%
	Partners	20%	20%	20%
Promote suitable wheat based systems incl. farm power	NARS, private sector input and service providers, CRP DLAS, Farmer orgs, mech providers, small business developers, NARS, other AgriFood System CRPs	18	18	15
of which	Personnel	50%	40%	30%
	Operation / travel – staff	25%	40%	30%
	partners	25%	30%	40%
Improved germplasm & seed systems (incl. regional germplasm exchange)	Public and private sector pre/breeders, phenotyping platforms, farmer orgs & cooperatives, farmers, Public, private seed suppliers	27	25	23
Of which	Personnel	40%	40%	40%
	Operation / travel	40%	30%	30%
	Partners	20%	30%	30%
Policies	Ministries of Agriculture, Rural Development, Finance, Trade, CRP PIM, other	4	3	3
Of which	Personnel	70%	70%	60%
	Operation / travel	20%	20%	20%
	Partners	10%	10%	20%
Foster South-South collaboration	NARS, universities, Ministries of Higher Education, other CRPs	9	12	10
Of which	Personnel	40%	40%	40%
	Operation / travel	30%	30%	30%
	Partners	30%	30%	30%
	Total estimated $M	62	62	54
	Broken down p.a.	20.7	20.7	18

d) Rice

i. Short Term (year 1 to 3)

Budget Items	Year 1	Year 2	Year 3	Total
Personnel cost	4,242,500	4,454,625	4,677,358	13,374,483
Collaboration (partners)	6,000,000	6,125,000	6,125,000	18,250,000
Supplies and Services	11,272,000	10,760,000	11,000,000	33,032,000
Travel	565,000	797,000	565,000	1,927,000
Equipment/Capital	365,000	0	0	365,000
Technical Services	384,000	244,000	244,000	872,000
Central Scientific Services	4,700,000	4,700,000	4,700,000	14,100,000
Direct administrative Support	4,129,275	4,028,795	4,096,703	12,254,773
Total direct Costs	**31,657,775**	**31,109,420**	**31,408,061**	**94,175,256**
Overheads	3,514,013	3,453,146	3,486,295	10,453,454
Sub-Total	**35,171,788**	**34,562,566**	**34,894,356**	**104,628,710**
CGIAR Cost Sharing Percentage CSP)	703,435	686,317	695,888	2,087,640
GRAND TOTAL	**35,875,223**	**35,248,883**	**35,590,244**	**106,714,350**

ii. Medium and Long Term (Years 1-5 and 1-8)

Budget Items	Budget in US$		
	Year 1 to 5	Year 1 to 8	Total
Personnel Cost	8,702,869	8,748,975	17,451,844
Collaboration (partners)	4,375,000	8,600,000	12,975,000
Supplies and Services	12,836,000	10,592,000	23,428,000
Travel	1,180,000	1,200,000	2,380,000
Equipment/Travel	0	0	0
Technical Services	1,030,000	0	1,030,000
Central Scientific Services	7,500,000	5,600,000	13,100,000
Direct Administrative Support	6,200,830	5,211,146	11,411,976
Total Direct Costs	**41,824,699**	**39,952,121**	**81,776,820**
Overheads	5,276,907	4,434,686	9,711,593
Sub-Total	**47,101,606**	**44,386,807**	**91,488,413**
CGIAR Cost Sharing Percentage (CSP)	1,056,332	887,736	1,944,068
GRAND TOTAL	**48,157,938**	**45,274,543**	**93,432,481**

6. REFERENCES

1. Alene AD et al. (2009) The economic and poverty impacts of maize research in West and Central Africa. Agricultural Economics 40: 535-550.
2. Balasubramanian, V., Sie, M., Hijmans, R., Otsuka, K., 2007. Increasing rice production in sub-Saharan Africa: challenges and opportunities. Advances in agronomy 94, 55-133.
3. Baudron et al, (2015). Re-examining appropriate mechanization in Eastern and Southern Africa: two-wheel tractors, conservation agriculture, and private sector involvement, Food Security, May 2015
4. Bouis HE, Hotz C, McClafferty B, Meenakshi JV, Pfeiffer WH (2011) Biofortification: a new tool to reduce micronutrient malnutrition. Food Nutr. Bulletin 32: S31–40.
5. Childs N. (2015) Rice Outlook. http://www.ers.usda.gov/media/1902020/rcs-15i-final.pdf
6. FAO (2011). The state of food and agriculture. Women in Agriculture. Closing the Gender gap for Development. FAO
7. FAOSTAT (2010). http://Faostat.fao.org
8. FAOSTAT (2012). http://Faostat.fao.org (accessed October 6, 2015)
9. FAOSTAT (2014). http://Faostat.fao.org
10. Fisher M et al. (2015) Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. Climatic Change (DOI 10.1007/s10584-015-1459-2).
11. Foresight. The Future of Food and Farming (2011) Final Project Report. The Government Office for Science, London.
12. Grings E, Erenstein O, Blümmel M (Eds) (2013) Special Issue: Dual-purpose maize. Field Crops Research 153: 1-112.
13. Hardaker, J. B., Huirne, R. B. M., Anderson, J. R., & Lien, G. (2015). Coping with Risk in Agriculture, Applied Decision Analysis. CABI.
14. http://wheat.org/wheat-for-africa/
15. https://cimmyt.app.box.com/s/d68k14rejo0kkop45q8t
16. http://ageconsearch.umn.edu/bitstream/146936/2/idwp127.pdf
17. http://blog.cimmyt.org/tag/mechanization/
18. IFPRI (2000) 2020 Projections. Washington D. C.: IFPRI
19. Kamara AY et al. (2008) A participatoryapproach to increasingproductivity of maizethrough*Strigahermonthica* control in northeast Nigeria. Experimental Agriculture 44(3): 349–364.
20. Klapwijk, C. J., van Wijk, M. T., Rosenstock, T. S., van Asten, P. J. A., Thornton, P. K., & Giller, K. E. (2014). Analysis of trade-offs in agricultural systems: current status and way forward. Current Opinion in Environmental Sustainability, 6(0), 110–115. doi:http://dx.doi.org/10.1016/j.cosust.2013.11.012
21. Kostandini G, La Rovere R, Zhe G (2015) Ex-ante welfare analysis of technological change: the case of nitrogen efficient maize for African soils. Canadian J. Agri. Econ. (DOI: 10.1111/cjag.12067).
22. Lobell DB, Bänziger M, Magorokosho C, Vivek B (2011) Nonlinear heat effects on African Maize as evidenced by historical yield trials. Nature Climate Change 1: 42–45.
23. Lobell D.B., Schlenker W., Costa---Roberts J. (2011). Climate trends and global crop production since 1980. Science. DOI:10.1126/science.1204531.
24. Mahuku G et al. (2015) Maize Lethal Necrosis (MLN), an emerging threat to maize-based food security in sub-Saharan Africa. Phytopathology 105: 956-965.
25. Masih I, Maskey S, Mussá FEF, Trambauer P (2014) A review of droughts on the African continent: a geospatial and long-term perspective Hydrol. EarthSyst. Sci. 18: 3635-3649.

26. Mason et al (2012): Wheat Consumption in Sub-Saharan Africa: Trends, Drivers, and Policy Implications, MSU International Development Working Paper 127, December 2012
27. Nelson, G.C. et al. (2009). Climate Change. Impact on Agriculture and Costs of Adaptation. IFPRI, Washington D.C.
28. Nicole Mason et al, Wheat Consumption in Sub-Saharan Africa: Trends, Drivers, and Policy Implications, MSU International Development Working Paper 127, December 2012
29. Nuss ET, Tanumihardjo SA (2011) Quality Protein Maize for Africa: Closing the protein inadequacy gap in vulnerable populations. Adv. Nutr. 2: 217–224, 2011.
30. OECD/Food and Agriculture Organization of the United Nations (2015) OECD-FAO Agricultural Outlook 2015, OECD Publishing, Paris. http://dx.doi.org/10.1787/agr_outlook-2015-en.
31. Prasanna BM (2015) Maize lethal necrosis (MLN) in eastern Africa: tackling a major challenge. The African Seed (March 2015 Issue), pp. 18-21.
32. Robertson, M., Pannell, D., & Chalak, M. (2012). Wholefarm models a review of recent approaches. Austrailan Farm Business Management Journal, 9, 13–26.
33. Schlenker, W. and D.B. Lobell. 2010. Robust negative impacts of climate change on African agriculture. Environ. Res. Lett. 5 014010 doi: 10.1088/1748---9326/5/1/014010.
34. Seck, P. A., Diagne, A., Mohanty, S., and Wopereis, M. C. S, 2012. Crops that feed the world 7: rice. Food Security4 (1), 7-24.
35. Seck, P.A., Toure, A. A., Coulibaly, J. Y., Diagne. A. and Wopereis, M. C. S. (2013). Impact of rice research on income, poverty and food security in Africa: an ex-ante analysis. In: Wopereis, M. C. S., Johnson, D. E., Ahmadi, N., Tollens, E., and Jalloh, A. (Eds.), Realizing Africa's Rice Promise. CABInternational, Wallingford, UK. pp. 24-33.
36. Shi W, Tao F (2014) Vulnerability of African maize yield to climate changeand variability during 1961–2010. Food Sec. 6: 471–481.
37. Shiferaw B, Prasanna B, Hellin J, Banziger M (2011) Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. Food Security 3: 307-327.
38. Shiferaw B et al. (2014) Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather and Climate Extremes 3: 67-79.
39. Smale M, Byerlee D, Jayne T (2011) Maizerevolution in sub-Saharan Africa. Policy Researchworkingpaper 5659. Washington DC: World Bank.
40. Tahirou A et al. (2009) Assessing the constraints affecting production and deployment of maize seed in DTMA countries of West Africa. IITA, Ibadan, Nigeria. 40 pp.
41. Thenkabail, P.S., Knox, J.W., Ozdogan, M., Gumma, M.K., Congalton, R.G., Wu, Z., Milesi, C., Finkral, A., Marshall, M., Mariotto, I., 2012. Assessing future risks to agricultural productivity, water resources and food security: how can remote sensing help? Photogrammetric Engineering and Remote Sensing 78, 773-782.
42. World Bank. (2007). Population Issues in the 21st Century: The Role of the World Bank. Health, Nutrition and Population (HNP) Discussion Paper. The World Bank, Washington D.C., http://siteresources.worldbank.org/.HEALTNUTRITIONANDPOPULATION/Resources/281627---1095698140167/PopulationDiscussionPaperApril07Final.pdf).