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Challenges and opportunities to the African agriculture and food systems

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Abstract

Reduction in the proportion of undernourished people worldwide has been achieved despite global population increase. However, the achievement of reducing undernourishment globally was uneven; sub-Saharan Africa (SSA) in particular has the least progress. In SSA, agriculture is only slowly changing with actual well below potential yields. Failures in agricultural policies, weak institutions, and poor governance are the root of growth stagnation. Agriculture contributes a significant share to the SSA economy and a majority of the population derives their livelihood from this sector. It is justifiable to assume that for sustainable growth of the African economy, significant investment and creative innovation in agriculture are needed. However, several factors such as growth of the farming population, loss of soil fertility, climate change, water scarcity, post-harvest losses, and limited market access could challenge such expectation. On the other hand, new policy reforms and initiatives, and appropriate investment that directly or indirectly support agricultural innovation and growth are emerging. This chapter discusses the challenges and opportunities to advance agricultural growth and food systems in Africa and makes recommendations for solutions.

Key words: Africa, food systems, agriculture, agricultural research, agricultural investment

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Introduction

Significant progress in the effort to reduce the proportion of undernourished people worldwide has been achieved. Despite the addition of 1.9 billion people to the global population between 1990 to 2016, the proportion of undernourished people has declined by 21.4 %. However, the 2015 FAO, IFAD and WFP report on the status of food security shows that 232.5 million people in Africa (20.0%) are undernourished, which is higher than in other regions of the developing world. Eastern (31.5%) and Central (41.3%) Africa are the most affected areas on the continent. Worldwide, the prevalence of undernourishment decreased from 18.6 to 10.9% between 1990 and 2014-16. However, in Africa, the reduction in the proportion of undernourished people was from 27.6 to 20.0% and in SSA the decrease was from 33.2 to 23.2%, indicating that in SSA, nearly a quarter of the population remained undernourished, which is the highest prevalence of undernourishment in any of the UN regions (FAO, IFAD and WFP, 2015).

Agriculture contributes a significant share to the SSA economy and the majority of the population depends on this sector as their primary source of livelihood. According to the Food and Agriculture Organization of the United Nations, more than half (57%) of the SSA population relies directly on agriculture. Improvement in agricultural productivity could reduce rural poverty by ensuring a sustainable supply of food, reducing food prices, generating export earnings and higher income for farmers, increasing on-farm employment and farm wage rates, and by creating linkages between farming and other sectors that are drivers of the rural economy and provide capital and labor for growth in other sectors of the economy. In addition, improved agricultural productivity can support human capital development through investments for better nutrition, health, and education (Irz *et al*., 2001). A sustainable supply of a variety of foods as a result of agricultural growth could enhance productivity of individual lives and collectively of the national economy and social wellbeing (Demment *et al*., 2003).

Agricultural development and food systems in SSA countries face considerable challenges. While the world population is projected to reach 9.7 billion by 2050, more than 50% of this increase is expected to come from Africa, an increasingly significant driver of food demand. However, the potential of African agriculture to satisfy a growing food demand in response to the population increase is constrained by several factors. Africa is experiencing a decline of farm size mainly due to agricultural population increase, traditional land inheritance customs and to rapid urbanization which stimulates cropland conversion for expansion of urban residency, industry, roads and other infrastructure (Jayne *et al*., 2014; Döös *et al*., 2002).

Additionally, climate change is a global phenomenon that affects agricultural productivity in every corner of the world by causing variable weather conditions, more intense weather events, drought, and alterations in diseases and pests; however, the extent of its adversity depends on adaptive capabilities of farmers (Gornall *et al*., 2010). For example, projections suggest that in SSA, a temperature increase by 1^{o}C can cause a significant revenue decline to dry land crops ($27 per hectare) and livestock ($379 per farm), but an increase in revenue from irrigated crops ($30 per hectare) (Kurukulasuriya *et al*., 2006). Thus, in response to temperature increase, irrigated

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agriculture clearly buffers the revenue loss due to dry land agriculture productivity decline. However, irrigation requires considerable capital investment that a majority of African farmers cannot afford.

An increasing demand for agricultural products in the supply chain is a key driver for productivity growth, agricultural transformation, and increasing household income. Despite increased retailing through supermarkets in a few countries in Africa, farmers' market participation is still constrained by food safety standards, poor infrastructure, weak agricultural institutions, and high transaction costs (Holloway *et al*., 2000; Shiferaw *et al*., 2011).

Despite the challenges facing African agriculture, initiatives tailored to encourage investment in domestic agriculture are emerging. African governments are reshaping yield-focused agricultural policies to nutrition-sensitive agriculture with public health promotion components. Considering that a high portion of the projected increase in world population by 2050 is expected to come from SSA, origination of this growth in a limited-resource setting could be considered a risk for development. However, unlike other parts of the world where the population transition has already occurred, SSA countries are at the early stage of population transition. The demographic structure is characterized by a high proportion of the population at economically favorable ages. For example, during 2015 the working age (25-64 years) group reached 36.2 % of the population and is growing more rapidly than in other parts of the world (UNECA, 2016). The estimated demographic dividend in SSA could reach 11–15% of the GDP growth by 2030 and contribute to 40–60 million fewer poor during the same period (Ahmed *et al*., 2016). Sub-Saharan Africa countries are experiencing rapid urbanization and income growth. Urbanization and income growth are again accompanied by changes in dietary patterns. For example, in Asia in response to income increments, consumption has shifted from rice to wheat and then to livestock (Pingali, 2007). In addition, urbanization and increase in income give rise to higher per capita consumption of animal source foods which stimulates growth in the livestock sector (Speedy, 2003; Randolph *et al*., 2007). People will follow healthier eating styles such as increasing consumption of fruits and vegetables. Furthermore, trends and total expenditure for consumption of food away from home will increase (Ma *et al*., 2006). These scenarios will create demand for the agricultural sector to increase production of a large volume of diversified food crops and animal source foods which again will support expansion of modern supermarkets and development of restaurants. On the other hand, urbanization and income growth could result in a shift in dietary habits to a typical "western diet" characterized by greater inclusion of processed foods, meat and more fat and sugar which are linked to the development of chronic diseases (Popkin *et al*., 2011). This dietary transition is occurring in developing countries, thus posing the joint challenges of both under and over nutrition (Abdullah, 2015). The cost of over nutrition is not insignificant. For example, medical and economic costs of obesity in the US for the year 2014 were estimated to be $1.4 trillion (Waters and De Vol, 2016). Similarly, in developing countries non-communicable disease contributes to 33% of disability adjusted life years (DALYS) and this percentage is projected to increase to 45% in the year 2030 (Bygbjerg, 2012). In this chapter, we reviewed available evidence

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from published literature on challenges and opportunities facing the agriculture and food systems in SSA and have made recommendations.

Farm size decline

Since the mid-1990's, agricultural production worldwide has shown dramatic increases in yields resulting in a significant decrease in the proportion of hungry people. These increases are attributed to several factors such as the use of improved agricultural inputs, the discovery of high-yield and pest-resistant varieties, and the use of labor-saving mechanizations. However, the increase in agricultural production in Africa mainly has come from the expansion of farm land. About 52% of the world's arable land is in Africa. However, there has been a higher rate of growth in the agricultural population than in the expansion of cultivated land (Jayne *et al*., 2014). Population is a threat to agricultural development by causing increased demand for land as well as cropland conversion for urban expansion, industry, roads and other infrastructure at the expense of the arable land. The estimated loss of crop land due to conversion into spaces for non-agricultural purposes in developing countries will reach 30-60 million hectares by the year 2030 (Döös *et al*., 2002).

FAO data from 1960 to 2000 show that while cultivated land in SSA only increased marginally, the agricultural labor force increased dramatically resulting in a steady decline in the ratio of cultivated land to agricultural population from shrinkage in farm size (Figure 1). The trend is especially high for Ethiopia and Kenya with dense rural populations. Moreover, as agriculture productivity is strongly associated with land distribution, variation in land access among farmers is also an important factor to consider for agricultural growth. In general, land distribution in Africa is highly unbalanced. An average landholding in six countries (Ethiopia, Kenya, Mozambique, Rwanda, Zambia and Zimbabwe) during the year 2000 was in the range of 0.56 hectares per person in Zambia to 0.16 hectares per person in Rwanda**.** Compared to average landholdings by households in the lower quartile, those in the highest quartile controlled eight to twenty times more land. Country specific data analysis showed that, in Kenya, the mean land holdings by household at the lower and higher quartiles were 0.08 vs. 1.10 hectares per capita. Similarly, in Ethiopia and Rwanda per capita land access for those in the lowest quartile was less than 0.03 hectares (Jayne *et al*., 2003). This condition affects the viability of the smallholder farmers and the agricultural system in the region, in general, by constraining use of new agricultural technology and inputs, and limiting agricultural commercialization and revenues from crop sales (Jayne *et al*., 2010).

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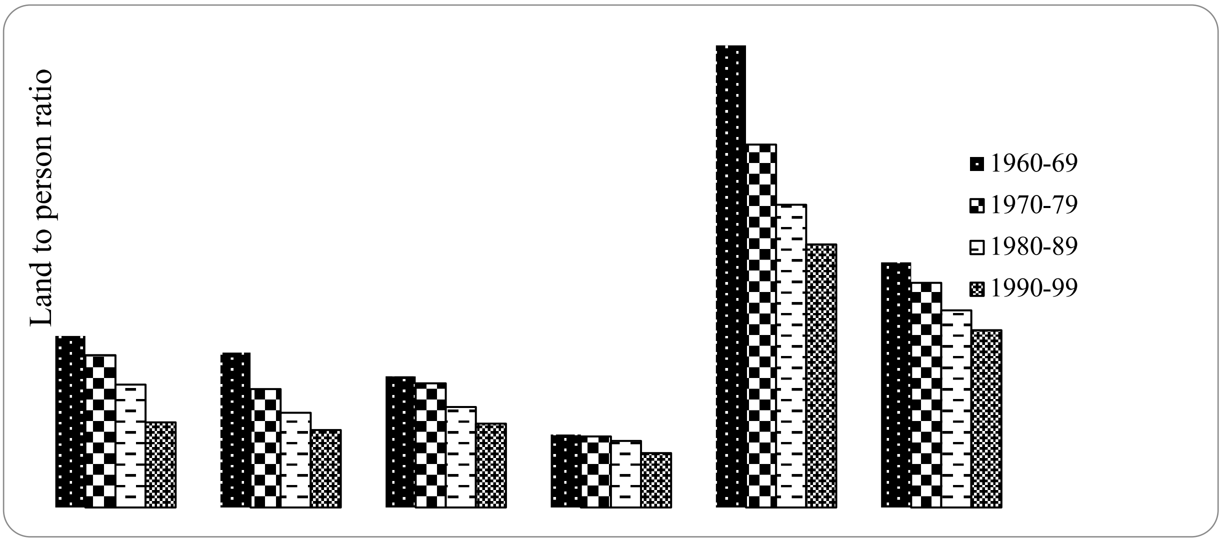

Figure 1: Land to person ratios by 10-year increments in six African countries
(Source: Jayne *et al*., 2003)

Population density influences agricultural intensification by reducing farm size, increasing demand for agricultural inputs such as inorganic fertilizer, lowering farm wages, decreasing revenue from crop sales, creating dependency on off-farm income of limited elasticity (up to 400 persons/ km^2), lowering crop yield compared to the amount needed to satisfy the demand of the increasing population (Josephson *et al*., 2014; Ricker-Gilbert *et al*., 2014). Land pressure due to continuous population growth and socio-economic changes in Africa raises the need to develop adaptive responses and lifestyle changes such as rural-urban or rural-rural migration, reduction in population growth by reducing rate of fertility, and income diversification from non-farm activities (Jayne *et al*., 2014; Muyanga and Jayne, 2014). However, alternatives such as off-farm income generation for rural populations exhibit thresholds beyond which no significant increase in income can occur (Ricker-Gilbert *et al*., 2014).

Climate change

Climate changes exert adverse effects on agricultural productivity through a wide range of meteorological and hydrological processes, including increases in the atmospheric temperature affecting rate of precipitation and evaporation resulting in water scarcity, lack of predictability of weather events such as the "seasonal" rains that require smallholders to plan cultivation, and by causing greater frequency of extreme weather events that can cause great soil and crop losses. Climate change can also affect agricultural productivity indirectly through elevating reproduction rate and movement patterns of pests. Moreover, a rise in temperature or drought affects the resistance of crops to disease (Gornall *et al*., 2010).

Climatic condition changes stimulate development of adaptive responses such as adjustments to the farming system to prevent productivity losses. It is assumed that moderate changes to farming systems due to climatic changes can be adapted by farmers. Nevertheless, this resilience could reach its limit of effectiveness as the

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severity of the change in climatic condition increases; these changes create risks that may overwhelm the resilience of resource-poor African farmers (Howden *et al*., 2007).

A panel analysis of crop production and weather data to estimate yield response to climatic change reported that by 2050, the mean production changes in SSA are estimated to be -22% for maize, -17% for millet, -17% for sorghum, and -18% for groundnuts. However, a change of only -8% was estimated for cassava (Schlenker and Lobell, 2010). A report on future prospects for cereal production from rain-fed agriculture showed that by 2025, the annual cereal deficit for SSA would reach 35 million tons compared to 9 million tons during 2000, putting Africa as a net importer of cereal (Rosegrant *et al*., 2002). Such predictions illustrate the need to develop robust adaptive mechanisms, create supportive policies that help farmers deal with risk and build agricultural support systems to develop local food systems that function in such an environment.

Water Scarcity

Water is a critical driver of agricultural production. Agricultural activities such as crop and livestock production, fishing and agro-processing are directly influenced by the availability of quality water. Scarcity of water can cause significant threats to the smallholder farming society of SSA by adversely affecting yields (Namara *et al*., 2010). Globally, by the year 2050, it is predicted that about 66% of the world population will be vulnerable to water shortages. Such shortages will have a strong impact on food production because agriculture uses a large proportion of the fresh water and SSA will be among the most affected regions (Wallace and Gregory, 2002).

Half of the land in SSA is arid and semi-arid characterized by limited precipitation with a high rate of evaporation. Yet, a large percentage of the population in the region relies on rain-fed agriculture which is the source of about 90% of the staple food. In addition, livestock production, which again is vulnerable to an increasingly variable precipitation, is among the main economic sources in SSA (Cooper *et al*., 2008). By the year 2025, 22 of 28 countries in SSA could face water scarcity. In addition, it is estimated that even before the onset of 2050, per capita water availability will be reduced below the basic requirement (1000 m^3/capita/year) in Eastern and Southern Africa countries and will be in the range of 1000-2000 m^3/capita/year for West African countries (Wallace, 2000).

In 2007, the fourth regional assessment report of the Intergovernmental Panel on Climate Change (IPCC), projected that by 2020, potential yield from rain-fed agriculture in some African countries could be reduced by up to 50% due to climate change. In addition, it was estimated that 75-250 million people would be exposed to scarcity of water. They further projected that due to a rise in water temperature, fishing would be compromised. Although the potential impact of climate change on agricultural productivity can be reduced substantially by putting adaptive mechanisms in place, the cost of coping with variable weather conditions and adaptation to climatic changes could be more than 5-10% of the Gross Domestic Product (GDP). In addition to the expected impact of climate change, the increasing population growth coupled with climate change could further intensify water scarcity (Cooper *et al*., 2008).

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Developing and implementing adaptive strategies to cope with the challenge of water scarcity is increasingly emphasized in the agricultural sector. Agricultural policies now appear to advocate for greater use of more irrigated agriculture, which is less affected by climate change and may be a better option for water usage efficiency than rain-fed agriculture (Molden *et al*., 2007).Globally, 1.1billion hectares of land, constituting 80% of the total agricultural area, is used for rain-fed agriculture; this land generates about 60% of staple food production. On the other hand, only 19% of the crop land is irrigated, yet it provides the remaining 40% of production (Cassman, 2016). However, as stated earlier, irrigated agriculture is limited to only small areas of Africa, and it incurs capital investment difficult for poor African farmers to afford. On the other hand, improving institutional, agronomic, technical and managerial factors that positively affect efficient use of water by reducing water loss through storage, and controlling runoff and drainage to respond to water scarcity have been suggested (Rijsberman, 2006). As summarized in Wallace and Gregory (2002), these approaches include the use of deep rooted and rapid early growing crop varieties, use of fertilizers, application of mulching, weed control, rain water harvesting, drip irrigation, saline and waste water management, provision of incentives for efficient use of water or disincentives for inefficient use, and training and extension programs.

Post-harvest loss and sanitary and phyto-sanitary standards

An unacceptably high number of people go hungry every day and post-harvest losses due to spoilage and infestation make significant contributions to food insecurity. Post-harvest loss in developing countries is larger than in the developed world mainly due to inadequate pre- and post-harvest management. In Africa, post-harvest loss could reach up to 40% of the crop. In monetary terms, post-harvest loss of grain crops alone in Africa is estimated to cost US$4 billion per year suggesting the need for quick intervention to curb this problem to find important pathways for increasing volume of available food (World Bank *et al*., 2011).

Agricultural food crops pass through several processing steps to reach the end consumer and food loss can occur in all of these stages. Post-harvest food losses in maize farming in Tanzania were estimated at about 15% in the field, 13-20% during processing, and 15-25% during storage (Abass *et al*., 2014). The food loss can be due to mechanical damage, contamination by spoilage microorganisms, and invasion by birds, rodents, insects and other pests. Changes in weather conditions and poor pre- and post-harvest practices such as inappropriate handling, storage and processing techniques are the most important factors responsible for post-harvest food loss (Abass *et al*., 2014, World Bank *et al*. 2011). Nationally representative household surveys of post-harvest loss in Malawi, Uganda, and Tanzania showed increased loss with humidity and temperature, and declines with better market access, improved storage practices and education level (Kaminski and Christiaensen, 2014).

Post-harvest loss, in addition to affecting the amount of available food to consumers, also has economic implications because sub-standard quality foods have low market acceptability. Agricultural products constitute the major export commodities for foreign exchange but only crops that pass stringent regulatory requirements are acceptable for

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high end domestic and international food markets, leaving poor quality crops for domestic consumption. Mycotoxin contamination of agricultural crops is one example of a common post-harvest loss challenge.

High temperature and humidity in SSA create conducive environment for fungal growth. In addition, traditional harvesting, such as field threshing using cattle hooves or sticks, breaks the kernels exposing the grain for fungal spore inoculation. Moreover, the practice of sun drying of crops on the field on one hand is not effective to reduce the crop moisture but also could contaminate grain with fungal spores from soil. Traditional storage methods provide little protection against mold growth and insect infestation (Wagacha and Muthomi, 2008).

A contributing factor is that African subsistence farmers have limited resources to invest in improving the production system, processing facilities, and storage conditions to produce crops that meet the quality and safety requirements in the international market (Otsuki *et al*., 2001).

Not only do food losses cause reduction of food availability for consumption but they also pose environmental concerns by raising the emission of greenhouse gas. Harnessing post-harvest losses could contribute substantially to pathways for reducing food insecurity for an ever-increasing population. Agricultural research and development programs in SSA need to be designed with a whole food systems approach that includes food loss reduction components. Farmers training and extension programs should focus on enhancing farmers' skills and knowledge about post-harvest management. Even though securing many modern processing and storage facilities require resources beyond the financial capacity of subsistence farmers in SSA, development and adoption of alternative and affordable technologies are essential to the reduction of post-harvest loss and enhanced earning potential of African farmers.

Agricultural growth favoring policies

Nutrition sensitive agriculture

The existence and nature of local, regional and international agricultural policies and investments as well as multilateral policies on trade in agricultural products are important in defining earning from agricultural products. Agricultural policies in Africa, as in many parts of the world, have been tailored to improving yield and ensuring food availability but with little or no thought of agriculture's explicit goal of improving nutrition and public health. The last 100 years have been marked by emphasis on increased food production and the supply of adequate or even excessive calories per person through the introduction of improved varieties, application of pest controls, and labor-saving technologies. Despite this dramatic achievement by the agricultural sector, malnutrition, both under and over-nutrition, is still persistent suggesting a missing link between agriculture and key elements of human nutrition and health. For example, even though there has been a progressive decline in energy deficiency, the prevalence of vitamin and mineral deficiency is still high. This prevailing under nutrition, mostly in the developing countries, can be partially attributed to failure of agricultural initiatives to incorporate nutrition-related objectives.

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Similarly, nutritionists and community health advocates also are responsible for the existing under nutrition for failing to integrate programs with agriculture as an instrument to attain sustainable nutrition security (Welch and Graham, 1999). Over-nutrition is a major factor in developed countries and an increasingly important one in developing countries (Abdullah, 2015).

The determinants of optimal nutrition and health outcomes are multidimensional and go beyond availability and access to food. Availability of clean water, access to nutrition education, infection and inflammation, recognizing food quality and successfully integrating cultural practices are among the factors affecting nutritional status. Women have key responsibilities for food acquisition and preparation and for child feeding and care; hence, inadequate attention to women's roles and time demands can negatively affect nutrition outcomes for children and households. A review by Berti *et al*., (2004) documenting the impacts of agricultural interventions such as home gardening, livestock, mixed gardens and livestock, cash cropping, and irrigation on nutritional outcomes showed that while most of these agricultural interventions increased food production, their impact on nutrition and health of participating households was not significant. However, projects with components that empowered women and provided nutrition education had higher likelihood of positively impacting child dietary intake and physical growth, micronutrient status and incidence of morbidity suggesting the need for holistic approaches linking agriculture, nutrition and health. Another project, Enhancing Child Nutrition through Animal Source Management (ENAM), addressed the constraints on incorporating animal source foods (ASF) in the diets of children in Ghana (Colecraft *et al*., 2012). The work built on the link between the consumption of ASF and cognitive and physical development of children in Kenya (Whaley at al., 2003; Neumann *et al*., 2007). ENAM showed the importance of addressing caregivers' income and knowledge barriers through implementation of integrated interventions such as providing microfinance, entrepreneurship and nutrition education to women to achieve increases in ASF consumption in children (Hagan *et al.,* 2012; Marquis and Colecraft, 2012).

Dietary diversification is the most sustainable approach to providing macronutrients as well as the wide range of micronutrients needed to support growth and health. Yet, the process takes time and requires implementation of robust integrated programs. Nutrition-sensitive agriculture, beyond increasing food production and involvement of the agricultural sector, also aims at increasing utilization of food for improved nutritional outcomes. This multi-sectoral approach encompasses health, education, economic, environmental and social aspects in addition to agricultural production to address the underlying causes of malnutrition (Jaenicke and Virchow, 2013). Successful programs are also needed to promote gender mainstreaming and the need for investing in women's empowerment for improved outcomes. Women's empowerment is especially important because it has implications for human and social capital as well as economic development. Undernutrition has immediate and long-term effects on physical growth and cognitive development that can reduce overall performance and GDP growth rate. Available country level reports show the staggering impact of undernutrition on social and economic development. The cost of hunger to children from Central America and the Dominican Republic is estimated to represent

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1.7% and 11.4% of GDP, respectively (Martínez and Fernández, 2008) and in Africa, the annual cost associated with child undernutrition could reach to 16.5% of the GDP (African Union Commission *et al*., 2014).

Nutrition-sensitive agriculture positively influences both consumption of nutritious foods for improved nutritional outcomes and household economic status by encouraging farmers to produce diversified crops and livestock products (Berti *et al*., 2004). Initiatives to mainstream nutrition in national agricultural policies in Africa are underway. For example, 39 of 58 countries participate in the Scaling Up Nutrition (SUN) movement which aims at reducing malnutrition in all of its forms through the engagement of several sectors and stakeholders such as donors, the United Nations, the private sector and researchers from Africa (Scaling Up Nutrition, 2015).

Infrastructure development

Availability of well-developed infrastructure networks among African member states facilitates opportunities for communities to access regional and international market destinations and allows labor mobility. However, in Africa, inadequate transportation facilities and other infrastructure limitations are still bottlenecks to the agricultural market. An annual loss of about 2% of the African economic growth has been attributed to inadequate infrastructure. On the other hand, well developed infrastructure could result in up to 40% productivity increases of African firms in general (Ondiege *et al*., 2013).

Establishing major projects to connect African countries and cities through transport infrastructure such as high-speed railways, highways, maritime transport, and the aviation industry are among the political commitments being discussed among SSA countries through Agenda 2063. An example of this commitment by member states is the 'Cape to Cairo' transport infrastructure development among tripartite regions of eight COMESA (Common Market for East and Southern Africa) countries, five EAC (East African Community) countries, and thirteen SADC (Southern African Development Community) countries (Sandrey *et al*., 2011). In addition, China's newly introduced 'One Belt, One Road' initiative could connect Africa with Asia and Europe and will be another opportunity for African agricultural food products to reach export markets (Ziro Mwatela and Changfeng, 2016). However, these infrastructure developments also could create a reverse output such that the already developed agricultural sector in Europe and Asia can even dominate the African food market favored by international quality standards.

Comprehensive African agriculture Development Program (CAADP)

Comprehensive African Agriculture Development Program is an initiative developed by the African Union (AU) and the New Partnership for Africa's Development (NEPAD) and by the African countries to transform and bring agriculture to the top of the development agenda. One of the key and unique aspects of CAADP is that it is African led. The program is based on the principle of multi-sectoral approaches and the engagement of multiple institutions. It pays attention to investments related to management of resources such as land and water, infrastructure development, food supply, and agricultural research enhancement (NEPAD, 2003). The plan requires

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African countries to align their economic policies and development objectives with its principles and visions and to include it as an instrument to achieve the development objectives. For example, Ghana considers CAADP implementation as a requirement to reduce the poverty rate by half. In addition, CAADP is also viewed as a means for the country to achieve its goal of attaining middle income status by the year 2020 (Kolavalli *et al*., 2010).

Even though agricultural growth is central to the development of Africa, inadequate national spending and investment are limiting factors resulting in stagnant growth of the sector. Overall, less than 10% of total national budgets in African countries are used for agricultural spending. As part of the CAADP, African leaders through the Maputo declaration in 2003, passed a commitment that each member countries should allocate at least 10% of their national budget for the agricultural sector (African Union, 2003). As a result, total expenditure on average has grown at a rate of 8.5% per year. In absolute terms, the $10.1 billion agricultural spending per country during 2003 has increased to $16.9 billion in 2010 (Benin and Yu, 2013). However, the performance review of the Maputo declaration a decade later shows that investment is not consistent across countries and only fewer than one in five countries (Burkina Faso, Guinea, Mali, Niger, Senegal, and Ethiopia) fulfilled the 10% agricultural spending as pledged by CAADP (African Union, 2014).

Agricultural research and development

The majority of impoverished persons in Africa lives in rural areas and derive most of their incomes from agriculture. Agricultural growth could, thus, play a crucial role to improve the livelihoods of farmers and landless laborers by increasing employment, reducing rural-urban migration, stabilizing food prices, and increasing their resistance to shocks by enabling them develop assets. Research-led agriculture and extension services are especially effective in accelerated poverty reduction by way of increasing agricultural productivity (Alene, 2010; Alston, 2010). However, the process requires dedicated budget allocation and commitment from the government, development partners and donor communities.

Following the independence of most African countries, public spending for agricultural research and development during the 1960s and 1970s grew substantially across the continent. The total number of researchers increased dramatically and personnel composition changed such that dependence on local agricultural scientists rather than expatriate researchers increased. In addition, during the two decades, growth in the number of researchers was proportional to the increase in agricultural spending. However, during the 1980's the trend was reversed due to stagnation of funding from national governments and shrinkage of grants and loans (Pardey *et al*., 1997). During the new millennium however, investments in human capital development grew by more than 20% and even though agricultural spending and human capital development were not consistent across countries, governmental expenditure for agricultural R and D increased substantially. Similarly, during 2008 alone, more than 12,000 fulltime agricultural researchers were employed (Beintema and Stads, 2011).

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Research-supported agriculture generates high productivity by using improved varieties that have higher yields and are more resistant to pests and harsh conditions. A summary of impact of research on improvement of African major food crops and returns to research investment reported positive impact in increasing agricultural productivity by increasing availability of improved varieties to farmers. In addition, the summary also noted that investment on crop research had positive return (Maredia *et al*., 2000). Several research reports have estimated the potential impacts of investments in agricultural research and development on productivity growth. Alene and Coulibaly (2009) empirically demonstrated the positive contribution of agricultural research on productivity growth and poverty reduction such that in SSA agricultural research can provide an aggregate rate of return of 55% with wide variation by country ranging from 5% for Lesotho to 82% for Ethiopia. It is also reported that investment in agricultural research would liberate about 2.3 million people (0.8%) out of poverty per annum. Doubling the amount of investment is estimated to liberate 9% of the population out of poverty annually. In addition, research indicate that in the least developed countries, agricultural productivity growth could generate sufficient capacity to pay for expenditures on agricultural research that again increase yield and reduce poverty. A 1% increase in yields would reduce the number of people living on under $1 per day by over six million, with 95% of these in Africa and Asia. Per capita cost of poverty reduction by way of research-led agricultural productivity in Africa was estimated at only $144, and was lower than Asia ($180) and far below expenditures in wealthier countries which is estimated at $11,400 (Thirtle *et al*., 2003).

In addition to scientific research and training of high level agricultural scientists, participatory platforms representing groups of local farmers also exist to critically analyze and tackle local problems. One of such platforms is Farmer Field Schools (FFS), which support problem-solving capability of the farming community and become more actively embedded in the agricultural knowledge and information system. Benefits have been demonstrated on several aspects such as application of integrated pest management (Van Den Berg and Jiggins, 2007), empowering local farmers to make their own choices and decisions for increased uptake of agricultural innovations and to get access to markets and services (Friis-Hansen and Duveskog, 2012). A study on economic and production impact of FFS in East Africa reported a positive impact on production and income among women. On average, participation in FFS resulted in 61% income increment. In addition, it contributed to illiteracy reduction (Davis *et al*., 2012).

The USAID has been actively supporting agricultural research in Africa with focus on building human capital through training in the US to both MSc and PhD levels and through institutional partnerships that helped strengthen agricultural universities. The Feed the Future Innovation Labs for Collaborative Research and the former Collaborative Research Support Programs (CRSPs) since 1978 have trained a total of 209 students from Kenya and 115 students from Uganda in several disciplines related to agriculture, food and nutrition at first degree and graduate level education. The innovation labs are also active in providing short term training and capacity building in the areas of adaptation of the livestock system to climatic changes, aquaculture and fisheries, livestock research and trade, increasing consumption of animal source foods,

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horticulture, pest management, and breeding of high yielding and pest resistant crops (The CRSP Digest Project, 2014). In addition, currently, USAID through the University of California, Davis is supporting capacity building on agricultural leadership (Norman E. Borlaug Leadership Enhancement in Agriculture Program) for outstanding MSc and PhD students from Africa, in collaboration with US universities and CGIAR centers. International agricultural centers are also playing important roles on agricultural policy analysis, germplasm research, and natural resource management. For example, all of the15 international agricultural research centers of the CGIAR have research programs in SSA to support agricultural productivity growth, poverty reduction, and environmental sustainability. In addition, 4 of these centers are located in Africa (Africa Rice Center in Benin, International Institute of Tropical Agriculture in Nigeria, and International Livestock Research Institute and World Agroforestry Centre in Kenya) (Renkow and Byerlee, 2010). While all these modest efforts are excellent programs, the extent of the effort relative to the need is small and inadequate.

What is absent from the development work and donor agenda is improving the relevance and quality of higher education both in the Science, Technology, Engineering and Mathematics (STEM) fields and in agriculture. Much effort was expended, quite successfully in the post-World War II era, in building higher education systems in India, Latin America and in Africa but that effort has been minimal in the past two decades. It is the universities of Africa that will be critical to the trajectory and impact of the projected youth bubble. They are the engines of education that will produce the thousands of Africans who will sustain agricultural led development and who will develop and adapt technologies and policies to feed the continent and much of the world. The prevailing investment of donors has been in basic education which is essential, but without higher education to complement these investments, countries have limited capacity to participate in a modern economy. Of great interest is a World Bank study which comes to two important conclusions (Montenegro and Patrinos, 2013). First, that the poorer the country the greater the return to higher education, in fact nearly double the return on investment in primary and secondary education. Second, the highest rate of return for investment in any level of education in any region of the world is for Africa in higher education. So in the end will African youth, if well trained, be a source of creativity and entrepreneurship or a force of social instability and lackluster economic growth? Transforming African higher education, is a major challenge but one that is fundamental to Africa's future.

Changes to food consumption habits

African economies are on the rise, stimulating the rapid pace of urbanization. Income growth and urbanization are major drivers of changes in dietary habits. There is a distinct contrast between eating habits between urban and rural residents. Urban residents consume more energy-dense foods, more animal source foods, and more processed foods compared to rural residents. In addition, urban inhabitants eat away from home more frequently which may stimulate the growth of restaurants. This pattern is even more apparent in urban areas of developing than developed countries (Popkin, 1999). Although these dietary transitions are implicated in the rise of non-communicable chronic diseases like cardiovascular disease, hypertension, diabetes and cancer, they also create opportunity to change agricultural practice from mono-

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cropping to production of more diversified foods crops. In addition, consumers in urban areas become heath conscious thus are increasing the demand for quality and safety of foods. A rise in income level also fuels an increase in the demand for animal source foods improving the livelihood of poor farmers. However, the dietary transition following income growth and urbanization also poses public health challenge of the double burden of both under and over-nutrition that puts great stress on the social and health services (Popkin and Ng, 2007).

There is an increasing trend in the global economy and Africa. Economic growth is associated with a change in dietary patterns to more diversified foods. An increase in per capita income increases expenditure for and consumption of meat and other livestock products (Delgado *et al.*, 1999; Seinfeld *et al.*, 2006).

As observed in other parts of the world such as Asia, per capita income increases in Africa could be accompanied by a dietary shift from intensive cereal consumption to more meat and animal source foods (Randolph *et al.*, 2007). This creates an opportunity for the livestock sector in Africa to grow. In addition, by the year 2050, the worldwide demand for meat is projected to increase by 56% (de Fraiture *et al.*, 2007) and the increasing supply of livestock products to the global market will come especially from the developing countries. An FAO working paper speculated that during the time period from 1961 to 2050, SSA will be the only region where livestock production growth will continue to be fairly strong, while only slow growth was foreseen for the other regions. In addition, developing countries are expected to increase their world meat production share from about 58% during 2005/2007 to 70% by 2050. Furthermore, in a similar time span, milk production in developing countries is expected to increase from 46% to 61% of the global totals (Alexandratos and Bruinsma, 2012). In addition, livestock rearing will be a major livelihood alternative for farmers living in areas marginal for crop production as a way of buffering the effect of climatic change (Jones and Thornton, 2009) thereby increasing the supply of animal source food to local and international markets. There is also significant opportunity for the integration of crop and livestock production as both systems evolve. The ability to use the vast grass and arid lands for production to feed into more intensive finishing operations that use byproducts of crops has significant potential for growth in Africa. However, while non-ruminant production (pigs and chickens) will likely expand dramatically in Africa, there will be likely major food safety issues and emergence of zoonotic diseases.

Projections indicate that by 2025, nearly half of the population on the African continent will live in towns (Njoh *et al.*, 2003). Even though, urbanization in most SSA countries is a recent phenomenon, it is increasing rapidly. The 2014 UN World Urbanization Prospects report shows that urbanization in Africa is increasing by 1.5% per annum (UNDESA/PD, 2014). Urbanization is another important factor for an increase in food demand and changes in patterns of food consumption by providing access to infrastructure such as transportation and cold storage that positively impact the distribution of perishable foods (Delgado, 2005). For example, in China, a rise in per capita expenditure for livestock products was observed in response to an increase in percent of urbanization. In the years 1981-2001, there was a 45% decline in grain

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consumption in urban areas while only a 7% decrease in rural areas was observed. On the other hand, meat and egg consumption has increased by 85% and 278%, respectively in urban areas but in rural areas, the increase in meat was 29% and the increase in egg consumption was 113% in the comparable time period (Seinfeld *et al.* 2006).

Demographic dividend

During mid-2016, SSA's population reached 1 billion and this number is projected to double by 2050. In addition, the population increase from this region is expected to contribute to 80% of the global population growth during the next century (May and Turbat, 2017). On one hand, continued population growth while relying on limited natural resources is a serious threat to food security and sustainable development. On the other hand, with an age structure favoring a relatively high proportion of working population (high percentage of young adults joining the labor force compared to the proportion of dependent age groups), population growth is a driver for accelerated economic growth.

Unlike currently industrialized nations where the population transition occurred slowly over a century, or Asia and Latin America where the population transition occurred so rapidly that they were unable to get the full benefit of the economically favorable age structure, SSA countries are at their early stage of population transition (Yoonjoung, 2016). In Africa, the active working age group (25-64 years) makes up 36.2% of the population and this age group has grown very rapidly compared to other age groups. In addition, about 19% of the population is in the 15-24 age bracket (UNECA, 2016). Proper positioning of the active working group will create a window of opportunity for productive potential and economic development in SSA.

An estimate based on the UN World Population Database by the International Monetary Fund suggested that 80% of the population increases in the global population during the 22nd century will come from Africa. Over the same period, the working age population in Africa is predicted to increase by 2.1 billion compared to a 2 billion increase in the rest of the world. The share of the active working class is expected to increase from 54% during 2010 to about 64% in 2090 (Drummond *et al.*, 2014). If properly tapped, this population increase may create a window of opportunity to maximize productive potential and economic development in Africa. Ahmed *et al.* (2016) reported that the gain from the demographic dividend could reach 11–15% of the GDP growth by 2030, and would contribute to 40–60 million fewer poor during the same period. The study group also estimated that an increase in the proportion of the working age by 1% will be associated with a mean increase of 0.5% in per capita GDP. For countries with median per capita income of $550 during 2010, the benefit from the demographic divided is predicted to reach $1,350 by the year 2100. The increase in the proportion of the working class in Africa will also have major implications for global economic transformation by creating a flexible labor market. This is especially because the increase in the working class will happen in Africa while other countries with developed economies have already experienced the population transition (Drummond *et al.*, 2014).

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The youth bulge can be a source of creativity that produces new business, good policy and good governance. It can be globally and regionally competent with a vision to build their nation's domestic and international engagement. Well educated and nourished African youth will create the businesses that employ the other youth in their cohorts and create the policies that foster economic growth and social well-being. However, the rising working population can also be a threat to African countries by creating tension and unrest if not properly nurtured. Therefore, developing the right policies to support investment in human capital development, education, and job creation, and devising mechanisms for proper tapping of the demographic dividend are essential (Drummond *et al*., 2014).

Conclusion and recommendations

There has been a marked growth in food production in recent times and a significant reduction in the number of hungry people in the world despite increasing population number. However, slower progress was recorded in the SSA and South Asia regions. This is because, even though the majority of the rural poor in SSA derive their livelihoods from the agriculture, the sector is only slowly changing with low yields, limited marketability and minimal industrial development. Failure of agricultural policies, weak institutions, and poor governance contribute to the growth stagnation. For agriculture to be changed from a slowly growing to a progressive sector which would be a major successful contributor to the African economy, radical transformation is needed. Such expectations, however, are challenged by factors including farming population growth with consequent farmland shrinkage, climate change, water scarcity, post-harvest losses, and limited market participation. On the other hand, there are significant policy reforms with direct or indirect implications on agricultural growth. For example, even though uneven and not automatic, public spending for agricultural research and development by African countries is increasing. In addition, African governments have committed, at least in theory, to allocate at least 10% of the national budget for agriculture. Development of transportation and communication infrastructure, are underway.

Create and implement a strategy to strengthen local institutions that build human capital to advance food security. It has been repeatedly mentioned that Africa will realize economic benefits from the increasing number of youths and active working age population. This will happen especially if appropriate strategies to maximize and tap the demographic dividend are properly applied. While training Africans in developed country institutions is a component of a human capital development strategy, the vast majority of the Africans who will lead economic growth will get their education domestically. It is the quality of their institution's education and research capacity that determines if the thousands of graduates each year will be ready to advance the agriculture and food systems of their countries. Jayne *et al*. (2017) recommend that donors should stop bypassing local institutions and support their development. Instead, the support should be to build them so they produce good policies, relevant science and have sufficient capacity to interact productively with the global science community to address African challenges.

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Focus on nutrition early in life as part of a human capital development strategy. Nutrition intervention coupled with a robust, relevant and effective education system (k-12 and higher education) is essential for human capital development which is a driver of a sustainable and vibrant economy and a builder of effective food system (Qadri and Waheed, 2013). In the end, it will be the Africans, the youth of today and the leaders of tomorrow, who will create the policies, science and businesses that produce a food system that provides food and nutrition security to Africa. Ample evidence exists that a diverse, high quality diet early in life affects the productivity, earnings and well-being of individuals for their life time (Martorell *et al*., 2010; Fink *et al*., 2016). School feeding programs, nutritional education for parents, and women's empowerment and earning capacity are all effective ways to improve child nutrition. Good early life nutrition coupled with a full spectrum of education is a proven way to advance economies, improve the agri-food sector and promote long term social stability.

Diversify the training of the agricultural work force. Of importance is that the human capital development be diverse in the anticipation of increasingly complex food systems that are emerging in Africa. With a rapidly expanding middle class, Africa is transitioning to food systems that require much post-harvest expertise. The system requires engineers, high level managers, and marketers to bring foods to the consumer. Innovation to support the system and make it safe, efficient and competitive both domestically and internationally will require scientists in both applied and more basic fields. Agriculture's labor force will move from predominantly production to a whole food system focus. With that shift, the demand for well-trained human capital is much more diverse and for many Africans provides a much more attractive means of employment. If Africa is to more fully participate in the global food markets, quality improvements will be required and to achieve that a future workforce that is diverse and highly skilled must be developed.

Strengthen multi-sectoral coordination. African agricultural policies are now beginning to make the transition to incorporate public health outcomes as well as productivity measures in their objectives. However, for this approach to be effective and for accelerated malnutrition reduction to occur, strong coordination and critical efforts among different sectors (health, agriculture, education, gender, water) is key. The challenge rests both with interdisciplinary science, both the biophysical and social sciences, and the public policy area.

Increase the intensification not the extensification of agriculture. While more food is needed in the future, Africa, of all regions, has the greatest gap between actual and potential yields. Sustainable intensification that does not harm the environment and builds the natural resource base for production requires new technologies and methods that have to be developed and adapted, often locally. This approach requires an effective agriculture research system. In the absence of sustainable intensification, food requirements will default to extensification, converting much of the savanna and rainforest to crop production.

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Develop systems to manage risk for African agriculture. The impact of climate change will increase risk for farmers and livestock producers. With expanding human populations pushing out into marginal lands for crop production where weather patterns are increasingly unpredictable and weather events more intense, small scale farmers are hard pressed for resources to cope with risk. Similarly, the expansion of farm lands has taken away refuge pasturelands that pastoralists have historically used to manage risk in their environments. To capture the full potential of crop and livestock production in Africa, resources, policy and science must be developed to support success in the face of increasing risk. Of particular importance, as this trend continues, is the emphasis on building roads to connect rural producers to markets and extend government and private sector services to remote communities. Roads are essential to both risk management strategies and to relief efforts.

Focus on water productivity. On a global scale, irrigated agriculture supplies about 40 percent of our human food supply on less than 20 percent of farmland (FAO, 2008). Cassman (2016) argues that globally and in Africa food yields to meet future demand will require large contributions from irrigated agriculture. At all scales of farm size, irrigation will be an important component of food production and R and D should be directed at devising techniques that are profitable and efficient. To ensure that water resources are protected and used sustainably, policies and organizations can be created that manage the shared water resource responsibly. An excellent example is that of the Nebraska Natural Resource Districts and Ground Water Governance Policies (http://waterforfood.nebraska.edu) that shows how users of a shared water resource have come together to govern their individual use.

Focus on the environmental and safety attributes of intensification of meat production. Predicted meat consumption in developing countries, and particularly in Africa, will increase markedly in the next decades. This trend will promote an intensification of meat production, likely most intense in non-ruminants. Intensification, as seen in developing countries, has considerable environmental impacts, particularly on water systems. In addition, chickens and pigs are prime hosts for the development of a range of zoonotic diseases. There will need to be strong cooperation between developing and developed countries to address both these concerns, but particularly the zoonotic disease potential. Production technologies, monitoring systems and containment and remediation capacities will be required. These will need to be supported by well-trained veterinarians, animal scientists and production managers.

Increase donor and national government support for CAADP. The CAADP goals of investment in the agricultural sector are still woefully short of what was pledged and what is necessary to advance African agri-food systems. Of all types of expenditures in the agriculture sector, R and D is the most effective in producing growth (Pardey *et al.*, 2006). African R and D systems are underfunded. African funding for agricultural R and D is 1/8 that of Asia, which is one of the reasons why Asia has surpassed Africa in agricultural productivity growth (Fuglie and Rada, 2013). Building the budgets and the human capital to support R and D should be addressed if Africa is going to reach its potential and provide food and nutrition security in the future.

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Rural income diversification. Even though agriculture is the backbone of the rural economy, income diversification by engaging in complementary non-farm activities such as trade, small industries, and handicrafts improves rural livelihoods and reduces risk and problems associated with seasonality. Rural non-farm enterprises are often small-scale and require minimal capital investment, however, rural population still will require availability of local financial institutions that provide credit services to start up new businesses in order to diversify off-farm incomes to contribute to reduction of vulnerability and poverty of farming communities. In addition, even though several factors including infrastructure availability and accessibility of raw materials determine set-up locations, establishment of industries at rural areas will have an income-earning role for the rural poor, will relieve the land pressure by creating employment opportunity, and potentially will transform agriculture by using its products as raw materials.

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