

Guest Editorial

The Urgent Need for African Leadership in Science, Engineering and Technology to Transform African Agriculture into Agri-Food Value Chains

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Prologue – why it is urgent to act NOW

Africa is a huge and diverse continent in terms of land mass, natural resources, peoples, culture and level of economic development, with each region and country showing considerable variations and further diversity. The economic history of many countries in Africa and the continent at large during the last century has been one of negative results, false starts and even decline. The continent often leads the rest of the world in nearly all the wrong and negative statistics – high poverty incidence, low human development index, corruption with impunity, prevalence and persistence of some of the most deadly communicable diseases such as malaria and HIV/AIDS, high infant and maternal mortality, recurrent food and nutrition insecurity, high frequency of political strife and instability, and the list goes on and on.

Acknowledging that much progress has been made at both continental and national levels to address some of these development challenges, Africa appears to remain the weakest link in the global economic chain and the last bastion of widespread poverty, where economic development and policies thereof still depend heavily on foreign influences through aid and other forms of donor support. Consequently, the agriculture-based economies of most African countries remain largely under-developed, focusing mainly on production of food for local consumption and low value raw materials for export. Intra-African trade currently at less 15% remains the lowest in the world compared with other regions. This is not surprising, particularly in the agri-food sector, given the low levels of preservation and processing and other value addition activities, which are necessary to extend storage life of products and development of a wide range of quality, safe and nutritious food products to meet market demands and trade standards.

The consequences of ‘famine in the horn of Africa’ resulting in widespread hunger, starvation and massive displacement of people, has now become too frequent and somewhat ‘predictable’, and yet affected people continue to lack the resilience and ability to adapt to assure their own food and nutrition security. Lacking the needed support of their governments to cope, it is often only the staff of foreign NGOs working in the affected communities that enable us to know that our people are suffering and dying in our midst for lack of food and exposure to the vagaries of harsh weather and extreme climatic conditions. Consequently, despicable and shameful images of an African child continue to headline world print and electronic news media: children with emaciated bodies, popped eyes and swollen bellies, eye sores and runny noses, wobbly tinny legs, and mothers latching dry breasts to the mouth of their hungry and crying and sometimes dying babies. These images of the African child, which still confront us one decade after the dawn of the 21st Century, surely represent an indictment of the failure of Africa’s past generations and our present generation to do the right thing for our people and humanity at large: to pursue the right economic pathways and provide the necessary strong, brave, selfless and foresighted political leadership to restore the dignity of our people. Recent social events around the world and North Africa, for example, which have resulted in regime changes, suggest that we are running out of time to truly serve our people in all areas of leadership. It is also obvious that both history and the next generation of our children and grandchildren will judge us harshly for failing to do the right time during our time.

The increasingly globalised world economy means that nations and regional economic blocs must cooperate and work together through trade and cooperation in knowledge creation and innovation for mutual economic benefits. However, this is far from the current situation for most African countries. Continuing reliance on foreign aid and policy directions for economic development means that many African countries lack the necessary capacity to direct their own development strategies and implementation. One consequence of this situation is that often the solid foundation necessary for country-led economic progress are lacking. One particular area where this deplorable situation is most evident is in role of science, engineering and technology (SET) in sustainable economic development. While the role of agriculture as the critical engine for economic development in Africa, particularly South of the Sahara, is well recognized and expounded by both governments and international development agencies, the agricultural sector of the African economy has lagged behind for so long that it has now been left behind by other developing regions in Asia and Latin America.

It is now a common parlance among various schools of economic thought that Africa missed the Green Revolution that swept past countries in Asia and Latin America, which contributed towards transforming countries such like China, India, Malaysia, Thailand, Brazil and Argentina into modern economic success stories that have earned many of them as emerging economies. While many researchers and political pundits have espoused a plethora of reasons why Africa's Green Revolution has not happened, a cursory look at some critical events during the past several decades in some of the newly emerging countries in Asia and Latin America show that a combination of country-led targeted investments, policies and strong political leadership were the key to success. Obviously, this argument does not negate the contributions made by partners such as external agencies and other nations and institutions in supporting these countries, such as India and Brazil, which has helped them to successfully transform their agriculture into thriving economic success stories that underpinned and catalyzed economy-wide industrialization.

Getting country-led SET to modernize African agriculture

The economies of most African countries are still largely rural, and therefore, agriculture remains the backbone and often only source of economic activity. The farmers growing the food that feeds the majority of Africans are mainly subsistent or smallholder farmers, cultivating small areas of farmland (often less than 0.5 ha per family per annum), using non-high-yielding plant materials and livestock, under mixed cropping system, relying on increasing erratic and unpredictable rainfall patterns, using no fertilizer or agro-chemicals for pest, disease and weed control, relying on manual labor (and animal power in some areas) and simple hand tools and associated human muscle to carry out on-farm and postharvest operations, and lacking the necessary knowledge and infrastructure for preservation and value-adding of their produce.

Furthermore, the majority of African farmers are old, women and often rely on their young children at school age to support them on the farm. In many parts of Africa, field operations (from planting to weeding and harvest) for cultivation of cereals and grains (such as sorghum, millet, maize, beans) and root and tuber crops (such as cassava and yam) are still carried out with the same small hand-hoe used over millennia by our forebears, which requires the farmer to bend about 45 degrees during cultivation. No wonder widespread acute waist pain and hip and knee related injuries and diseases such as arthritis are some of the most common debilitating diseases affecting many women in these rural areas such as Imerienwe, Imo State, Nigeria. For these rural farmers, food is grown primarily for household consumption, with some parts or surplus harvest sold to purchase other food items or to pay of other household

expenses such as education, healthcare and community projects. Few livestock may be kept as insurance for unexpected major expenses or special occasions, and rarely killed for household consumption. Major consequences of this form of agriculture and livelihood include low yield and low productivity of labour and inputs, contributing to widespread poverty due to lack of income to meet the needs of food and nutrition security, access to good quality education and healthcare, etc. The lack of non-farm employment opportunities in the rural areas makes it unlikely for people living in those areas to earn additional income. For the children of such rural poor families, one prevalent option is to migrate to the sprawling urban townships and cities, where the lack of relevant skills and expertise either make them unemployable or condemn them to very low paying manual and often season labour. And hence, the cycle of poverty and deprivation continues within and across generations due to very limited economic opportunities for both the family and their children.

Assisting these rural families and their rural communities to change their own lives and those of future generations so that they are able to help themselves to gradually but steadily slide out of the poverty trap and vicious cycle of food and nutrition insecurity requires radical new ways of practicing agriculture which has been their main source of livelihood. With increasing globalization of world food system, where the prediction of low grain harvests in one season (e.g. due to drought in producing areas in the USA in 2012) can spark food price spikes in faraway places as in countries in sub-Saharan Africa, it is now clear that the destiny of the African smallholder farmer no longer resides entirely on the economic decisions and rural choices they make. The impacts of the 2007-2008 food price volatility and rise in food insecurity incidence around the globe is another example. Combined with the perfect storm of climate change, declining energy and fresh water resources, and rising human population, the vulnerability of the African rural smallholder farmer to these global economic and financial shocks has come to the fore. Smallholder agriculture, therefore, requires both structural and technological transformations to improve productivity of both labour and inputs, as well enhance the resilience and adaptive capacity of the farmer.

Success of the new African agriculture requires the development and deployment of disruptive and game-changing technologies for both on-farm, postharvest handling and processing operations, just like mobile telephony has forever positively transformed information and communication (and lives of people) in both urban and rural Africa. It requires a value chain approach to agriculture development that integrates farming families into the wider economy through trade for their value-added products and services. It also requires a closer look at the resource base of farmers such as access to fertile land in quantities that enables them to produce higher

outputs and also promote value-addition to meet market demands. Furthermore, farmers need access to new technological tools to enable them mechanize smallholder operations, manage those biotic and abiotic stresses, and manage weather and climatic variability which reduce productivity of their inputs and labour. Transformation of African agriculture must be driven by advances in science, engineering and technology. Not merely 'appropriate' or 'small' technology that is developed elsewhere for 'African conditions'; but rather based on country-led innovation systems across the value chain, from world-class education and research institutions developing the best human resources finding cost-effective and resource-efficient solutions for the agriculture and food industries, to extension and technology transfer agencies serving the real needs of all actors from farm to plate, and to future thought leaders and entrepreneurs creating jobs and new industries.

When harvest is good, technological innovations in postharvest handling and food science and technology are necessary to meet market standards as well as transform raw agricultural products into novel and highly sought-after quality and nutritious products. The practice of this new agriculture based on value chain approach of linking farmers to markets is knowledge intensive. It cannot be sustained on existing knowledge alone, but rather requires continuous and targeted investments in education, research and development, and extension services to promote and facilitate development of new knowledge, adaptation and refinement of existing knowledge, and adoption and dissemination of new and improved technologies in agricultural science and engineering, food science and technology. Multi- and trans-disciplinary approaches are also needed to continuously and systematically assess the cost-benefits and impacts of existing and new technologies to guide policy and investment decisions.

The principles of value chain approach to agricultural development also apply to the development of the knowledge base needed to support education and research in agriculture and food science and technology. The entire education system, from primary to tertiary, needs to be properly aligned to address both the human capacity and technology needs of a vibrant African agriculture and food system. Just as industry and the public sector need well educated and trained employees in various aspects of agricultural science, agricultural engineering, food science and technology, and nutrition, we also need well trained and motivated teachers who can inspire the next generation of agri-food business entrepreneurs, educators, policy makers and politicians. We need well trained people at all levels of the technical cadre – engineers, technologists, technicians and artisans. Any missing link in this value chain will weaken and may even threaten our ability to succeed. While continental and regional frameworks and directives such as the Common African Agricultural Development

Plan (CAADP) are needed to create the necessary platforms and shared development agenda, success in transforming African agriculture will depend largely on country-led initiatives and programmes which are adequately financed and backed up with the necessary policies and legislation. States and local governments within a country can also adopt such strategies and approach to transform agriculture in their local economies.

We have read and witnessed examples of agricultural development agenda and strategies for Africa formulated elsewhere in Paris, New York, London, etc, and supported with financial aid and other forms of development assistance. We have also seen and learned about the shift towards in-country agricultural development activities involving short and long term training, crop and livestock production, mechanization services, extension services, etc, led and supported by well meaning donors, development practitioners and volunteers. Africa will always be grateful to its friends and partners who share and support its aspirations for a peaceful, just, prosperous and developed continent. However, both Africa and its development partners and friends should also agree and unequivocally state and promote the idea that these aspirations can only be achieved by country-led (designed and implemented) programmes. Nowhere else in the economic transformation agenda is this agreement and action most urgent and critical than the transformation of African agriculture and food system through innovations in science, engineering and technology. No continent or country has achieved progress in transforming its agriculture (and thereby sparking the economy-wide industrialization that followed) through other means. The success and sustainability of Africa's ongoing economic transformation requires a cadre of well educated and trained human resources in agribusiness and other economic sectors. Even when foreign direct investment opportunities beckon, it is vital that well qualified local human resources are available to participate as partners and employees.

Lessons from both developed and developing economies

Economic historians have widely described how Western Europe and allies in North America and Australasia have successfully transformed their rural agricultural economies after the World Wars to become fully industrialized nations that are able to meet the food and nutrition security needs of their people. Many people in Germany and Japan who grew up during WW II still tell remarkable stories about their experiences about lining up for food rations and scouring and scavenging harvested fields for grain and potato harvest losses. In a short time, through deliberate and targeted government policies and actions supporting agriculture and their rural economies, these countries became major food producers, assuring food and nutrition security for their people and exporting surpluses. More recently, countries like Brazil,

Argentina, China, India, South Korea, and Singapore have experienced astonishing economic transformations and improvements in the welfare of their people, starting with agricultural industrialization (including smallholder agriculture), which then catalyzed economy-wide industrialization that now characterizes these countries.

When the success of Malaysia as emerging and industrializing economy is discussed, many leaders and observers from Nigeria and Ghana are quick to point to the fact the seedlings used to sow the thriving palm oil industry in Malaysia were delivered from their respective countries. Today, oil palm tree cultivation and processing in Malaysia is a mechanized and sophisticated industry, providing sustainable employment and generating millions in revenue in trade, while the majority of the plantations in West African countries have become shadows of their glorious past. India is now the world's largest producer of milk based on outputs from smallholder families, often owning about two cows. Through a government assisted programme involving millions of families and thousands of cooperatives, milk is delivered to nearby collection centers from where they are transported to industrial dairy processing plants that are mostly designed, installed and operated by local engineers and scientists. As a result of this market-led 'White Revolution', most rural families in India now make their own yoghurt and other home-made dairy products while earning income from fresh raw milk sales, thereby contributing to reducing poverty and enhancing food and nutrition security in India. The success of the Indian dairy industry in both local and international markets shows that with the right policies, technical support and financial investment that link production to markets, it is possible to transform smallholder agriculture into profitable agribusinesses.

With regard to the success of its Green Revolution, the pivotal roles of the land-grant universities and the Indian Council for Agricultural Research (ICAR) through sustained and impactful research, education and extension services across the country are widely acclaimed. During the recent International Agricultural Engineering held in Valencia, Spain, the distinguished agricultural engineer, educator and researcher and former President of the Indian Society of Agricultural Engineers (ISAE), Professor Gajendra Singh, talked about the important role played by ISAE in articulating the necessary policy framework and persuading the Indian government to set up agricultural machinery testing stations in agricultural engineering departments in the universities. In addition to the success of India in mechanizing its agriculture through irrigation and use of mechanical power and implements, India is now a major global producer and exporter of tractors and other agricultural machinery.

The recent success of Brazil in transforming its agriculture and food industry as the engine for economic growth and development is also worth mention. Like many

countries in Africa and the continent at large, Brazil has one of the largest areas of agricultural land, accounting for 31% of the total land area of 851 million ha. And this is where the comparison stops. While the abundance of idle and fertile land in sub-Saharan Africa has recently attracted the rush by many foreign countries and investors to acquire large areas of land for food production following the aftermath of the recent global food crises and price volatility, Brazil has invested steadily over the past 40 years in rural infrastructure development and human resources in all aspects of the agri-food value chain, ranging from agricultural engineering to food science and technology and agribusiness. Agriculture now accounts for 28% of Brazilian GDP, 37% of employment and 42% of total export. Brazil has become a major global player in the agri-food and bio-energy industries, with overall yields and cultivated area increasing by 180% and 30%, respectively, resulting in estimated saving of over 60 million ha. Today, Brazil is the world's largest exporter of orange juice. Similarly, with more than 50% of its energy coming from renewable resources, including bio-energy, Brazil expects to become a major environmental power. While the rest of the world now debates the pros and cons of bio-fuel production from agricultural land, Brazilians have long become accustomed to the choice of having both bio-fuel from energy crops and fuel from petroleum at their fuel stations. Today, the mechanization of agriculture and large-scale production in Brazil has enabled simultaneous harvesting and planting of alternate crops on the same field, thereby, raising productivity and output of major food and energy crops.

Recent accounts by EMBRAPA (the R&D arm of the Ministry of Agriculture) on the evolution of Brazilian agriculture showed that during the period 1975-2010, the production of grains and oilseeds increased by 228%, with increases of 31% in cultivated area and 151% in productivity (kg/ha). A close look at the Brazilian horticultural sector provides further snap shot of this remarkable transformation of the Brazilian agri-food sector (Table 1), which shows that with annual vegetable production of over 19.3 million tonnes, this sector provided about 7.3 million jobs, and makes available about 102 kg of produce per inhabitant per annum. The importance of this remarkable progress in improving food and nutrition security is underscored by recent studies reported by Dr. Dyno Keating and his colleagues at the World Vegetable Centre demonstrating the strong correlation between increasing availability of vegetables per person per day and lower mortality rate and proportion of underweight children below the age of five that are, respectively.

Table 1: Contribution of vegetable crops to Brazilian economy (Source: EMBRAPA)

Revenue	US\$ 10 billion
% GDP – Agriculture	13.4%
Total production	19.3 million tonnes
Total area	800,000 ha
Average yield	24 tonnes/ha
Employment	7.3 million jobs (9/ha)
Availability	102 kg/inhabitant/yr

A striking and noteworthy feature of the Green Revolutions of both India and Brazil is the pivotal role of science, engineering and technology (SET). The story of Brazil sending thousands of postgraduate students to study in the USA and other developed countries in the 1970s, many of whom are now thought leaders in government and the private sector and senior researchers in EMBRAPA and universities is widely talked about among the scientific community. It is also worthy to note that EMBRAPA was set up by the government in 1973 under tough economic conditions and widespread poverty in Brazil. Today, it has 9,589 personnel, 2,355 researchers, 2,144 PhDs, annual budget of R\$1.7 billion, and operates in 47 research and service centres across urban and rural parts of Brazil, providing innovative SET services that link farmers to markets and supporting the rapid industrialization of the agricultural and food processing industries. Together, the preceding experiences of country-led and science-driven agricultural transformation of India and Brazil demonstrate that with the right mix of strong and sustained political leadership, supportive policies and favorable investment, African countries can make their own Green Revolution for food and nutrition security a reality. The two case studies and indeed experiences in successful agriculture in developed countries also show that agricultural transformation towards improved productivity, outputs and efficiency must run parallel with the development of postharvest handling and food processing industries to preserve and convert the harvested plant and animal raw materials into a wide range of high quality, safe and nutritious products that are delightful and sought after in both local, regional and international markets. The role of agricultural engineers, postharvest technologists and food scientists in achieving this goal cannot be over-emphasized.

Note also the age-long focus on SSF/SHF and somewhat repulse of industrial agriculture, while we now watch multi-national food businesses and countries from both developed and developing regions of the world acquire millions of hectares of fertile agricultural land (and associated resources such as fresh ground water and trees) to grow food crops, for food and industrial raw materials.

Epilogue - Agricultural transformation and food industrialization go hand-in-hand

Industrial agriculture was once mainly associated with developed countries (large-scale commercial farmers) and considered too ‘disruptive’ for the rural economies of Africa, Asia and Latin America. Many economists had argued that the mechanization of small-scale agriculture and food processing, particularly in rural areas, was not appropriate due to the lack of economies of scale and the potential to displace many people into unemployment. Consequently, many governments in Africa and Asia failed to provide the necessary support and incentives to support smallholder agriculture and related businesses while at the same time providing loans, production inputs and other support services to medium and large-scale farmers and other businesses. We have known all along that this long held view about smallholder agriculture is not and cannot be true, and more recently, we have watched and seen countries in Asia and Latin America transform their rural economies based on agriculture into industrial enterprises as the engine for broad-based economic development. We have seen smallholder dairy farmers in India and rice farmers in Vietnam become major suppliers of food that feeds their countries and the world at large. We now talk about the successful Green Revolution that has occurred in both Asia and Latin America during the past 40 years, which laid the foundation and sparked the rapid industrialization of these regions. The jury is still about on why this Green Revolution has eluded Africa. As I see it, this Green Revolution did not elude Africa because it was ‘Asian Green Revolution, and neither did the Green Revolution that unleashed industrial agriculture in Europe and North America evade Africa. Rather, African countries and the continent at large must be brave to define and lead their own Green Revolution, just like others have done.

The current state of agriculture in most parts of Africa as a sleeping giant – full of potential but inactive in the face of numerous challenges facing it – remains the major stumbling block to our economic development. How could we successfully eradicate poverty when the majority of our people are engaged in an economic activity (subsistent or smallholder farming) that cannot guarantee them access to sufficient (a) quantities of nutritious and safe food at all times, and (b) income to meet their welfare needs? While we talk and debate about what to do and how to transform our

agriculture and food system into engines of economic prosperity, the world has moved on, leaving us with a broken agricultural system not fit to meet the food and nutrition needs of the current and future generations. Many governments and global food chains are now acquiring fertile land that we have refused to mechanize over the years across sub-Saharan Africa for their commercial food and fibre production. In the meantime, global supermarkets are expanding rapidly into African cities, stocking largely imported processed food products and other materials. Consequently, the food system and diets of people across the continent are changing rapidly, and many consumers now buy their food from these new sources. Many countries, like Nigeria, which depended largely on locally produced roots and tuber crops (such as cassava and yam) and cereal grains (such as sorghum, millet and maize) now spend billions of their currency importing rice, wheat and other food products which have benefited from long-term investments in R&D. As a result, many African countries now consider these imported foods as top in their list of basic staples, and generating new interest to cultivate them locally, at near expense of the traditional staples. The transformation and industrialization of African agriculture will be incomplete if we do not industrialize the food system through scientific and technological innovations in postharvest handling and food processing to reduce losses and add value. It is often said that one can import a mechanical device, but it is not possible to import all the human resources needed to operate and manage it sustainably. Africa must grow its own timber of human talent and thought leaders to lead the continent in this ever complex and increasingly science-driven global economy. Investing in agricultural education and research, building the necessary infrastructure and implementing the right policies to support farmers and private sector investors are critical to ensure success of the ongoing agricultural transformation agenda. Finding ways and means to addressing our socio-economic challenges will enable us contribute better to the broader global development agenda. Nothing short of these will guarantee our long-term success and competitiveness.

Biographical Note

Professor Umezuruike Linus Opara is an agricultural and postharvest engineer, and holds the positions of research professor and the South African Research Chair in Postharvest Technology at Stellenbosch University, South Africa. He is a chartered engineer (UK) and graduated with degrees in agricultural engineering from the University of Nigeria, Nsukka (BEng Hons, First Class; MEng) and Massey University, Palmerston North, New Zealand (PhD). He has held academic and management positions at Massey University, where he was the Director of Engineering and Technology programmes and Senior Lecturer in Postharvest Engineering, and served on the University Governing Council among other

responsibilities. At Sultan Qaboos University in Oman, he held the positions of Assistant Dean for Postgraduate Studies & Research, Director of the Agricultural Experiment Station, member of the University Academic Council and Quality Audit Committee, and is a certified auditor of the Oman Accreditation Council. He was a Visiting Expert on Postharvest Technology at the Food and Agriculture Organization of the United Nations, served under the United Nations Oil-for-Food Programme in Iraq, and was member of the technical experts who drafted a strategic plan for agricultural development in Timor-Leste. He was a lead co-author of the Agricultural Mechanization Study component of the 1989-2004 Agricultural Development Plan of Nigeria.

Professor is a member of several international scientific bodies including life memberships of the American Society of Agricultural & Biological Engineers, Asian Association of Agricultural Engineers, and Indian Society of Agricultural Engineers. He is the Chair of Section VI (Bioprocesses, dealing with postharvest technology and agro-processing) of the International Commission of Agricultural and Biosystems Engineering. He has designed and implemented postharvest training programmes for international development agencies in several countries in Africa, South Pacific, Asia and the Middle East. Professor Opara is actively promoting human capacity development in postharvest technology and food engineering research and education as critical input for sustainable development of agriculture and food industries in Africa.