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Guest Editorial

ENHANCING AGRICULTURAL RESILIENCE IN AFRICA THROUGH TECHNOLOGICAL INNOVATIONS AND POLICY CHANGE

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INTRODUCTION

Sub-Saharan Africa (SSA) region accounts for more than 13% of the global population (or 1.2 billion people), a figure that is projected to grow to 2.1 billion people by 2050. This will have direct implications on demand for food from agriculture, a sector that supports the livelihoods of over 70% of the population and contributes to over 25% of the GDPs in a majority of the countries in the continent. Despite its huge agricultural potential considering the fact that the continent has most of the world's arable land, food production in Africa still lags behind demand. Toward this end, some important trends on the continent are worth re-highlighting. *First*, agricultural productivity has largely stagnated since the 1980s, with the yields of staple cereals currently averaging at 1.5 t/ha, the lowest in the world, leading to food insecurity and undernourishment. Unlike most continents of the world, African agriculture is predominantly rain-fed with less than 10% of arable land under irrigated production. *Second*, agricultural value addition is generally low with unprocessed commodities accounting for a large percentage of Africa's agricultural exports. *Third,* the absolute number of undernourished people currently stands at 240 million and is projected to increase to 320 million by 2025. *Fourth,* increased food demand and changing consumption habits driven by demographic factors, amid low production, has resulted in rising expenditure on food imports, which was projected to grow from US$35bn in 2015 to over US$110 bn by 2025. All these trends point to aggravated levels of vulnerability of farmers and their livelihoods, which is highly dependent on the agricultural sector. Reversing these trends requires concerted efforts to orient the continent's agricultural sector towards a trajectory of faster transformation that will make African farmers and their support systems resilient.

Against this backdrop, this paper provides an insightful look at constraints hampering agricultural productivity in Africa, while going to great lengths to articulate remedial technological interventions to underwrite agricultural transformation in Africa. This paper also evaluates policy considerations that African governments need to explore to usher in necessary political, regulatory and institutional reforms essential for unlocking Africa's agricultural potential.

CONSTRAINTS TO AGRICULTURAL PRODUCTIVITY

The dismal performance of African agriculture described above is attributable to challenges under two broad categories. On one hand are biological (biotic) stresses while on the other hand are non-biological (abiotic) stresses that work in unison to limit crop and livestock production. In addition, policy, regulatory, institutional arrangements further constrain access to productivity-enhancing technologies and markets.

Field and storage insect-pests and diseases are notably the most serious biotic stresses threatening crop productivity in Africa. Specifically, different types of stemborer (mainly *Busseola fusca; Chilo partellus* & *Sesamia calamistis*), the Fall Armyworm (*Spodoptera frugiperda*), the Large Grain borer (*Prostepanus truncatus*), and Tomato leafminer (*Tuta Absoluta*) lead in the list of pests of economic importance that threaten crop yields. Bacterial and viral diseases have also been a threat to crop production in the continent. Coincidentally, water-stressed and less vigorous crops suffer more when subjected to pest infestations, making the situation more complex. Thus, drought and insect-pest damage have often led to complete crop failure under severe cases, further compounding the food insecurity and hunger situation in Africa and, therefore, decreasing farmers' resilience. Building resilience for smallholder farmers through the adoption of climate change technologies/specific management practices/water conservation at the field, farm and landscape scales is crucial to building resilience for smallholder farmers to create more sustainable food supply chains [8].

The advent of climate change in recent times, often largely characterized by an increase in average global temperature, is aggravating abiotic stresses such as frequent drought and heat events, and biotic challenges including the outbreak of new pest biotypes that further constrict Africa's productivity and food security. Climate change imposes stress conditions on agricultural production through hydrological processes that impose physiological disorders to crops from water deficits, poor precipitation distribution, and extreme temperature changes, leading to crop losses as well as increased pest and disease dynamics [4]. It is estimated that yields from rain-fed agriculture are projected to fall by as much as 50% across sub-Saharan Africa (SSA) by 2030 due to climate change effects. According to the Weather Index-based Risk Services program (WINnERs programme), the yields of wheat, maize, sorghum, and millet across Africa are currently estimated to have dropped by 8% as a result of drought-related stress. Another important abiotic constraint to productivity is low fertility of African soils [7, 9]. Despite this, the use of fertilizers by smallholder farmers in Africa is still very low, which limits productivity [5].

In addition, African agriculture is also faced with policy and regulatory challenges that limit access to new technologies and markets. For instance, long bureaucratic procedures lead to slow formulation and implementation of agricultural input policies. Particularly, the public sector has a limited capacity for input quality control, border surveillance, and enforcement of phytosanitary and quality standards, leading to the proliferation of counterfeit inputs in the market. This, coupled with long processes and high cost of seed certification and variety release, testing and registration of pest control products, limit access to new products among farmers. Secondly, the agricultural sector often faces unfavorable macroeconomic policies such as high import duties on farm inputs including farm machinery and implements, non-tariff barriers limiting cross border movement of agro-inputs and commodities, high-interest rates on agricultural credit, exchange rate policies that disadvantage agriculture, and high duty on agro-processing equipment. Third, there are high incidences of input and output market failures and other imperfections as a result of high transaction costs and market inefficiencies. This limits the gains from agricultural commercialization and increases the cost of doing business in agriculture, hence eroding the gains from the adoption of improved agricultural technology. Finally, public opinion on innovative applications such as genetic modification (GM) technology in many parts of the world is still steeped in controversy. As a result, public policy on GM technology in many African states is laced with precautionary overtones. In these circumstances, regulatory regimes have emerged that implicitly assume that all genetically modified organisms (GMOs) present high risks unless proven otherwise, an approach which often requires inordinate amounts of information and data to be included in the safety dossier for regulatory clearance. Clearly, setting regulatory safety standards on such an impossibly high oversight pedestal is a sure way of keeping GM crops from these countries, thereby depriving their farmers of the benefits of such technologies.

Creating an enabling policy and regulatory environment is critical in facilitating the transfer of technologies that have the potential to deal with farmers' vulnerabilities and help to build the resilience of production and marketing systems. It is, therefore, imperative that policymakers deal with these challenges to reduce farmers' vulnerabilities associated with biotic, abiotic, and policy-related challenges so that farming systems can be resilient.

POTENTIAL TECHNOLOGICAL AND INNOVATIVE SOLUTIONS

The need to build farmers' resilience, create more wealth, and improve livelihoods for the majority of Africans in the agricultural sector makes it imperative to explore technologies that drive agricultural value chains in a responsive and transformational trajectory. Achieving long-term sustainability to our production processes equally means that Africa must explore practices that support sustainable use of natural resources. Several technological applications have evolved that hold promise for addressing food production and malnutrition challenges that are prevalent in Africa [2, 3, 11). For instance, genetic and non-genetic technologies are strategically required for the development of innovative products that will radically shift the calculus of food production on the continent. These technologies include those targeting seed systems (quality seed production), resource use efficiency (nutrients, water, and efficient application), biotic stress (pests/diseases), abiotic stress (droughts, flooding, gas emissions, soil/land management), and post-harvest challenges (storage and processing).

Conventional and genetic advances, especially, through breeding and biotechnology have rapidly evolved to address a series of these challenges especially the biological (biotic) stresses and those related to climate change. These technologies have contributed to better crop adaptation, high yield, and efficient use of resources with increased utilization of marginal lands for agricultural activities globally including Africa. Through conventional breeding, it has been possible to introduce drought tolerance and other important traits in farmer-preferred varieties, helping to boost yields and reduce crop losses. A case in point is the Water Efficient Maize for Africa (WEMA) maize project championed by AATF in collaboration with national agricultural research systems (NARS) of seven African countries, CIMMYT, and Bayer Crop Science that has so far delivered over 120 climate-smart maize hybrids for deployment in 8 years.

Besides, GM technology has successfully been applied to develop a variety of crops with desirable attributes such as Water Use efficient Maize, insect-resistant (IR) cowpea, maize and cotton, and herbicide-tolerant (HT) soybean and cotton. Besides enhancing the capacity of crops to withstand harsh environments and increase yields, these technologies have also helped to reduce mechanical and hand weeding as well as reduced chemical sprays, hence benefiting the environment. Thus, these technologies have great potential to transform farmers' livelihoods and reduce their vulnerability to the shocks highlighted earlier. For example, the GM cowpea varieties released by AATF in Nigeria in 2019 have the potential for increasing cowpea productivity by over 300%.

Genetic modification and genome editing technologies can also help to improve the marketability of agricultural products and boost commercialization by introducing consumer-preferred attributes. For example, GM technology has raised the solid content of tomatoes having good size and toughness to withstand mechanical harvesting. This technology directly helps to address post-harvest losses, a challenge that reduces farmers' income from highly perishable products substantially. Genetic modification technology has also been demonstrated to hold potential for addressing post-harvest insect-related losses such as transgenic avizin maize against diverse storage pests including *S. zeamais* and *Sitotroga cerealella* [6].

Modern technological advances have also provided substantial contribution in the area of human nutrition, to address malnutrition and other nutrition-related health issues such as wasting and stunting. Plant breeding and molecular tools have been used to accelerate the development of nutrition enriched products such as pro-Vitamin A crops: yellow cassava, orange-fleshed sweet potato, orange maize, iron-rich beans and others. Such technologies offer rapid and strong hope in reducing health-associated risks facing poor households in Africa. These traits command high commercial value and good demand to sufficiently incentivize adoption and production of nutrient-rich products globally (including Africa). Nutrition-sensitive agriculture offers strong opportunities to enhance nutritional outcomes and improve household economic status [1]. As with crops, genetics have equally boosted productivity and improved nutrition in the livestock sector by enhancing both dairy and meat production leading to increased protein intake. The integration of artificial insemination and selective cross-breeding tools in farm animals has been a major factor for increasing the rate of livestock improvement.

The impact of genetics-based technologies on crop and livestock yield can further be boosted if used in conjunction with complementary technologies such as digital tools and irrigation technologies. The application of digital technologies is helping to improve precision in agricultural operations, bring accuracy to predictions on inputs, outputs, and profit margins. Precision agriculture using unmanned aerial vehicles (UAVs) such as drones has emerged as a strong area in digital agriculture that has huge potential to address some of the farm management challenges of African farmers. Precision Agriculture (PA) is useful in monitoring the physical and chemical parameters of vegetation as a management function to ensuring that the optimal conditions for plant growth are achieved. Multispectral cameras used on the UAVs allow farmers to identify crop health, perform risk mitigation, and even monitor soil health. The application of efficiently computed specific quantities of required farm input resources like fertilizers, insecticides, herbicides, water to plants and, the reduction in farm labor activities is a key area where the technology has been effective. The concept of digital technology has also expanded beyond production to supporting marketing in commercial agriculture involving several applications that support vital information on crop prices, market and value-chain solutions among others. African agriculture also stands to benefit from increased investment in and use of irrigation given the increasing incidences of drought on the continent.

Arguably, there is no single technology or practice that independently offers a *panacea* to all the challenges in African Agriculture. The array of technologies identified above need to be combined into a Climate-Smart Agriculture (CSA) technology package that aims to significantly increase agricultural productivity and incomes in environmentally and socially sustainable ways to help build farmers' resilience to climate change while mitigating its effects. This, however, needs to be supported by a conducive policy and regulatory environment as highlighted in the next section.

POLICY CONSIDERATIONS

Agriculture has been and will continue to be the foundation for economic transformation in Africa, just like it was in Europe, North America, South America, and Asia. The process has to be accompanied by not only technological change but also through strong government involvement and leadership. Governments have a duty of care to ensure that vulnerable rural populations have access to technologies that can catalyze adequate food production. If smallholder farmers in Africa were to have easy access to the tools and products highlighted in the foregoing section, their livelihoods would be improved. Policy must focus on the agricultural transformation agenda of Africa to accelerate the adoption and use of productivity-enhancing technology as well as creating an environment within which agricultural markets and trade will thrive.

Since 2003, the commitment of African leaders to the realization of the Comprehensive Africa Agriculture Development Programme (CAADP) goals has been unequivocal. This commitment was reaffirmed in 2014 with the adoption of the Malabo Declaration on Accelerated African Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods. The resolve of African leaders to promote programs that will generate a critical mass of technological expertise in targeted areas such as harnessing biotechnology for improved agricultural productivity must be sustained. The need for investment in the sector is dire, due to the need for substantial investment in research and development as well as critical infrastructure. Embracing regional approaches to tackle issues affecting the continent is key, considering that protectionist approaches to trade and technology development and deployment have done more harm than good to the sector. Inter-continental trade is, for instance, very low owing to tariff and non-tariff barriers across nations as well as poor connectivity across the continent due to the poor road, rail, and air travel connections.

Policy needs to focus on accelerating the process of variety release and registration to ensure farmers can access new technologies within a reasonably short time after their development. Embracing new partnership mechanisms, such as public-private partnerships (PPPs) can help in this area. One approach that has demonstrated success is the training and engagement of private seed inspectors to enhance quality control in seed production. Domestication and implementation of regionally harmonized regulations and guidelines can also help to accelerate the deployment of technologies across regions sharing similar agro-ecological zones even when they fall under different geographical boundaries. Very few countries on the continent have embraced mutual acceptance of products traded under the regionally harmonized frameworks.

Policy also needs to focus on easing access to innovative products of Genetic Modification and Genome editing. There is a need for pursuing a policy approach that will engender responsible regulation of innovative products balanced around optimizing benefits from such products, while ensuring sufficient safeguards to public and environmental health. Although the application of biotechnology and especially the use of GM technology is hailed as a major success in many parts of the world, there are still persistent concerns about the safety and trade-related aspects of GM products to consumers and the environment, necessitating the need for their regulation. In formulating a national regulatory policy for GM technology and GM food, countries often take into consideration both the opportunities presented by the GM crops and the potential risks associated with them. In Africa, there are 55 nation states with diverse political persuasions, trade considerations, and environmental interests. As such, Africa is characterized by a mosaic of national policy positions on GM technology, ranging from those which can be considered to be permissive to those which are more pre-cautionary and ultimately to those which are prohibitive to the adoption of GM crops [10]. For instance, inspired by the potential benefits of modern biotechnology in improving agricultural productivity, South Africa took the lead among African countries and has adopted a permissive policy approach to GM crops that resulted in the commercialization of its first biotech crop in 1998. Through this policy approach, South Africa is one of the four African countries that have commercialized the cultivation of GM crops. Taking a cue from South Africa and encouraged by the prospect of revitalizing its cotton sector to make it globally competitive, Burkina Faso followed suit and encouraged commercial production of GM cotton, known as Bt cotton. Several other African countries exercise a precautionary approach to the regulation of GM technology. These comprise countries such as Kenya, Nigeria, Uganda, Ghana, and Malawi, which have permitted field trials of GM crops *albeit* in a highly cautious manner. While these countries believe that this approach fairly addresses the risk considerations associated with GM technology, undue precaution in regulating GM crops has in some instances turned out to be the Achille's heel that has hampered the progress of biotech adoption.

It must be emphasized that Africa is a continent where population growth far outstrips food production capacity amid the Biotic and Abiotic stresses discussed earlier and cannot, therefore, afford to miss out on the promise of modern biotechnology and other innovations. Whereas the science of biotechnology is neither a full panacea for agricultural ills nor a guarantor of successful sustainable agricultural practices, its application alongside other sciences, and given a favorable public policy environment, holds enormous promise and potential for Africa.

CONCLUSIONS

Technologies have to be increasingly made available to farmers to address dynamic environmental challenges, to keep pace with food and nutrition security needs. For agriculture to be changed from a slowly growing to a progressive sector (making a major successful contribution to the African economy), radical transformation will be needed. Based on the mitigations discussed in this article, Africa would have to efficiently harness promising technological options, appropriate policies, and functional institutional frameworks to effectively manage climate change and adopt good agronomic practices to support applied technologies for increased productivity. Considering that women, alongside youth, make a strong composition of farmers in Africa, there is also a need to get gender-sensitive technologies to address these groups. Combining multifarious agricultural technologies (such as water-efficient varieties, increased shelf-life in crops, nutritionally enhanced varieties, and precision agricultural practices) with appropriate policies (that are relevant for creating an enabling environment) are crucial to driving increased crop productivity leading to improved food security in SSA.

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