Development, **2013**, **56**(2), (266–273)

www.sidint.net/development/

The Role of Technology in Ensuring Adequate Food Security in Africa*

NICHOLAS OZOR AND KEVIN URAMA

ABSTRACT *Diverse technologies exist in Africa that could ensure adequate food security (when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life) in the continent. These technologies range from mechanical technology to biological and biochemical technology, biotechnology and nanotechnology as well as indigenous technology options. The article examines the potentials and opportunities offered by these technologies in addressing the persisting food security challenges in the continent.*

KEYWORDS *role; technology; food security; agriculture; Africa*

Introduction

Africa's underdeveloped agricultural sector remains a major challenge to food security. The sector is characterized by over-reliance on primary agriculture, low fertility soils, minimal use of external farm inputs, environmental degradation, significant food crop loss both pre- and post-harvest, minimal value addition and product differentiation, and inadequate food storage and preservation that result in significant commodity price fluctuation. These challenges mainly bother on poorly developed and non-adoption of good mixes of technology ranging from high-technology, medium-technology, low-technology and indigenous technology systems by small-scale farmers who form the bulk of the farming population in Africa.

A brief analysis of some of the technological challenges to food security in Africa provides the impetus for urgent action by concerned stakeholders in the continent. For example, cereal production in most African countries like other crops is carried out without adequate irrigation. Only 7 percent of African agricultural practices are using reliable water supply. In Nigeria alone, only 0.8 percent of arable land is under irrigation compared to the 28 percent in Thailand (Uguru, 2012). The use of improved crop varieties and agro-chemicals such as fertilizer is not yet adequate in Africa. The average application of fertilizers in SSA is less than 10 kg/ha, while the average application in Latin America and South Asia is nearly 140 kg/ha (Baker, 2012). As a consequence, even high-yielding crop varieties lead only to limited productivity. The adoption of modern technologies such as biotechnology is not common either. With the exception of South Africa most countries in SSA are yet to embrace the biotechnology while a few others such as Nigeria, Ghana, Burkina Faso, Tunisia, Kenya, Uganda, are at the different stages of confined field trials (CFT) to commercialization of different crops such as cotton, maize, cowpea and cassava among others. With 10 tractors per 100 hectares in most African countries compared to 241 tractors per 100 hectares in Indonesia and with one extension agent to 25,000 farmers in most African countries compared to 1: 400 in Europe (Uguru, 2012), Africa still has a long way to go in securing adequate food for its teeming population. This will not only affect food security but will hamper the spread and adoption of various technologies with the potential to reduce hunger and starvation in the continent.

Studies further show that post-harvest losses of cereals in developing countries including countries in Africa are between 10 and 20 percent, with even higher losses (up to 100 percent) for fruit and vegetables (UNCTAD, 2010). These sizeable losses could offset any significant investment made in raising productivity. Crop losses could be reduced and the world food supply increased by between 10 and 30 percent through the application of readily available technologies and input management using minimal additional resources. Developing post-harvest technologies and innovation therefore provides considerable opportunities for food security, trade and economic growth. Technologies among other factors have also been linked to developments (Harcourt, 2012).

The article therefore examines the potentials and opportunities offered by different types of technologies and its mixes in ensuring that Africa meets its food security needs. It utilized relevant and current case examples in discussing these potentials and opportunities.

The role of technology in ensuring adequate food security in Africa

Technology is the application of scientific knowledge for the creation of a novel object, process or technique (Ozor, 2012). Technology advancement in this era and subsequent adoption of innovative tools has the potential to pave way for better crop productivity and higher quality food at lower cost (Adenle *et al.*, 2012). Various technologies have been adopted to increase yield and to reduce poverty and enhance environmental conservation. The article distinguishes between four broad types of agricultural technologies suitable for achieving food security in Africa namely: mechanical technology, biological and biochemical technology, biotechnology and nanotechnology, and indigenous technology.

Mechanical technology

This encompasses various degrees of mechanization of agricultural operations and ranging from simple traditional hand tools to animal and engine-powered equipment, post-harvest technologies and irrigation systems. Mechanization strives to reduce drudgery in agriculture and increase production as a result of increased productivity per unit area.

Tractorization and draught animal power (DAP)

Reports show that mechanization reduced drudgery in Mali as the number of tractors and power tillers increased significantly and this led to increased food production because many youths went into agriculture and this was seen mostly in cereal production (Fonteh, 2010). Similarly, mechanization was reported to raise productivity in Ghana from a low US$308/capita in 1997 to a high productivity of US$379 in 2004. Mechanization under DAP programme in Africa generally increased the area under cultivation and the yield as well. In Mali, use of DAP increased the area under cotton cultivation nearly four-folds, raised yields six times over and animal traction adoption rates jumped to 80 percent between 1968 and 1986 (Sims *et al.*, 2007). Nigerian farmers using DAP derived supplementary income by renting them out to other farmers (Haque *et al.*, 2000). Similarly, in Kenya the use of DAP brought about higher yields and greater economic efficiency, including less weeding (Ghutiga *et al.*, 2007). The use of DAP for inter-row weeding in the United Republic of Tanzania reduced the time spent on weeding from 48 h/ha to 30 h/ha (Sosevile, 2000). It is however important to assess the advantages of moving up the technology ladder in terms of productivity gains and timeliness of cultivation, employment for the landless poor and increased cropping intensity.

Irrigation technology

Investments in irrigation and better management of existing systems have increased crop yields, created jobs and raised rural economic growth in Africa. Irrigated lands now account for about 20 percent of the world's farmed area and 40 percent of global food production. Increases in irrigated areas, cropping intensity and crop yields have helped stabilize food production per capita (UNCTAD, 2010). Over the past 30 years, there are developments on innovative irrigation techniques. Many of the new techniques have been designed for relatively large and fairly sophisticated systems, and tend to be adopted by well-resourced farmers. These techniques include automated canal and piped water delivery systems, laser land levelling for surface irrigation applications, automated sprinkle irrigation, micro-irrigation (including surface and subsurface drip systems), and sophisticated control systems for managing these technologies. The majority of resource-poor smallholders are not able to afford these types of irrigation technology.

Irrigation systems must match smallholders' unique characteristics, including small land holdings, low capital availability, low risk tolerance and a relatively low opportunity cost of family labour (Keller and Seckler, 2004). This is to avoid excluding farmers from the benefits of such technologies due to high costs. Examples of improved irrigation technologies suitable for smallholders include: the low-cost drip irrigation for efficient water application; treadle pumps for water lifting; and bagging water for irrigation. Bagging water in plastic water tanks brings the benefits of supplemental irrigation to smallholders who have no other access to irrigation water. Each tank stores 10 cubic metres of water that is completely enclosed to eliminate evaporation losses and costs roughly $40 each with a life expectancy of about five years (UNCTAD, 2010).

Post-harvest technology

The main post-harvest technologies can be classified into primary and secondary processing technologies. The primary processing of agricultural produce involves cleaning, grading, packaging, drying, pre-cooling, storage, etc. It is often poorly developed in rural areas compared to secondary processing industries such as flour mills, sugar mills and oil mills. Mechanization has ensured improvements in food processing and storage at both family and industrial levels. Processing crops is necessary to increase their shelf life and could contribute considerably to transforming local economies. Development of grain silos and other storage systems has enabled the long-term storage of particularly bulk grain produce. For instance, silos (5–2,500 MT capacities) and warehouses (200–5,000 MT capacities) have been built by government agencies (e.g. the National Strategic Grain Reserve Unit in Nigeria) for the storage of grain products at strategic locations all over Nigeria as intervention efforts and for research purposes to prevent food shortages while private agencies use them for the storage of bumper harvests (Asoegwu and Asoegwu, 2007).

Technologies for processing roots and tubers could expand crops' roles as sources of both food and income. Overcoming the perishability of crops, enhancing their nutritional value and adding additional economic value locally through agricultural processing is therefore one important way to increasing food security in Africa.

Biological and biochemical technology

This comprises of a package of high-yielding varieties of seeds, chemical fertilizers and pesticides used to enhance the food security systems.

Biological technology

Improved varieties and high yielding quality seeds and animal breeds are basic requirements for productive agriculture, which is the basis for food security. Genetics and breeding have the ability to significantly contribute to solving several possible future problems such as food insecurity and hunger, high inputs, as well as increasing nutritional values and other traits useful for mankind (Afari-Sefa *et al.*, 2012). Breeding has led to the development of high quality plant and animal products that are resistant to diseases, pests and other abiotic factors in Africa. Such products have high yielding capability, prolonged flowering for leafy-type vegetables, long seasonality of picking, improved taste, better appearance, longer shelf life, improved nutritional value, uniformity and environmental stress resistance. Typical examples of products from crop breeding in Africa are New Rice for Africa (NERICA), Africa Biofortified Sorghum (ABS) and Water Efficient Maize for Africa (WEMA). Research by Consultative Group on International Agricultural Research scientists, in collaboration with national agricultural research systems in Africa, has helped control two major diseases of cassava – bacterial blight and leaf mosaic – through genetic breeding, the incorporation of resistance genes into high-yielding cassava varieties, and an Africa-wide programme of biological control of the cassava mealybug. The late maturing six-tons-per-hectare-varieties have been replaced by varieties that yield 20–30 tons/ha. On the other hand, animal products from genetics and breeding usually have high fecundity and prolificacy amidst other preferred traits such as disease resistance.

Biochemical technology

Fertilizers, both organic and inorganic, do supply essential elements to plants for its growth and development. Such elements include nutrients such as nitrogen, phosphorus, potassium and sulphur, as well as trace elements such as iron, zinc and magnesium. The use of inorganic fertilizers was spurred by government subsidies in most developing countries but dropped sharply with the elimination of these subsidies. Small-holder farmers in sub-Saharan Africa use only a tenth of the global average inorganic fertilizer use. The annual total input of fertilizers in Africa is only 21 kg (nutrients) per ha of harvested land, compared to 100 kg/ha for South Asia, 135 kg/ha for East and Southeast Asia, 73 kg/ha for Latin America and 206 kg/ha for the industrial countries (UNCTAD, 2010).

Harnessing the potentials of soil microorganisms can help plants to absorb nutrients. The utility of these microorganisms can be enhanced by selecting the most efficient, culturing them and adding them to soils directly or through seeds. The cultured microorganisms packed in carrier material (such as peat or lignite powder) for easy application in the field are called bio-fertilizers. Biofertilizers could help reinforce these natural nutrient sources. For example, *Azolla prinnata* (a water fern) has a symbiotic association with the blue-green algae (BGA) *Anabaena*, and can fix atmospheric nitrogen. Ploughed into the soil between rice harvests, it can increase the crop yield by over 50 percent and its effect, which lasts for two years, is equivalent to the use of 60 kg of nitrogen fertilizer per hectare. BGA can fix up to 77 kg of nitrogen per hectare in a cropping season under non-symbiotic conditions.

Biotechnology and nanotechnology

Biotechnology consists of commercially acceptable techniques that use living organisms or parts thereof to make or modify a product; while nanotechnology is the study, design, creation, synthesis, manipulation and application of functional materials, devices and systems through control of matter at the nanometer scales.

Biotechnology

Biotechnologies used in agriculture are developed through two different innovative systems: the informal system at farm or village level responsible for most traditional products and processes, and the formal institutional system linking farmers with research and technology transfer services in the development and dissemination of modern technologies (Ozor and Igbokwe, 2007). Biotechnology has been used to develop several crop varieties and germplasm with improved yield, quality, disease and pest resistance, and better storage quality. Some traditional agricultural biotechnology practices include: pest control through intensive mixed cropping system to maintain biodiversity; protection of the natural resource base and maintenance of soil fertility through shifting cultivation practices, bush fallowing and composting; natural fermentation processes used widely to prepare foods and beverages example, beer, wine etc. On the other hand, some modern agricultural biotechnology practices include: enzyme technology in food processing, bio-fertilizers in plant nutrition and health, drug and vaccine development, tissue culture, genetic markers, mutation induction, somatic hybridization and cybridization, and genetic modification.

Genetically modified (GM) crops are often held up as the solution to yield deficits as well as offering other benefits such as improved appearance, taste and nutritional quality, drought tolerance, and insect and disease resistance. The most common trait being introduced into GM crops is herbicide tolerance, which is now found in about 80 percent of all GM crops planted worldwide.

The current status of GM crops in West Africa show that cotton (Bollgard II) is the biggest export crop in Burkina Faso with production of up to 180,000 tons (2006/2007–2010/2011) from about 250,000 ha with a 50–70 percent reduction in insect damage. In Nigeria, the GM crops under study at the field trial level are cassava, cowpea and sorghum. Biofortified Cassava (BC+) (GM cassava enriched in carotene and iron) has been selected for high resistance to African Cassava Mosaic Virus. The legal statuses of GM crop in West Africa show that Burkina Faso, Ghana, Senegal and Togo are the only countries in the subregion that have biosafety legislation in place that can allow the handling of GM crops up to commercial release (Alhassan, 2012). Burkina Faso has been handling a GM crop (Bt cotton) at the commercial level since 2008 while Nigeria has a cabinet approval for the handling of GM crops up to the CFT level. In Ghana, the state of legislation determines biotech products that can be handled and only GM requires special legislation. The enabling laws available are the LI 1887 of 2007, which allowed handling GM crops up to CFT level, and Act 831 of 2011, which is a comprehensive biosafety law covering the handling of GM products up to and including commercial release.

In East Africa countries such as Uganda, efforts are being made through the national agricultural research organizations to support the regeneration of genetic materials and other progress on technology testing such as bacteria wilt testing and production of vitamin A enhanced bananas. Other crops receiving attention at the research organization on genetic modification are: cassava, maize, cotton, rice, sweet potato and groundnut (Kiggundu *et al.*, 2012).

There is therefore need to accelerate biosafety legislation across the continent prior to trialling and use of GM products. Such legislation should, however, not be restrictive but allow for full exploration of the potentials of the technology in addressing the food security challenge in Africa. Again, there is need for an enabling environment for agriculture including input supplies, infrastructure support services, market, and favourable policies and programmes, etc. Finally, there is urgent need for scientific human resource development in the critical areas such as plant breeding, animal breeding, crop protection, veterinary medicine, fermentation, molecular biology and biosafety.

Nanotechnology

Nanotechnology has made available such products as agrochemicals, genetically engineered preservatives, sensors, telecommunications, global positioning, automation, computing and modelling, which are essential for agricultural production. It has been proven to be very useful in information technology, energy, medicine and agriculture. This science of working with smallest possible biological particles raises hopes for future agriculture in Africa by breaking the barriers that cannot be addressed by conventional breeding technology. Nanotechnology could play an important role in meeting the Millennium Development Goal (MDG) goal number one that is aimed at eradicating extreme hunger and poverty (Kiplagat, 2012) as shown in Table 1.

Nevertheless, the future of nanotechnology is uncertain due to many reasons such as: lack of public awareness, negative reaction of the public towards nanoparticles, lack of requisite skills and facilities in public agricultural research organizations, and the somewhat hesitant regulatory structures to deal with the new technologies.

Indigenous technology

Indigenous technology comprises of unique knowledge that is peculiar to a given culture or society,

Table 1. *Nanotechnology applications that addresses MDG One*

S/n	Applications of nanotechnology	Examples of nanotechnologies in agriculture
1.	Agricultural productivity enhancement	• Nanocapsules for herbicide delivery • Nanosensors for soil quality
2.	Water treatment and remediation	• Nanomembranes for water purification • Non-porous zeolites & atta clays for water purification
3.	Food processing and storage	• Nanocomposites for use in food packaging • Antimicrobial nanoemulsions for food equipment
4.	Vector and pest detection and control	• Nanosensors for pest detection • Nanoparticles for pesticides & insecticides

which has sustained them over so many years and passed on from one generation to another. Indigenous technologies are products of traditional and local knowledge systems developed by and within distinctive indigenous communities and different from the international knowledge system generated through universities, government research centres and private industries sometimes called the western knowledge system.

Indigenous knowledge has contributed greatly to the survival of local populations while ensuring food security in Africa. Almost in every culture in Africa, there exist indigenous technologies, techniques and practices in agriculture, which have sustained the people for so many years. Most often, such practices are modified with time in order to address the ever-changing challenges and opportunities of human society. It is therefore pertinent for any modern science or technology to take cognizance of the indigenous knowledge system and build upon it in the development of new agricultural technologies. Besides, the indigenous people are the custodians of the genetic resources upon which modern science depends for their research and development. This should be appreciated and credited especially considering the non-classical nature in intellectual property rights that such knowledge system possess, hence the case for *sui generis*.

For example, farmers in the semi-arid part of Burkina Faso use pit, otherwise called 'Zai' for growing trees to increase and diversify plant biomass. Through this method farmers have rehabilitated degraded land and increased the diversity of trees. The practice enhances the natural regeneration of important plant species such as acacia (Syn. faidherbia) and baobab; and the integration of livestock keeping and cropping systems, which is the basis for sustainable agricultural intensification. Furthermore, it minimizes risks due to variations in rainfall and ensures substantial crop yields in marginal lands.

Agricultural diversification is another area where indigenous knowledge has proven effective in ensuring food security in Africa. In response to many issues, mainly climate change, many farmers in Africa now plant different kinds of crops and rear different species of animals as a way of hedging risks and uncertainties that may arise from the vagaries of weather. Reports show that some farmers in Tunisia now plant more than ten species of fruits in their fields – a radical change from the traditional olives, figs and palms (Reij and Waters-Bayer, 2002). They further observed that some farmers are very skilled in grafting fruit trees, even grafting different species on one tree. For instance, combination of apples and pears and of peaches and plums can be found. These technologies have raised farmers' income level in addition to ensuring improved availability of food.

Much as the indigenous technologies and knowledge systems have passed the test of time, it is yet not adequate to secure food security condition for Africa that is faced with population explosion, environmental challenges especially climate change, and poverty. A combination of both indigenous and modern technologies (low, medium and high) becomes germane in ensuring sustainable food security in Africa because each has its own peculiarities and advantages. African farmers and development practitioners should therefore harness the opportunities provided by each of them depending on specific contexts and priorities of each country to ensure food security in the continent.

Conclusion

The article discussed some technologies that could be applied in African agriculture based on need and priorities in order to ensure a food secure continent. Four major technologies were discussed, namely mechanical technology including tractorization, draft animal power, irrigation and post-harvest technology; biological and biochemical technology; biotechnology and nanotechnology; and indigenous technology and knowledge systems.

A combination and good mixes of all the four types of technologies is needed to ensure adequate food security in Africa. However, in order for the continent to benefit from these technologies, a number of actions will be required. First and foremost is the need to invest in educational and extension programmes in order to enhance the absorptive capacities of farmers. Second, there is a need for strong and effective legislation to protect against the potential adverse entailments of some technologies. Third, there is a need for predictable and stable incentives necessary for the uptake of technologies by the farmers. Fourth, there is a need to systematize and make available the best lessons from the persistence with indigenous technologies.

However, technology is not everything. While biophysical potential often exists to significantly increase yields, institutions, governance systems, political will and poor rural infrastructure remain obstacles to achieving full technological potential required for food security in Africa. These challenges are particularly striking in African countries, which could most benefit from new technologies and practices.

References

Adenle, A. Adenle, C. Aworh Ogugua, Richard Akromah and Govindan Paryil (2012) 'Developing GM Super Cassava for Improved Health and Food Security: Future challenges in Africa', *Agriculture and Food Security* 1(11): 1–15.

Afari-Sefa, Victor, Abdou Tenkouano, Christopher O. Ojiewo, J.D.H. Keatinge and Jacqueline d'Arros Hughes (2012) 'Vegetable Breeding in Africa: Constraints, complexity and contributions towards achieving food and nutritional security', *Food Security* 4(1): 115–127.

Alhassan, Walter (2012) 'Current Situation on GM Research and Innovation in Ghana and the Region – Opportunities and Challenges', paper presented at the 2012 ATPS Annual Conference and Workshops held from 19–22 November 2012 at the African Union Commission Headquarters, Addis Ababa, Ethiopia.

Asoegwu, S.N. and A.O. Asoegwu (2007) 'An Overview of Agricultural Mechanization and Its Environmental Management in Nigeria', *Agricultural Engineering International: The CIGR Ejournal*. Invited Overview IX(6): 1–22.

Baker, Melissa (2012) Do Attitudes Matter?, paper presented at a workshop organized by the social and political division of TNS East African and funded by the Bill and Melinda Gates Foundation and held on 13 November in Nairobi, Kenya.

Fonteh, Mathias Fru (2010) *Agricultural Mechanization in Mali and Ghana: Strategies,' experiences and lessons for sustained impacts*. Rome: FAO, Available online at: http://www.fao.org/fileadmin/user_upload/ags/publications/K7325e.pdf, accessed 10 January 2013.

Ghutiga, P.M., J.T. Karugia and R.A. Nyikal (2007) 'Does Use of Draught Animal Power Increase Economic Efficiency of Smallholder Farms in Kenya? *Renewable Agriculture and Food Systems* 22(4): 290–296.

Haque, M.A., Bobboi Umar and U.A. Kawuyo (2000) 'A Preliminary Survey on the Use of Animal Power in Agricultural Operations in Adamawa State, Nigeria', *Outlook on Agriculture* 29(2): 123–127.

Harcourt, Wendy (2012) 'Editorial: The times they are a-changin', *Development* 55(1): 1–4.

Keller, Andrew and David Seckler (2004) 'Limits to Increasing the Productivity of Water in Crop Production,' California Water Plan Update 2005. Available online at: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c03a10_cwp2009.pdf, accessed 9 January 2013.

Kiggundu, Andrew, Wilberforce Tushemereirwe, G. Arinaitwe and Y. Baguma (2012) 'Current Status of GM Research and Innovation in Uganda: Application of gene technology to staple crops, the Case of banana and cassava', paper presented at the 2012 ATPS Annual Conference and Workshops held from 19–22 November 2012 at the African Union Commission Headquarters, Addis Ababa, Ethiopia.

Kiplagat, J.K. (2012) 'Nanotechnology: Key to meeting the Millennium Development Goals (MDGs)', paper presented at the 2012 ATPS Annual Conference and Workshops held from 19–22 November 2012 at the African Union Commission Headquarters, Addis Ababa, Ethiopia.

Ozor, Nicholas (2012) 'The Role of Science, Technology and Innovation (STI) in National Development', keynote paper presented at the Science, Technology and Innovation Week held from 21–23 June 2012 at the University of Liberia Auditorium, Monrovia, Liberia.

Ozor, Nicholas and E.M. Igbokwe (2007) 'Roles of Agricultural Biotechnology in Ensuring Adequate Food Security in Developing Societies', *African Journal of Biotechnology* 6(14): Academic Journals: 1597–1602, Available online at: http://www.academicjournals.org/AJB/contents/2007cont/18Jul.htm.

Reij, Chris and Ann Waters-Bayer (eds.) (2002) *Farmer Innovation in Africa: A source of inspiration for agricultural development*. London: Earthscan Publishers.

Sims, Brian G., Josef Kienzle, Roberto Cuevas and Gavin Wall (2007) 'Addressing the Challenges Facing Agricultural Mechanization Input Supply and Farm Processing'. Proceedings of an FAO Workshop held at the CIGR World Congress on Agricultural Engineering Bonn, Germany, 5–6 September 2006. FAO, Rome. Available online at: ftp://ftp.fao.org/docrep/fao/010/a1249e/a1249e.pdf, accessed 8 January 2013.

Sosevile, H. (2000) 'Constraints to the Adoption of Animal Power Weeding Technology in Tanzania', in P. Starsky and T. Simalenga (eds.) *Animal Power for Weed Control*. Wageningen, The Netherlands: Technical Centre for Agricultural and Rural Cooperation (CTA).

Uguru, M.I. (2012) 'Genetics for Farming and Food Security in Africa: Lessons from Nigeria', paper presented at the 2012 ATPS Annual Conference and Workshops held from 19–22 November 2012 at the African Union Commission Headquarters, Addis Ababa, Ethiopia.

United Nations Conference on Trade and Development (UNCTAD) (2010) Technology and Innovation Report 2010: Enhancing food security in Africa through Science, Technology and Innovation. United Nations, New York and Geneva.

*This paper was prepared for the SID Conference 'Rethinking Food Security in Africa: New Paradigms, New Approaches' held in June 2013. This conference was part of the SID African Dialogue Speaker Series supported by the Rockefeller Foundation. The views expressed in this paper are those of the author(s) and not those of the Rockefeller Foundation.