Engineering and Technology Innovation for Global Food Security

A report on the 2016 Global Initiative Conference at Stellenbosch, South Africa, hosted by the American Society of Agricultural and Biological Engineers (ASABE)

Since its founding in 1907, the American Society of Agricultural and Biological Engineers (ASABE) has supported research and promoted solutions in food, agriculture, natural resources, and the environment. Today, our fast-growing global population, which is estimated to reach 9.2 billion in 2050, creates new challenges that will require new solutions. To address these challenges, and recognizing the need to unite its international membership with other organizations, ASABE implemented a global vision in 2012:

*ASABE will be among the global leaders that provide engineering and technological solutions toward creating a sustainable world with abundant food, water, and energy, and a healthy environment.*

ASABE recognizes three critical themes among these challenges—food security, water security, and energy security, all in the context of sustainability and climate change. These three themes were explored in a report titled “Global Partnerships for Global Solutions: An Agricultural and Biological Engineering Global Initiative” (available at http://www.asabe.org/media/195967/globalinitiative.pdf). In that previous report, ASABE identified specific goals and objectives related to food, energy, and water security.

As part of its Global Initiative toward achieving these goals and objectives, ASABE is organizing an ongoing series of conferences focused on the three themes. The first Global Initiative Conference, titled “Engineering and Technology Innovation for Global Food Security,” convened October 24-27, 2016, at Stellenbosch, South Africa. This conference brought together agricultural and biological engineers and other international experts from academia, government, and industry to meet with local stakeholders and address the challenges of producing and providing safe and healthy food in a sustainable manner for the growing population. The conference identified specific ways in which engineering and technology can be applied to advance global food security, including partnerships with other organizations to address local and regional issues.

The participants came from six continents and included engineers, researchers, educators, and executive staff at a variety of international organizations. Through technical presentations (abstracts available at http://www.asabe.org/media/248622/book_of_abstracts_binder_3.2017revised.pdf) and open discussions, the attendees shared food security challenges and examined current successes. The conference was organized around six themes, which are summarized at the end of this paper. The conference concluded by identifying specific opportunities for advancing food security and mitigating threats. The following section summarizes four key priorities, followed by opportunities specifically linked to the food security goals and objectives previously identified by ASABE.

**Toward Global Food Security**

Four key priorities for achieving global food security that were reinforced by conference participants include positive perception of agriculture, higher education/training and capacity building, technology adoption, and international partnerships.

Agriculture, which is humanity’s primary food source, is an extremely diverse enterprise, including food production, processing, and distribution, with complicated biological, environmental, cultural, political, and financial factors. All these factors must be considered when contemplating changes that are needed to feed our rapidly growing population. Agriculture must be promoted universally as the critical business and valued profession that it is, rather than as a drudgery-filled vocation characterized by difficult and menial labor, shunned by young people entering the work force.

The significance of the perception of agriculture, compared to other industries, can be seen in Nigeria, which in recent years has declined from a food-secure country to food insecurity. The transition occurred during Nigeria’s oil boom, when agriculture was seen as much less profitable and less prestigious than the
oil industry. As a result, the priorities of labor and government shifted, and Nigerian agriculture fell into a decline from which it has not yet recovered.

The technological innovations of modern agriculture can be a means for updating the popular perception of agriculture and demonstrating that the work of feeding our growing population can be very rewarding—personally, socially, and financially.

*Education/Training and Capacity Building*

In addition to changing the popular perception of agriculture, higher education must meet the growing demand for technical skills in agriculture and food processing. Agricultural programs in developing countries must include environmental protection and sustainable land use. Educational and training programs in agricultural and biological engineering and technology should include sustainable production systems, water resource management, food processing systems, and soil management at multiple scales. Models of such programs are already in place and are readily adaptable to specific regions.

Hands-on training programs, including vocational training and short courses, are needed to meet the growing demand for skilled labor. Training in mechanical skills, for the repair and maintenance of increasingly sophisticated farm equipment, is particularly needed. Short courses can teach specific skills quickly. For example, AGCO Corporation’s Future Farm in Zambia helps small- and medium-scale farmers increase their productivity and profitability by providing access to training, technology, financing, and markets in a setting where farmers can see the practices in use and interact with technical experts.

*Technology Adoption*

For any technology to be adopted successfully, it must align with stakeholders’ vision of their future and empower them to attain their vision. Support networks are necessary for technology changes to be adopted and sustained. Network components include education and training, repair parts availability, repair and service expertise, dependable energy sources, as well as risk mitigation and credit availability. Just as important, the new technology must not create undesirable social impacts—such as the workforce segregation that exists in some cultures, where young women are assigned menial tasks that prevent them from attending school. In many developing areas, women are a majority of the smallholder farmers and produce most of the food. However, they often have limited land ownership options, decision-making authority, technical education, and access to financial resources. In developing new technology to improve productivity, we must consider how the technology will be received by its intended users, how it will affect the local culture and larger society, and how it can be protected from abuse by adopters.

The successful adoption of any technology should be measured by the extent of long-term implementation at the farmer level. Many of the production and post-harvest technologies that could provide food security have been used or demonstrated successfully in particular regions; however, in many instances, alternate implementation approaches are required, for a variety reasons. In general, specific solutions to specific problems are much easier to adopt than broad, system-level changes. The scale of technologies implemented must be appropriate for the conditions that exist at initial implementation, but consideration should be given to scalability to keep pace with market demands that develop. While smallholder farmers benefit most from improvements at the local scale, options for larger scale, more resource-efficient operations must be evaluated for both their short- and long-term effects on the economy, the environment, and society. Stakeholders often envision changes on a larger scale, and occurring more rapidly, than those who are proposing changes, and they may be disillusioned by plans they consider too limited.

*The Importance of Partnerships*

Partnerships improve the development and deployment of technology. International partnerships bring together experts from different fields, while local partnerships bring expert solutions to local populations.

- Partnerships provide opportunities to resolve issues related to local decision-making authority, training,
and access to credit.

- Partnerships can establish model farms and training centers, with on-site demonstrations and technical assistance. Such programs have been successful in bringing technology to smallholder farmers because they reach a large local audience.
- Partnerships with local equipment manufacturers and distributors promote the adoption of local solutions and provide local employment. Commercial partnerships also increase access to inputs that improve productivity, such as improved seed, fertilizer, and pest control methods.

In addition, marketing and producer partnerships promote broader market opportunities, private and public partnerships promote better engagement of policy makers and enhance government focus on food production and agriculture, and investment partnerships enhance the availability of capital to fund scale-up of promising technologies and risk-mitigation strategies.

Technology leaders must find ways to collaborate with government and nongovernmental organizations (NGOs) to share current and future innovations with the larger world. Successful efforts, that are sustainable and appropriately scaled, require the cooperation of everyone involved. The path forward is challenging, but targeted education, appropriate technology, and effective partnerships will help all food producers capitalize on new economic opportunities while reducing stress on the resources we need to feed our growing world.

Opportunities and Challenges Aligned with the ASABE Food Security Goals and Objectives

Opportunities and challenges identified by conference participants, presented in bulleted lists below, provide further insight into how the food security goals and objectives of the Agricultural and Biological Engineering Global Initiative (http://www.asabe.org/media/195967/globalinitiative.pdf) can be achieved.

**GOAL 1: IMPROVE FOOD PRODUCTIVITY**

**Objective 1. Establish agricultural informatics and analytics to quantify food production.**
- Develop weather-water-cropping systems and methods to reduce risk and improve productivity and that are translatable to a variety of locations.
- Improve climate literacy, resilience of production systems, monitoring, and adaptation through improvement of farmers’ understanding, and crop and climate modeling systems.
- Develop models for the livestock sector that take into account macro-level concerns about reducing greenhouse gas (GHG) emissions and increasing productivity.
- Develop decision-making tools to help agricultural producers manage and conserve water resources during drought.
- Develop drought indices and wastewater recycling systems.
- Develop smartphone applications (apps) for data collection, mapping, and support. Apps would appeal to the younger generation and could be developed at different levels for different people. Education can be offered with the apps.
- Use Internet of Things (IoT) devices in food and agriculture.
- Use satellite data, which has global coverage and regular, high frequency intervals.
- Collect long-term climate data for effective use of models.
- Increase funding for model development and application.

**Objective 2. Develop, adapt, and utilize scalable, regionally appropriate technologies for sustainable intensification.**
- Develop mechanization and precision agriculture strategies to promote sustainable intensification of food production and residue management.
● Develop new methods for renting and custom-hiring of equipment.
● Develop strategies for global farm machinery manufacturing technology transfer.
● Develop automation for small-holder farm machinery through innovative, low-cost field sensors and appropriate tools based on application of information and communication technology (ICT).
● Identify scalable forms of data to expand lessons learned from one region to other appropriate regions.
● Develop strategies to mechanize gender-centric tasks aimed at reduction of drudgery and reduction of post-harvest losses.
● Increase irrigated agricultural land areas in sub-Saharan Africa, where only 6% of agricultural land is currently irrigated.
● Develop low-cost technologies, including low-cost automated control systems.
● Develop local capacity for manufacturing irrigation equipment.
● Involve communities in monitoring.
● Implement alternative irrigation, improved irrigation scheduling, introduction of high-value crops, improved tillage management, ponds to irrigate farms, and rainwater harvesting.
● Implement precision farming technologies to keep animal production healthy, improve meat safety inspection, and promote better odor and waste management.
● Develop approaches for reducing fertilizer use without reducing production.
● Partner with local communities to develop user-friendly technologies to translate research into practical, sustainable, commercial solutions.
● Evaluate government policies to determine those that are unfavorable and often contradictory.
● Approach water resource management in a holistic way in which all uses of water, including wastewater, are evaluated. This approach is important in areas where a poverty-gender-water nexus exists.
● Consider poverty, high population density, low productivity, small land parcels, poor water management, and land tenure in identifying appropriate technologies.
● Consider gender roles, migration, cost and income disparities, and need for capacity development in developing solutions.

Objective 3. Develop sustainable urban agricultural production systems.
While urban agriculture was not specifically addressed during this conference, it is a very important dimension of global food security. The contribution and impact of urban and peri-urban agriculture is considered more specifically in other ASABE activities related to food production and security.

GOAL 2. REDUCE FOOD LOSSES AND WASTE

Objective 1. Develop methods to quantify losses in production, processing, and distribution.
● Encourage studies on assessment of post-harvest loss to determine the extent of variation at farm and processing stage.
● Provide input to inform policy alternatives for minimizing post-harvest loss.
● Standardize the method for measurement of food waste (postharvest and otherwise).

Objective 2. Develop real-time prediction and monitoring of product quality and safety.
● Define expiration dates on foods so that they reflect the quality within.
● Develop standard approaches to measure quality and safety.
● Investigate Internet of Things (IoT) devices for use in real-time prediction and monitoring of product quality and safety.

Objective 3. Design scalable, regionally appropriate harvesting, drying, storage, processing, and handling systems to minimize loss.
● Improve efficiency of crop dryer designs for developing countries.
Establish regional hubs for supply, processing, storage, and equipment.

Develop strategies to address raw material acquisition, sanitary technical implementation, and final product commercialization in small-scale food industries.

Develop strategies to mechanize gender-centric tasks aimed at reduction of drudgery and reduction of post-harvest losses.

Improve awareness of small-scale farmers in developing countries of modern postharvest storage technologies.

Develop dependable continuous electricity supplies in rural areas to power postharvest storage technologies.

**Themes from the 2016 Global Initiative Conference**

The following six themes were developed at the Global Initiative Conference, “Engineering and Technology Innovation for Global Food Security,” that convened October 24-27, 2016, at Stellenbosch, South Africa.

**Theme 1: Enhancement of food availability through mechanization and precision agriculture**

Agricultural mechanization is one of humanity’s greatest engineering achievements. Mechanization transformed agriculture from subsistence farming to a major industry, laying the foundation for modern societies. Mechanization has vastly improved the quality of our food and the efficiency of our farms while reducing the burden of manual labor. Globally, however, less than 10% of all farm operations are performed by engine power, 25% of operations are performed by animal power, and fully 70% of all farm operations are still performed by manual labor, mainly by women and children. In addition, nearly 70% of all farms are small holdings (less than 1 ha), and 50% of these farm households are food insecure.

Sustainable intensification is one of the strategies that have been identified for achieving global food security, and intensification requires mechanization. Because most of the world’s farmers are smallholders, appropriate-scale mechanization is needed for sustainable intensification. Historically, agricultural mechanization has been a challenge for smallholders, particularly because of the lack of suitable equipment. Smallholder farmers can benefit from mechanization that is appropriate for their small-scale and local conditions, and that is developed using locally available materials and expertise. The increased availability of information technology will also benefit smallholder farmers.

**Theme 2: Enhancement of food availability through water management**

Agriculture is the world’s largest consumer of water, and fully 70% of global water withdrawals are used for irrigation. Water scarcity is worsened by drought and by population increases. Projected climate change and increased climate variability will also disrupt the availability of water for agriculture and other uses. Studies from around the world have emphasized the growing need for water management and irrigation technology. Because 84% of global food production occurs on smallholder farms, water management technology must be developed for small-scale agriculture, and this technology must include climate forecasting and intelligent control systems.

**Theme 3: Postharvest and value added processing**

Postharvest losses in developing countries have been estimated as high as 50%. Reducing these losses can feed more people while adding value for producers, with no increase in production or resource requirements. Regionally appropriate postharvest processing systems, including refrigeration, drying, canning, and long-term storage, that work with local producers and that are supported by locally sourced maintenance and service, provide increased food security and economic opportunities.

A variety of postharvest processing systems have been successfully deployed. Evaporative coolers provide cold storage of perishable products at much lower energy and capital costs than refrigeration, which is often unavailable to smallholder farmers. Solar dryers, constructed from locally available or low-cost materials, provide drying of food products at much lower cost than conventional fuel-fired drying systems.
cost materials, are widely used for dehydrating fruits and vegetables as well as for drying grain. Solar dryers can also supply household energy needs.

However, adoption of postharvest processing is limited by lack of awareness of these technologies. Many technologies require capital investment, leading to credit problems for small producers. In particular, the producers who would most benefit from postharvest processing are often women, and cultural norms can deny them access to credit. Economical and dependable energy is also needed and may not be available in remote areas. Renewable energy sources, such as solar, wind, and biomass, can address both the cost and supply of energy, while user groups and farmer collectives can address the financial and cultural barriers by serving a larger number of producers with larger-scale systems.

**Theme 4: Food distribution and logistics for accessibility**

Significant losses occur throughout the food supply chain, resulting in a need to enhance food security through improved storage, transport, and distribution systems. Coordinating the output and distribution of agricultural operations so that an adequate supply of food is available—at the right time, in the right places, and of sufficient quality—is an on-going challenge, even in developed countries. These logistical problems are particularly challenging in developing countries that lack adequate transportation, communications, and storage facilities. Postharvest losses are significant throughout the supply chain, and improvements in food handling and transport are critical to solving the global challenge of food security.

**Theme 5: Capacity building for food system stability**

In developing countries, food production is still labor intensive and is often based on inefficient methods. Improvements to production, including mechanization, irrigation, alternative crop varieties, weed and pest control, and soil conservation practices, are often readily available but are not implemented because of a lack of education and training. Producers may be unaware of these methods, or they may be hesitant to implement them due to uncertainty or perceived risk.

To encourage modern, efficient, and sustainable production methods, education must take place at all levels and involve all agricultural stakeholders, including national and local governments, the financial system, and farmer organizations. Targeted training, including vocational programs and short courses, must meet the immediate needs for skilled labor. Institutions of higher education must provide curricula to meet the research and development needs of industry and support on-going agricultural research.

**Theme 6: Systems level performance for food system stability**

Historically, agricultural research focused mainly on the influence of single factors (tillage, genetics, fertility, etc.) and had great success in increasing food production. However, as research has progressed, complex relationships have been revealed between production practices and local ecosystems. The interactions of food production, energy demand, and water needs—known as the Food-Energy-Water (FEW) nexus—demonstrate how production can be affected by external forces that are beyond the control of individual producers.

Computer-based modeling tools can evaluate the interactions of multiple climate, management, and resource factors with increasing accuracy. With these tools, the economic, environmental, and social impacts of production systems can be evaluated in a broader context. This kind of “system-level” analysis allows multiple solutions to be tested before any solution is applied, and it provides more appropriate and more sustainable solutions than were previously possible.

This evaluation of system-level performance overlaps with the other themes of the Global Initiative Conference. For example, alternative irrigation schemes must be evaluated by considering the sustainability of the water supply as well as competition with other water users. Similarly, the sustainability of a cropping system must reflect the producer’s ability to perform the recommended crop management practices, while also using new technologies, such as precision agriculture and variable-rate irrigation. These concurrent practices must be evaluated within cultural and economic constraints that do
not exist in the laboratory.

The efficient use of our soil, water, and energy resources—in the context of global climate change—is perhaps the greatest challenge facing humanity as the world’s population grows to nine billion and beyond. Agricultural engineering can provide practical solutions to this challenge, particularly in developing countries, by providing locally appropriate mechanization, managing precious water resources, improving post-harvest food preservation and distribution, sharing research and technology with the international agricultural community, and ensuring the long-term sustainability of our food systems and our global environment.

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