21^{st} Century Challenges and Opportunities in Agricultural Engineering

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ABSTRACT

Agricultural engineers made significant contributions to the farming community in the 21^{st} century by improving efficiency of various farming operations, increasing farm incomes, and making life of a farmer more comfortable by mechanizing many of the labor intensive tasks of agricultural production. Mechanization of agriculture is considered to be one of the top 20 technological advancements of the 20^{th} century. With the success of agricultural engineering profession in the 20^{th} century to increase overall global food production, the future challenges of the 21^{st} century still remain not only to feed the current population of 6.5 billion in 2009 but to feed an increasing population of 9.5 billion people in 2050. Despite huge gains in food production, there is still widespread hunger and malnutrition in the world. The problem of world hunger will not be solved until we solve the issue of poor man's access to food and every farmer's access to land, water, credit, and education on this planet. Today we have more than one billion people in poor countries, especially women and children, who go to bed hungry each night and about two billion people are malnourished because of extreme poverty. Therefore, key questions for leaders of agricultural engineering profession would be: i) Are today's agricultural engineers trained to solve global society's top four challenges (energy, water, food and environment) of the 21^{st} century? Ii) Are we providing right education and necessary skills to our agricultural engineering students to face global challenges in 2050? Can we grow enough food to feed 9.5 billion people in 2050? How do we provide clean drinking water, energy, quality healthcare, and clean environment for 9.5 billion people in 2050? Therefore, future of agricultural engineering profession in the 21^{st} century is very bright because large number of agricultural engineers would be needed to solve complex problems of climate change, energy, water, food and environment in developing a sustainable global society in the 21^{st} century.

History of Agricultural Engineering Profession

The United States of America (U.S.A.) is one of the few countries in the world that is blessed with rich natural resources and highly ethical, hard working people. The abundance of land and water resources, and the passage of the Morrill Act of 1862 (which established the U.S. land grant system to provide affordable education and generate the much needed knowledge in science, agriculture, engineering and technology for prosperous rural and urban societies) were the driving engines of success in the U.S.A and made U.S.A. the most successful model of agricultural education, research, and extension in the world in the 21st century. The US land grant system has continued to excel for the past 146 years. The history of agricultural engineering profession in the USA and possibly in the world is part of the US land grant system that began with the establishment of Iowa State Agricultural College and Model Farm in 1858. Several farm engineering courses on surveying, workshops, grain harvesting and storage, farm buildings, and soil, water and drainage were developed and taught between 1858 and 1902. In 1870, more than 50% of people in the USA were still employed in agriculture and in 1890 it required four farmers to feed ten people despite of putting countless hours of human labor in various farm production tasks.

In early 1900, Professor J.B. Davidson observed poor conditions of farmers and committed himself to relieve millions of farmers from the clutches of onerous labor for pursuit of other useful endeavors and make their lives more comfortable and pleasant. In 1905, under the leadership of Professor J.B. Davidson, agricultural engineering department was established at Iowa State University and a new profession of agricultural engineering was born to improve efficiency of various farming operations, increase farm income, and make life of a farmer more comfortable by mechanizing many of the labor intensive tasks of agricultural production. Since 1905, agricultural engineers made dramatic improvements in developing technical solutions for problems in agriculture, where manual work and horse-driven implements were replaced by machines such as implements and tractors for tillage, planting and chemical applications, sprinkler and center pivot systems for irrigation, combines for grain harvesting, and milking machines for on farm dairy. Mechanization and automation in the agriculture brought not only efficiency but reduced significant labor on the farm. Engineers brought significant improvements in farming methods and have tried to make agricultural production systems more sustainable. In addition, agriculture is becoming more and more industrialized model and society is asking if agriculture would be able to meet the future needs for food for humans, feed for animals, and bioenergy for society.

The net outcome of this profession was that by the end of 20th century most of the farming operations of planting, cultivating, chemical applications, harvesting, storage and transportation of grains, and water management, especially irrigation, were highly automated resulting in one US farmer feeding 100 Americans plus 35-40 people overseas. Therefore, the impact of agricultural engineering in mechanization agriculture is considered to be one of the top 20 technological advancements of the 20th century and helping the society solve food security issues on a large extent.

Key Challenges for Agricultural Engineering Profession in 21st Century

With the success of agricultural engineering profession in the 20th century to increase overall global food production, the future challenges of the 21st century would be not only to feed the current population of 6.5 billion and but to feed an increasing population of 9.5 billion people in 2050. Therefore, the major challenge for agricultural engineers would be how to help doubling the food production to feed a growing population of 9.5 billion people on the planet by 2050. Despite the gains made in 20th century in increasing food production, there is still widespread hunger and malnutrition in the developing world. The problem of world hunger will not be solved until we solve the issue of poor man's access to food and every farmer's access to land, water, credit, and education on this planet. Today we have more than one billion people in poor countries, especially women and children, who go to bed hungry each night and about two billion people in the world are malnourished because of extreme poverty. Agricultural engineers must help solve the problems of world hunger and malnutrition. Providing the growing world population with the necessities of life with sustainable solutions will be the prime challenge for agricultural engineers in the 21st century

Solve Environmental Pollution Problems: Mechanization resulted in developing and adopting intensive agricultural production systems to maximize farm profits. The intensive crop production systems required increased input costs of fertilizer, pesticides and irrigation water to obtain better and better crop yields which resulted in unintended environmental pollution consequences. The environmental problems caused by intensive agriculture systems have been compounding since the World War II period. Some of the environmental problems in the USA include pollution of surface and groundwater systems from nutrients and pesticides used in agriculture, accelerated soil erosion, and hypoxia in the Gulf of Mexico. Agricultural engineers have the responsibility to further refine and redesign machines for precision farming so that fertilizers and animal manure can be applied in precise amounts to meet the uptake needs of crops without causing water pollution. Therefore, future of agricultural engineering profession in the 21st century is very bright because large number of agricultural engineers would be needed to solve complex problems of climate change, energy, water, food and environment for developing a sustainable global society in the 21st century.

Throughout the 20th century, agricultural engineers and plant scientists kept on developing new seed varieties, technologies for fertilizers, pesticides, irrigation application methods, and advanced machines to make production systems automated to increase the crop production year after year. Engineers were successful in optimization the use of irrigation, fertilizers, and pesticides. At the same time, there is a widespread concern about the sustainability of production systems and impact of agricultural production on the water pollution and animal welfare. It was now well accepted and recognized by the farming community and urban society that agricultural production systems take into accounts not only an increase in production but also minimizing the negative impacts on the environment, natural resources and animal welfare.

Biosensors and nanosensors for Food Safety: Public is also now actively engaged in debates on organic farming vs chemically driven farming to assure public health and safety. Therefore, agricultural engineers need to find their role in the overall "sustainable agricultural production systems" of the 21st century and assure public that production systems are sustainable and foods are safe for consumption. Therefore, agricultural engineers have significant opportunities to develop new tools and technologies for risk assessment such as bio and nano sensors for data collection of food safety and traceability. In addition to bringing more land for sustainable food production systems, more and more land is being put under high energy crops to produce either biodiesel or ethanol as new sources of energy. This is another challenge facing the farming community.

Global Positioning Systems for Machines of the Future: Another opportunity for agricultural engineers is blend the knowledge of modern sensors, robots, automation, and manufacturing with information technology and global positioning system (GPS) to develop knowledge based machines of the future. Now robotics and automation are already being widely used in manufacturing and animal production and dairy industry. In the Netherlands, Denmark, USA, Canada, and many other Europeans countries, automatic milking systems (AMSs) are extensively and widely used. The global interest in AMS is very much to save labor cost and maintain better hygiene safety in dairy plants. Another application of sensors and controls would in the animal production facilities where advanced technical solutions are being investigated and used for reducing environmental impact of gases, particles, and odor. Minimizing the use of pesticides for weed control is another emerging field for use the robotics where the crops and weeds can be identified and pesticide sprayers will treat individual areas infected by weeds rather than spraying the pesticide over the entire field. There will be many more emerging new challenges for agricultural engineers and opportunities are going to be unlimited.

Biological Engineering: Another emerging opportunity for agricultural engineers is in the area of Biosystems Engineering. The bioeconomy industry in many countries represents a new generation in the technological revolution that promises to bring high paying jobs to the society. Bioeconomy based industries will need engineers who can transform the knowledge generated by life sciences research into products and services that add value to our agricultural and energy production while protecting the environment. It is envisioned that engineers and scientists from several disciplines will play a critical role in supporting this industry. Historically, agricultural engineers have worked at the interface of engineering and agriculture-based biological systems. In the early 1900's our agricultural engineers focused primarily on development of mechanized equipment, rural electrification and drainage. As our understanding of the biology governing agricultural systems has expanded over the past 25 years, our discipline has evolved, both locally and at the national level, to address more broad-based biological issues related to design and management of agricultural, food processing, and natural resource systems. For example, now agricultural engineers are working as biological engineers in critical areas facing the society including water quality, bacteria and pathogen monitoring and modeling, wetlands and riparian buffer strip design, physiology, bioenergetics, genetics and modeling of plant and animal systems, microbial bioconversion of biomass and waste for nutrients and energy, plant and animal composting, biomaterial harvesting, processing, quality and preservation, food safety and processing, biocontamination and biosensors. Our universities are recommending that we offer an undergraduate degree in biological systems engineering to capitalize on the strength and interest in biological systems engineering and help bioeconomy of grow for future economic systems. Agricultural and biological engineers will have the technical and biological background to understand how intensive agricultural production systems precisely affects the broader ecosystems within a given watershed under varying hydrological systems and what needs to be done to protect ecosystems from agricultural pollution. Intensive agricultural and animal production systems have become source water and air pollution in the developing and developed world future biological engineers must develop new technologies and practices that can help farmers use animal manure as a fertilizer and prevent nutrient losses to air and water resources.

Biological Engineering is the biology-based engineering discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems. Biological engineers will have a world view guided by their understanding of engineering science and design coupled with a fundamental understanding of life sciences principles in areas including biology, biochemistry, biophysics, microbiology, and genetics. Biological systems engineers approach engineering design from a biological systems perspective. They begin with a clear understanding of the characteristics and behavior of biological systems and then use appropriate tools of engineering to design new or improved systems. These biological systems may include microbes, plants, animals, humans and/or ecosystems. Biological systems engineering analysis may include characterization, measurement and modeling of biological processes and interactions between living systems and their environment. Biological systems engineering design may include developing processes and systems that monitor, simulate, replace, modify, control, optimize or utilize the mechanisms of living organisms and their products.

Carbon-neutral Renewable Energy Systems: The future farming systems may be required to limit greenhouse gas emissions and stricter regulations may be in the pipeline for protecting air, soil, and water quality. To remain economically viable, agriculture production systems must be ecologically sound and resource conserved for sustainability. In the future, farmers will realize new revenue from a diverse portfolio of biodiversity, carbon sequestration, water conservation, and renewable energy. Today's agriculture is largely an industrial enterprise sustained and made to appear efficient and economic with large inputs of energy, water, nutrients, and chemicals, derived from non-renewable natural resources. The availability of inexpensive external energy has allowed agriculture to avoid its own energy production and channel most of its effort into the mass production of food, feed, and fiber commodities. Vast amounts of energy are consumed in machinery and much more energy is expended in producing fertilizers, pesticides, and farm equipment, and in packaging and transporting produce to distant markets. As the true costs of our energy consumption practices become recognized, the need for a transition to carbon-neutral renewable energy sources becomes more urgent.

In addition to efficient food, feed, and fiber production from agricultural and biological systems, in the future agricultural engineers will work more in the production of ethanol and biodiesel, where crops are grown, harvested, and processed into liquid biofuels. However, crops and production systems currently available were developed primarily for food, feed, or fiber rather than for energy purposes. Large-scale expansion of biofuels production, therefore, has enormous implications for our agricultural production systems

Irrigation Systems for Water Scarcity Areas: Better water resource management and stewardship is just one of the many opportunities agricultural and biological engineers will play in the 21st century. Because water is basic to all biological life (human, animal micro-organisms, and plants) the impact of ensuring enough available water for all species will be incalculable. The availability of fresh water supplies for irrigation is declining in intensive irrigated areas of the world. Irrigated agriculture will continue to experience shortages and demands not only for food and fiber but also for emerging demand for supplying energy crops for a worldwide population that is increasing both in size and in industrialization. Future irrigation systems must use less water and provide maximum water application efficiency**.** Drip, sprinkler, and center pivot irrigation systems are capable of using less water and automatically, efficiently, and uniformly irrigating a variety of crops under different terrains, and soil conditions. Agricultural and biological engineers have improved the safety, efficiency, and dependability of the original design of these irrigation systems but must keeping on improving designs further for efficient use of soil and water, transforming agricultural production throughout the world. With the of precision application technology, irrigation systems will be applying water efficiently while reducing input costs and improving environmental problems in agriculture. To significantly improve irrigation efficiencies will require the use of technologies including remote sensing GPS, GIS-based spatially distributed information, and wireless technology.