Artificial Intelligence (AI) in Agriculture

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According to the Food and Agriculture Organization of the United Nations, the world population will reach over 9 billion by 2050. Rapid population growth, shrinking farmland, dwindling natural resources, erratic climate changes, and shifting market demands are pushing the agricultural production system into a new paradigm. The new agricultural system must become more productive in output, efficient in operation, resilient to climate change, and sustainable for future generations. Artificial Intelligence (AI) holds promise in addressing the challenges of this new paradigm.

The United States Department of Agriculture (USDA), Agricultural Research Service (ARS), is the premier agricultural research organization in the world with more than 2 000 scientists conducting agricultural research in more than 90 locations around the United States and in three foreign countries. ARS conducts research in areas such as crop production and protection, animal production and protection, natural resources and sustainable agriculture, as well as food nutrition and food safety. To harness the power of new technologies and transform agricultural research, ARS has established a virtual Center of Excellence (COE) to provide strategic leadership on the application of AI in agricultural research.

The COE provides a platform to transfer knowledge, share lessons learned, develop use cases, expand AI toolboxes, and continue to improve the technical capacity and talent pool within the ARS. This Special Section highlights the application of AI techniques in multiple areas of agricultural research so that readers can understand the range of AI-powered solutions within ARS.

- *Agricultural Production Management*—Agricultural production is a highly complex supply chain. AI is shifting the way our food is produced, distributed, and consumed. Researchers use AI-powered technologies to provide knowledge and guidance about crop rotation planning, planting times, water and nutrient management, pest management, disease control, optimal harvesting, food marketing, product distribution, food safety, and other agriculture-related tasks in the entire food supply chain.

Peters *et al.* in "Harnessing AI to transform agriculture and inform agricultural research," provides an overview of current advances, challenges, and opportunities for AI technologies in agriculture. They illustrate the potential of AI using four major components of the food system: production; distribution, consumption, and uncertainty. They conclude that agricultural enterprises are prime for the use of AI and other technologies. Sudduth *et al.* in "AI down on the farm," review several case studies where machine learning (ML) has been used to model aspects of agricultural production systems and provide information useful for farm-level management decisions. These studies include providing information important for developing

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precise and efficient irrigation systems and enhancing tools used to recommend optimum levels of nitrogen fertilization for corn.

- *Crop Monitoring*—Conventional crop health monitoring methods are labor-intensive and time-consuming. Utilizing AI is an efficient way to monitor and identify possible crop health issues or nutrient deficiencies in the soil. With the help of deep learning, applications are being developed to analyze plant health patterns in agriculture. Such AI-enabled applications are instrumental in understanding better, soil health, plant pests, and plant diseases.

Ramos-Giraldo *et al.* in "Drought stress detection using low-cost computer vision system and machine learning techniques," developed a low-cost automated drought detection system using computer vision coupled with ML algorithms that documents the drought response in corn and soybeans field crops.

- *Data Science*—Farms produce a large number of data points on the ground daily. With the help of AI, farmers can now analyze a variety of drivers in real-time such as weather conditions, temperature, water usage or soil conditions collected from their farm to better inform their decisions. AI technologies enable farmers to take advantage of the data at their fingertips to grow healthy crops while using fewer natural resources.

Peters *et al.* in "AI recommender system with ML for agricultural research," leveraged an AI recommender system (RS) with ML to maximize the use of data relevant to solving agricultural problems and to improve the efficiency of the scientific workforce while also improving the accuracy of estimates of the amount of food produced. They conclude that the RS provides a powerful approach to make use of the large amounts of data and scientific expertise in the agricultural enterprise to predict agroecosystem dynamics under changing environmental conditions.

- *Disease Detection*—Plant diseases are a major threat to the environment, economy, and food security. Early detection of crop disease is essential for effective disease management. AI-based image recognition systems could recognize specific plant diseases with a high degree of accuracy, potentially paving the way for field-based crop-disease identification using mobile devices, such as smartphones.

Bestelmeyer *et al.* in "Scaling up agricultural research with artificial intelligence," developed AI-based tools that leverage site-based science and big data to help farmers and land managers make site-specific decisions. These tools provide early-warning of pest and disease outbreaks and facilitate the selection of sustainable cropland management practices.

- *Food Quality*—AI and machine vision are playing a key role in the world of food safety and quality assurance. AI makes it possible for computers to learn from experience, analyze data from both inputs and outputs, and perform most human tasks with an enhanced degree of precision and efficiency.

Penning *et al.* in "Machine learning in the assessment of meat quality," employed ML to increase the speed and accuracy of carcass quality evaluation. They tested eight ML algorithms and achieved an impressive 81.5% to 99% accuracy in predicting carcass quality traits.

- *Predictive Analytics*—Remote sensing has been used to forecast the expected crop production and yield over a given area. It could also help to determine how much of the crop will be harvested under specific conditions. Advances in AI-based data analytics help farmers protect natural resources like land, air, and water, and reduce the amount of inputs needed for successful harvests.

Hatfield *et al.* in "Remote sensing: Advancing the science and the applications to transform agriculture," developed tools using remote sensing coupled with neural networks and ML to identify variable areas within fields and determine the potential adaptive strategies to increase the profitability for each field while reducing the environmental impact through more efficient use of nutrients and pesticides.

AI offers sweeping transformation with advanced approaches that will redefine the traditional pattern and limits of agriculture. AI will drive an agricultural revolution at a time when the world must produce more food using fewer resources. ARS scientists have applied AI technologies in various laboratories to advance agricultural research and speed up scientific discovery. Unfortunately, a lot of AI-based agricultural research projects in ARS could not be mentioned in this limited space. This Special Section has been prepared to make it as informative as possible with details of various AI techniques employed in ARS.