



Future of Work in Agriculture

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In 2019, the National Institute for Occupational Safety and Health (NIOSH) launched a *Future of Work Initiative*.¹ The new *Initiative* is organized around a series of changes affecting where work is done (workplace), how job tasks are accomplished (work), and who does work (workforce). One of the chief goals of the NIOSH *Future of Work Initiative* is to discover emerging workplace, work, and workforce trends in various industry sectors that may impact occupational safety, health and well-being in those sectors.² Nowhere are emerging future of work trends more apparent than in one of the oldest industry sectors – agriculture.

We are all dependent on the agriculture sector to support human life. The worldwide demand for agriculture's chief product – calories from food – is growing. The world's population is expected to increase by two billion persons in the next 30 years, from 7.7 billion currently to 9.7 billion in 2050, and could peak at nearly 11 billion around 2100.³ At the same time that food demand is increasing because of population growth, supply inputs such as factors of production like land, water, and labor are decreasing.⁴ These underlying supply and demand forces in agriculture are rapidly changing what the agricultural workplace looks like, the types of technologies that are used to accomplish agriculture work, and mix of occupations and job skills that workers need to succeed in agriculture.

Workplace

The agriculture workplace or farm has traditionally been an area of land suitable for growing crops or rearing animals. While the traditional workplace still exists, the agricultural workplace is expanding into places that have not supported agriculture previously (farming frontiers), into bodies of water (aquaculture), and to indoor

areas beyond the greenhouse (indoor vertical farming).

Farming frontiers. New geographies in the agriculture workplace represent the emerging future for agriculture. Research techniques are being used to address “desertification” or the degradation of land resulting from many factors such as human activities and climatic variations.⁵ Research methods have been developed to restore land that has supported crop growth in the past but has been so degraded that it can no longer support growth (desertification), or to convert land to active crop growth that has not supported crop growth in the past (desert sands).⁶ Restoring non-productive land that has been subject to desertification, and converting deserts through new soil technologies into viable farmland,⁷ is an emerging trend in the future of agriculture.

Furthermore, a projected consequence of climate change is the decrease of farmland and crop production. Over the past 40 years, crops like maize are now being grown in areas of the U.S. farther northward (upper-Midwest) than where they were previously grown (America's south-east).⁸ The climate-related northward shift in the agricultural workplace could lead to 76% of land south of the Arctic Circle, now characterized by coniferous forests, capable of supporting crop feasible conditions by 2099.⁹ All of these new farming frontiers will require an assessment of potential new occupational safety and health risks to farmers and farmworkers.

Aquaculture. Farming of aquatic organisms such as fish, crustaceans, mollusks, and plants can be done in freshwater, brackish water, or saltwater.¹⁰ While aquaculture has been practiced for centuries in Europe and Asia, aquaculture workplace production has been growing recently at a rapid rate worldwide.¹¹ In contrast to the growth in the number of aquaculture farming

workplaces, knowledge about the physical, chemical, biological safety and health hazards facing aquaculture workers globally¹² and in the U.S.¹³ has lagged far behind recent industry growth and is a critical need as growth of aquaculture workplaces increases.

Indoor vertical farming. In contrast to open field farming, large-scale indoor vertical farming (also known as “plant factories” or “controlled environment agriculture”) takes the small greenhouse to a new level literally.¹⁴ Crops are grown in tower-like walls of plant-holding cells that allow growth on a smaller footprint and require no soil. Water and nutrients are delivered aeroponically (through misting) or hydroponically (grown in nutrient-rich water). Non-weather-dependent light is delivered to the growing plants via LED lamps.¹⁵ Indoor vertical farming is touted as having a number of transformative economic, social, and environmental benefits over traditional land-based farming such as reduced pesticide and water use, prevention of fertilizer run-off into the eco-system, more crop yields per square foot of space under cultivation, enhanced food safety, decreased land use, and resistance to extreme climate conditions.^{16,17} Despite the benefits of indoor vertical farming,¹⁸ challenges to worker safety such as the risk of working at heights are largely unstudied and present a challenge to the future of indoor vertical farming as a safe agriculture workplace.

Work

Precision agriculture. The International Society of Precision Agriculture adopted the following definition of precision agriculture in 2019:

*Precision agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.*¹⁹

Precision agriculture can assist farmers by enhancing production management include profitability and efficiency of resource use, production quality, and environmental sustainability.²⁰ Precision agriculture relies on a number of emerging techniques

including agricultural sensors and robotic devices such as unmanned aerial vehicles and autonomous and semi-autonomous farm equipment. However, application of these advanced precision agriculture technologies is dependent on reliable wireless connectivity across operations on farms and ranches.

Sensors. A crucial technological tool in achieving the goals of precision agriculture is the use of sensor devices. Sensors can be selected and designed based on the needs identified by the farmer and exhibit a number of functionalities.²¹ These include: (1) location sensors which determine latitude, longitude and altitude of any item within a farm, the location of grazing animals, and are useful in interpreting yield and weed maps; (2) optical sensors which use light to measure various properties of soil including moisture, plant uptake of nitrogen, and chlorophyll content; (3) electrochemical sensors which can measure the pH and nutrient content of soil; (4) mechanical sensors which can measure soil compactness; and (5) air temperature and humidity sensors.²²

Robotics. Robotic devices are being developed to water, weed, prune, pollinate and harvest in an autonomous manner. Advances in robotic performance indicators including vision systems, harvesting speed, and reduction in plant damage rates are leading to the adoption of field crop robots.²³ One example of new robotic devices used in precision agriculture is an unmanned aerial device (UAVs) or drone. Agriculture UAVs can conduct soil and field analysis; engage in planting; replace satellite imaging to aid in 3-D imaging for crop monitoring; identify which fields, or parts of fields, need irrigation; spot bacterial or fungal infections;²⁴ and can aid in insect pest management.²⁵ Another example of a future agriculture robotic device is autonomous farm equipment. The ultimate goal is to offer growers driverless equipment that is smart – or autonomous – so farmers can perform tasks without human intervention.²⁶ Using artificial intelligence to perceive its environment, the fully autonomous or “self-driving tractor” is making its way into the market.²⁷

Connectivity. Realizing the promise of precision agriculture requires dependable access to wireless connectivity. Enabling smarter data communications between farm management systems and

sensors and robotic devices is critical to the future of agriculture in the 21st century.²⁸ A task force sponsored by the U.S. Federal Communications Commission (FCC) is expected to provide advice and recommendations on how to assess and advance deployment of broadband Internet access service on unserved agriculture land to promote precision agriculture.²⁹

Worker

Demographics. Between 1948 and 2017, U.S. agriculture output grew by nearly 187% even as the number of agriculture workers declined by nearly 76%.³⁰ The trend of rising agriculture productivity and falling labor participation is expected to continue. Overall employment in agriculture is projected to increase only two percent from 2020 to 2030, but agricultural equipment operators are projected to increase 13% during this same time period.³¹ The operation and maintenance of more technologically sophisticated agriculture equipment like sensors, and robotic devices operating by artificial intelligence methods is requiring greater educational attainment for agriculture workers. Between 1950 and 2017, the share of total hours from workers with a four-year college degree increased from one percent to 25%.³⁰

Job Skills. The increased use of robotics, sensors, and artificial intelligence is driving the need for engineers, economists, statisticians, software technologists and supply chain experts to join the ranks of the agriculture workforce. Agriculture has become less of an industry that relies on a farmer's manual labor and more one that requires farmers to have more cognitive skills in technology.³²

Summary

The articles in this special issue expand of the *Journal of Agromedicine* expand on many of the future concepts referred to in this editorial. Changes in the nature of the agriculture workplace, introduction of advanced technologies that determine how agriculture work is accomplished, and the changing face of the agriculture workforce are happening at a rapid pace. The

occupational safety and health risks to farmers and farmworkers are changing also. Occupational safety and health practitioners and researchers should become aware of these changes, assess the risk that these changes pose, and develop risk prevention strategies to ensure a bright future for all who labor to meet the increasing worldwide demand for agriculture's chief product – our food.

Disclosure statement

We have no conflicts of interest to disclose.

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