Review Article

Digital Future with Agriculture 4.0

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ABSTRACT
Agriculture is one of the most important fields of activity necessary for human beings to survive. It is predicted that the problem of food demand will increase in the future with climate changes caused by global warming, reduction of natural resources, unconscious use of agricultural land, increasing population. Therefore, it is necessary to emphasize the use of digital technologies for sustainable agriculture. In addition to increasing productivity in agriculture, methods to increase product quality and food safety should be developed. In response to the increasing population in agriculture, migration from villages to cities has led to a decrease in the number of people engaged in agriculture and consequently a decrease in agricultural production. With the development of technology, many methods are being developed for sustainable agriculture such as increasing productivity in the agricultural sector, producing quality seeds, protecting natural resources, and saving labor and production costs. Digital technologies such as precision agriculture, autonomous systems, agricultural robots, artificial intelligence, drone use, and image processing techniques are at the forefront.

Keywords: Smart agriculture, Agricultural robots, Agriculture 4.0, Artificial intelligence

INTRODUCTION

The development of the agricultural revolution from the most primitive level to the present day has taken place gradually over time. These periods are referred to as Agriculture 1.0, Agriculture 2.0, Agriculture 3.0 and Agriculture 4.0. Agriculture 1.0 is considered to be the period in which traditional agricultural practices were used from ancient times until the end of the 19th century, when farmers used simple hand tools based on human and animal power. Agriculture 2.0 covers the period between 1780-1870 when tractors and agricultural machinery were used for tillage, irrigation, planting and harvesting (Liu *et al*. 2021). The Agriculture 3.0 period, also called “Precision Agriculture”, started with the use of computers and electronics in agriculture (Ahmad *et al*. 2021). Digitalization in the agricultural sector is called Agriculture 4.0. Sensors are installed on agricultural machinery used in agricultural production, enabling the machines to be connected and communicated with each other throughout the agricultural production process through the Internet of Things (IoT). Thanks to digitalization, data is collected with sensors and then analyzed. Thanks to the data obtained, it provides convenience to farmers by showing how much and what kind of fertilizer should be given to which areas, the water and minerals needed by plants, the moisture condition of the soil, the weather, the fight against diseases and pests, the estimated harvest time in detail and in real time. Cloud-connected mini unmanned aerial vehicles (drones) with cameras can monitor farms and fields and intervene promtly manner. This process reduces costs while increasing work efficiency (Kılavuz and Erdem 2019). In this way, quality and efficiency will be increased by saving time and labor in the agricultural sector.

DIGITAL AGRICULTURE WITH AGRICULTURE 4.0

The term "Agriculture 4.0" was first used by the Food and Agriculture Organization of the United Nations (FAO) in 2020 and refers to the modern age of agriculture enabled by advances in digital technology (Garcia *et al.* 2020). Agriculture 4.0 consists of many different digital technologies, including sensor technology, robotics and automation, artificial intelligence and big data analysis. Agriculture 4.0 includes weather and greenhouse,

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plant, soil, water and animal monitoring applications as well as smart greenhouses, fertilization systems, irrigation systems, weed, pest and disease control, harvesting and similar control applications (Araújo *et al.* 2021). Monitoring, fast and accurate decision-making, and timely intervention save time and costs. One of the main aspects of Agriculture 4.0 is the recognition of diseases through monitoring and data collection using mobile devices such as smartphones and cameras directly in the field (Megeto *et al.* 2020). Agriculture 4.0 has been a production process empowered by various tools and technologies that help agricultural professionals to be more productive and efficient. There has been a transition from a labor-intensive process to a knowledge-intensive process. The main arguments of the process are as follows (Pakdemirli *et al.* 2019).

- Not based on experience; based on experience + current data,
- Based on the area and the individual, not the population
- It is not based on similarity; it is based on difference.

The main objectives of Agriculture 4.0 are as follows.

- Reducing costs and increasing efficiency
- Managing the field or animal at the smallest scale
- To produce in accordance with the expectation or market.

In the Agriculture 4.0 process, the motto of integrated farm management is adopted in order to receive all kinds of data that can be taken from the field, to create a decision support mechanism, to use variable rate inputs, to develop self-deciding systems. Thanks to various algorithms, it is possible to store and analyze big data and to follow the whole process from field to table, to direct and to make future projections (Pakdemirli *et al.* 2019).

AUTONOMOUS VEHICLES AND AGRICULTURAL ROBOTS

The physical difficulty of agricultural labor, its repetitive nature, and rising labor costs have accelerated the adoption of robotics and mechatronics in agriculture (Mekonnen and Hoekstra 2016). Agricultural robots are generally classified as outdoor and indoor robots. Open field robots are GPS-assisted steering system, pasture robot, spraying robots, sowing/planting robots, silage robot, pruning robots. Indoor robots are harvest robots, milking robots, barn robots (Tekin and Değirmencioğlu 2010). In addition to providing economic benefits such as increasing efficiency and reducing waste along the food supply chain, agricultural robotics applications also provide significant societal and environmental benefits. Mechanical robotic weeding applications and precision sprayer systems that do not require or reduce the use of pesticides and herbicides also make a positive contribution to the environment by reducing herbicide use (Mathiassen *et al*. 2006). A study conducted by Uzun *et al*. (2018), put forward that autonomous harvesters can distinguish the stalk part of the products, autonomous tractors and agricultural machinery can be used for precise seeding by plowing the lands, sowing can be done at the most efficient point with the help of robots, and the labor rate can be reduced in the fight against weeds in the field. An autonomous robot developed by Astrand and Baerveldt (2002) is designed to detect weeds in a field. This robot has two different vision systems that can recognize the row of plants on the field and guide the robot along the row in the field. The first system is a gray-level vision system and is used to recognize rows of plants in the soil. The second system is a color-based vision system and is used to recognize a single plant among weeds. These vision systems control a weed tool designed to remove weeds from plant rows. The row recognition system, developed using a new algorithm, has been tested to control the movement of the robot with an accuracy of ± 2 cm.

DRONE USE IN AGRICULTURE

Drones are primarily used in the military field in border security, natural disasters, land mapping, construction infrastructure inspections, traffic inspections, landscape shooting and many other areas. It is used in agricultural applications by attaching sensors and cameras on it. Providing high-resolution pictures and 3D images in agricultural areas, it allows farmers to monitor the development process of plants and to spray and fertilize as needed. Thanks to these systems, crop growth can be monitored, plant species can be distinguished, yield can be determined and automated processes can be performed in various agricultural activities. In addition, drones can be used in many applications such as agricultural drought, disease and pest detection (Tan *et al*. 2015). A study conducted in the vineyard with a drone with multispectral and thermal camera, the water content of the vineyard was tried to be determined. At the end of the study, a relationship was found between the image indices obtained at the end of the study and stomatal conductance and stem water potential. As a result, it was determined that thermal and multispectral images using drones allow the assessment and mapping of the spatial variability of the water status in the vineyard (Baluja *et al*. 2012). With drones, the disease-pest ratio of plants and differences due to irrigation can be examined. Thanks to specially produced cameras, diseased and stressed plants can be examined. Drones are used worldwide not only for data collection but also for variable rate application to the desired area in the field thanks to their autonomous and programmable capabilities. Doing more work in less time with renewed technologies and developing application areas raise the importance of drones to higher levels over time (Bozdoğan *et al*. 2016).The use of drones in agriculture saves farmers time and costs. The use of drone systems in the agricultural sector is divided into 5. These uses are crop condition monitoring, monitoring irrigation systems, weed identification, variable rate applications, and herd management and monitoring (Grassi 2014).

Monitoring crop condition: Farmers can inspect their developing crops faster and more effectively with drones equipped with Normalized Difference Vegetation Index (NDVI) or near- infrared (NIR) sensors.

Monitoring irrigation systems: Large farms can monitor irrigation systems to ensure the supply of water needed after some crops, such as maize, have reached a certain size and spread over large areas.

Weed identification: Weed maps are created by processing NDVI sensor data and post-flight imagery. With this map, farmers can identify the areas of weeds growing with the crops they grow in their fields.

Variable rate applications: Instead of variable rate application maps made with ground-based or satellite images, variable rate maps are prepared quickly and practically by using NDVI sensors in drone systems. In this way, increasing yields by reducing pesticide and fertilizer costs is possible.

Herd management and surveillance: Drones can be used to monitor the number and activity of free-roaming cows or sheep from above, which can be used to detect sick animals.

IMAGE PROCESSING TECHNIQUE IN AGRICULTURE

Image processing technique involves transferring the images of objects to the computer environment and processing them by computer in line with the specified target. With the use of these techniques, many studies such as disease, pest and weed detection, plant identification and detection, determination of plant stresses, yield estimation, determination of inter-row and over-row distances in the field, evaluation of plant growth, determination of soil moisture in plant production, monitoring of animal development in herd, lameness detection, monitoring of body temperature, etc. are carried out. (Altaş *et al*. 2019). This technique provides sustainability in agriculture by increasing efficiency in agricultural applications. With the help of optical sensors placed on the drones, crop quantity estimation and efficient use of land can be ensured. By using image processing methods on the field images taken from the satellite, problematic areas in the fields are identified and producers can focus on these areas. Thus, good yields can be obtained with smart irrigation and fertilization. By determining the yield of the regional or general crop cultivation area in the field, the harvest times of the products can also be estimated. Thanks to smart agriculture applications, humidity and temperature measurements of the air and soil in the region where the field is located are input to machine learning algorithms via GSM connection in real time and interpreted on Internet of Things applications (Tamura *et al*. 2018). Altaş *et al*. (2018) conducted a study to determine the level of sugar beet leaf spot disease (Cercospora Beticola) with image processing technique using a drone. The images taken by a DJI Phantom 3 Advanced drone from an area of approximately 200 m² where the disease was seen intensively in a local farmer's field where sugar beet was grown were processed using the Image Processing Toolbox module of the R2014a version MATLAB program. Leaf spot disease in sugar beet is detected by observations made by plant protection experts. It was tried to determine whether there is a disease on sugar beet leaves, if there is a disease, the stage of the disease and the spread of the disease by proportioning the dead areas seen depending on the severity of the disease to the leaf area. In the study, the images taken using the camera attached to the drone were processed with image processing algorithms and diseased areas were detected.

THE USE OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

Artificial intelligence involves deep learning consisting of artificial neural networks that mimic human brain functions. Artificial Intelligence, as a form of intelligence that can perform tasks such as seeing, learning, understanding, planning, acting and communicating similar to humans, covers predictive analytical categories that can be used in the agricultural sector for disease, soil management, pest and weed management, crop management, water use management, nutrient deficiency determination, crop analysis, and monitoring and prediction of environmental impacts and serves sustainable production (Ryan *et al*. 2023). Partel *et al*. (2019) designed and developed a smart sprayer using machine vision and artificial intelligence to distinguish target weeds and cultivated plants and spray precisely on the desired target. The sprayer includes machine vision software that uses deep learning to detect weeds in a given target and hardware with 12 separate short response nozzles for spraying. Overall, the smart sprayer sprayed only on the target (weeds), distinguishing between weeds (target) and pepper plants (non-target). A study carried out by the Central Research Institute of Agricultural Control with the project number TAGEM-BS-12/12-01/01-03, a prediction warning system study was carried out using artificial intelligence in the fight against the important pest of wheat, the common looper. In this study, the relationship between all biological periods and life cycles of the common fly and climatic data was revealed, a prediction-warning system that determines the time to fight against the common fly with the least error was created by using artificial intelligence techniques as a basis for the struggle, prototype software was made and the reliability of the software was tested in Aksaray and Kırşehir provinces for two years (Pakdemirli *et al*. 2019).

CONCLUSIONS

As a result, for sustainable agriculture, factors such as food safety, product quality, protection of natural resources, labor and time savings, and cost reduction are very important in addition to product efficiency. With the use of digital technologies in agriculture, it is necessary to make maximum use of the agricultural potential by integrating all stages of the information and communication technologies value chain into agriculture (Pakdemirli *et al*. 2019). To prevent foreign dependency in the agricultural sector and to compete with other countries, R&D studies should be increased, successful project examples should be supported and disseminated. In addition, to reduce rural-urban migration, the income level of rural people engaged in agriculture should be improved, agricultural lands should be consolidated and production should be revitalized. The importance of agriculture should be explained to future generations and support and incentives should be given to those who establish businesses and produce in the field of agriculture.

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