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Robotics and Automation Applications in Agriculture: A Review

Ahmet Murat Asan[a]

[a]*Dicle University, Department of Mechanical Engineering, Diyarbakir, Turkey.*

A B S T R A C T

The agricultural sector requires sustainable production methods due to the challenges posed by a growing population and climate change. Traditional agricultural methods are insufficient to meet this need due to labor shortages and low productivity. In this context, robotic systems and automation applications play a critical role in the transformation of modern agriculture. The literature examines studies on harvesting robots, weed control systems, irrigation and fertilization automation, drone applications, artificial intelligence, and big data-based solutions. The findings demonstrate that these technologies both increase production efficiency and support environmental sustainability. The purpose of this review is to summarize the current status of robotic and automation technologies in agriculture, examine prominent applications, and discuss future research directions.

Keywords : Robotics in agriculture, Automation, Precision agriculture, Artificial intelligence, Internet of Things (IoT), Drone technology

1. Introduction

The agricultural sector is of strategic importance for global food security and faces increasing demand due to population growth and climate change. Traditional methods are inadequate due to labor shortages and efficiency problems. At this point, robotic systems and automation applications play a key role in the transformation of modern agriculture. When the main studies on this subject in the literature are examined; Regarding harvesting robots, the use of harvesting robots is becoming widespread especially in fruit and vegetable production. Cai et al. (2024) developed an AGV (Automatic Guided Vehicles)-based cherry tomato harvesting robot and achieved over 80% success in product detection [1]. In a more recent study, Xiong et al. (2019) developed a robot to harvest strawberries (Fragaria × ananassa) grown in polyethylene tunnels [2]. The robot successfully picked strawberries with 96.8% success in an isolated environment and 53.6% success in a farm environment. Wang et al. (2023) designed a YOLOv5-based model for detecting cherry tomatoes [3]. Herbiside applications used to eradicate weeds from agricultural environments carry environmental risks. Using technology instead of applying chemicals to agricultural land is more environmentally friendly. In studies on weed control; Wu et al. (2020) used a non-overlapping multi-camera system to control weeds. Their experimental results show that the proposed system can perform weed removal in different field conditions and crop growth stages [4]. A robot developed by the German company Naiture was used in weed control in the field. It was reported that the robot's detection system can distinguish crops such as carrots, beets or spinach from weeds [5]. Due to the impact of climate change on agriculture and the emergence of water security problems, proper irrigation management has become increasingly important to overcome these challenges, and significant advances have been made in irrigation and fertilization automation. Some of the main studies in this field are as follows; Dong et al. (2024) developed an Internet of Things (IoT)-based sensor station, a user-friendly website, and a smartphone application for irrigation management. Consequently, they found that an IoT-based sensor-based irrigation strategy can provide savings of up to 30% on irrigation while maintaining yield and crop quality [6]. Similarly, nutrients are optimized and overuse is prevented through fertilization automation. Mulero et al. (2023) performed a technical and economic evaluation of a high-tech irrigation head that uses a new fertigation optimization tool designed to manage feedwater of different qualities. They found that fertilizer savings of up to 40% were achieved by using this tool [7]. Drones are widely used for field observations, plant health monitoring, and spraying. Reddy et al. (2025) investigated the effectiveness of drone-assisted crop monitoring in precision agriculture by evaluating the relationships between NDVI, leaf area index (LAI), and leaf nitrogen content (LNC) in three wheat cultivars (DBW-187, HD-3086, and PBW-826) under eight nitrogen treatments (N0–N210). They found that the use of drones increased crop yields [8]. Machine learning and big data analytics increase the efficiency of agricultural robotic systems. Through AI-supported analyses, early detection of diseases or nutrient deficiencies can be achieved, enabling proactive measures to be taken. This reduces dependence on chemicals and results in healthier crops [9]. This review aims to examine and discuss the current status of robotic and automation technologies in agriculture, prominent applications, and future research directions.

* *Corresponding author*. Tel.: +905362931704
E-mail address: ahmetmurat.asan@dicle.edu.tr

2. Discussion

The reviewed studies clearly demonstrate that robotic systems and automation technologies have the potential to increase efficiency in agricultural production. The introduction of harvesting robots, particularly in fruit and vegetable production, reduces labor requirements and speeds up the harvest process. However, as observed by Xiong et al. (2019) in strawberry harvesting, the decline in performance in field conditions despite high success in controlled environments highlights challenges regarding the technology's field compatibility. Similarly, while camera-based systems and autonomous robots developed for weed control offer environmental advantages, they can exhibit performance differences under different climate and terrain conditions. Studies on irrigation and fertilization automation contribute significantly to more efficient resource use and cost reduction. Irrigation management using IoT-based sensors saves up to 30% water, and fertigation systems reduce fertilizer use by up to 40%, clearly demonstrating the economic and environmental benefits of these technologies. Furthermore, drone-based observation and machine learning algorithms are seen to offer significant contributions to crop health monitoring and early disease detection. All these findings suggest that robotics and automation technologies in agricultural production can contribute to increasing productivity in the short term and supporting the transition to a sustainable and environmentally friendly agricultural structure in the long term. However, it is clear that widespread adoption of these technologies requires consideration of factors such as cost, technical infrastructure, farmer training, and site compatibility.

3. Conclusion

This review has outlined the current status, prominent applications, and future research directions of robotics and automation technologies in agriculture. The findings demonstrate that these technologies offer significant advantages in reducing labor requirements, optimizing resource utilization, and contributing to sustainable agricultural production. Furthermore, improving field performance, reducing costs, and developing user-friendly systems should be the focus of future research. Ultimately, the widespread adoption of robotics and automation technologies in the agricultural sector presents a strategic opportunity for global food security.

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