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Mini Review

The Use of Autonomous Robots to Address Labor Demands and Improve Efficacy in Agriculture

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ISSN: 2832-4463

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Submission: January 03, 2022
Published: March 03, 2022

Volume 1 - Issue 5

How to cite this article: Bernard GC*, Bolden-Tiller O, Egnin M, Bonsi C, McKinstry A, et al. The Use of Autonomous Robots to Address Labor Demands and Improve Efficacy in Agriculture. COJ Rob Artificial Intel. 1(5). COJRA. 000523. 2022. DOI: 10.31031/COJRA.2022.01.000523

Abstract

Agricultural robots, or agribots designed for agricultural purposes, are becoming essential tools to improve efficiency by addressing critical constraints such as labor shortage, agricultural input and cost, and environmental monitoring. The incorporation of autonomous tools like crop propagation Farm BotTM and Terra SentiaTM field bot can improve agricultural production schemes by meeting specialized labor demands and providing field data analyses; thus, advancing numerous aspects of precision farming, potentially lowering production costs and reducing environmental impacts. These technologies are integrated with advanced detection and analytical methodologies to develop growth monitoring models to improve overall performance under precision farming protocols, supporting sustainability.

Farmer Demographics and Labor Constraints

Currently, small-scale farmers (less than $350,000 in gross cash farm income) comprise 90 percent of all U.S. farms [1]. White farmers (including Hispanics) account for 95.4% of this group, while Hispanic or Latino farmers make up 3.3% of producers, followed by 1.7% identified as American Indian or Alaskan Native and 1.3% Black. One of the significant constraints faced by these farmers is labor costs, which can represent up to forty percent of the total variable costs for vegetable and fruit crop production [2]. A recent survey conducted by the California Farm Bureau Federation reported that 55% of responding farmers had experienced employee shortages, including 69% of farmers who hire due to seasonal needs [3]. Labor shortages are more impactful to farmers who require more exhaustive hand labor in production and harvesting, for example, for orchard and grape farmers. Improved labor-management strategies, thus, have become critical for the long-term sustainability of farms, especially for small-scale farmers that face increasing resource constraints and prohibited use of alternative labor sources (e.g., foreign workers) [4].

Agricultural Robots

Agribots are autonomous, decision-making, mechanized technologies that perform routine and specialized tasks in agricultural production schemes under human supervision without direct human labor [5-7]. Autonomous crop equipment (also known as crop robots) can potentially address labor constraints, global food security and reduce the environmental footprint of agriculture [5,8,9]. Additionally, in the U.S. and U.K, farm labor has decreased significantly due to the COVID-19 pandemic [10] and the restriction to address its transmission. Incorporating robots and autonomous farming into precision farming protocols for the modern farmer was envisioned long ago [7]. Autonomous robots, including "farm bots" and "field bots," are equipped with cameras, sensors, and mechanical arms (field bots) to help identify potential areas of concern in farming production, including disease monitoring, water management, and nutrient availability, as well as harvesting. The Farm Bot (Figure 1), developed by Rory Aronson et al., is an open-source precision agriculture tool equipped with a camera and several tool-mounts for planting, weeding, soil moisture sensing, watering, and data collection through sequence programming. Strawberry harvesters developed by Harvest Croo Robotics are designed to mechanically pick a 25-acre field within three days, potentially replacing a labor crew of about 30 workers (HCR, 2021). Automation is well-integrated into industrial livestock production compared to the adoption of autonomous machines for crop production, which is still in its infancy [7].

Figure 1: The Farm Bot Tool was developed by Rory Aronson, Rick Carlino, and Tim Evers.

Panel A: Farm Bot Genesis XL is an open-source precision agriculture tool providing autonomous farming and data collection through sequence programming.

Panel B: Tuskegee University Undergraduates assemble the Farm Bot (AI FARMS, USDA, NSF funding) currently housed in the Carver Phyto Research Unit housed within the G.W.C. Ag. Experiment Station, Tuskegee University, Tuskegee, AL

Agricultural Robots and Precision Farming

New developments in agricultural automation are currently underway to improve phenotypic assessment and harvesting during agricultural production. Terra Sentia (Figure 2) is a field rover developed by Dr. G. Chowdhary and Chinmay Soman (Earth Sense), utilizing onboard sensors and cameras, LIDAR, and GPS to autonomously collect data on physical parameters on crops to assess overall plant health through cloud-based data analysis and phenotypic evaluation. Such information can be tremendously valuable in precision farming while providing labor with potential reductions in input/production costs. Weed management is often associated with chemical herbicides, resulting in environmental impacts. Autonomous robots are currently under investigation as a viable method of mechanical weed control (McCallister et al. 2019) which may reduce the use of chemical control agents, thus supporting environmental resilience.

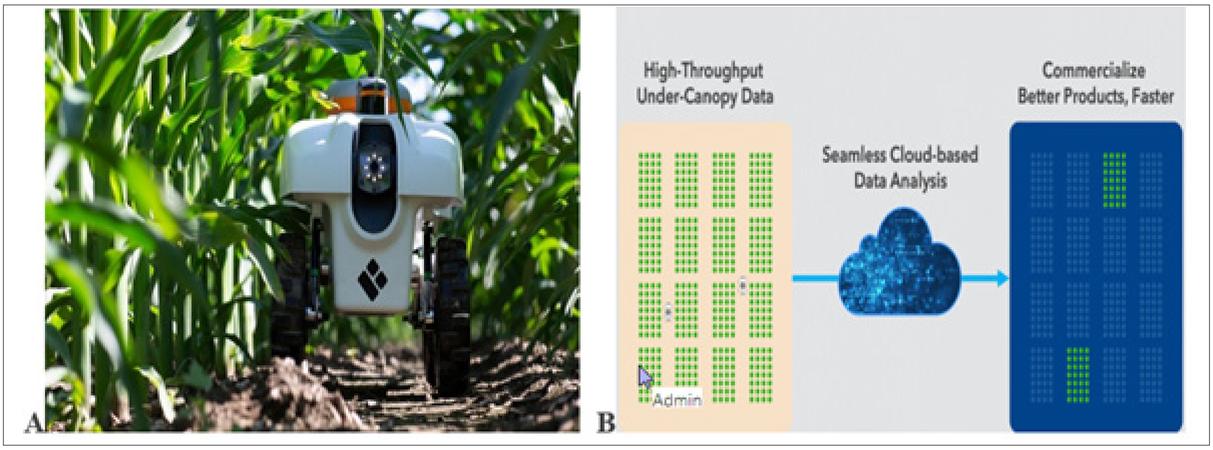

Figure 2: The Terra Sentia field rover.

Panel A: Field activity of the Terra Sentia field rover equipped with cameras, LIDAR, and global positioning software.

Panel B: Example of data output and analysis.

Source: courtesy of https://aces.illinois.edu/ and https://www.earthsense.co/

Conclusion

Implementing autonomous farming tools has become imperative with increasing labor costs as producers face increasing imported produce competition. The integration of these technologies may benefit organic crop yields that are often lower than conventional crop yields and reduce the environmental footprint by decreasing carbon emissions and chemical use. Adopting current and emerging autonomous tools leveraging new cost-effective labor-management strategies with innovations in precision farming protocols is becoming increasingly crucial for small-scale farms to remain viable in the future [4]. Incorporating these disruptive technologies may promote agricultural sustainability and produce a new generation of highly skilled agricultural workers for local and global food security through improved precision farming practices [11-14].

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