STUDY ON AGRICULTURAL SUSTAINABILITY USING RPA

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Abstract

Agriculture is the primary food, feed, and fiber source for human survival. Agricultural sustainability is increasingly critical in the face of global challenges such as climate change and food security. This study focuses on applying automation technologies to boost productivity, maximize the use of resources, and promote sustainable and economically viable agricultural practices. This review paper examines the role of RPA technology in promoting sustainable agricultural practices. The analysis encompasses various applications of RPA, including crop monitoring, disease detection, yield estimation, and resource management. It discusses the types of cameras and sensors used in RPA, such as multispectral, thermal, and visible, and highlights the importance of vegetation indices (VIs) in providing essential crop data. The review synthesizes recent research findings, showcasing how RPAs enhance precision agriculture by enabling efficient and targeted interventions, thus reducing environmental impact while maximizing productivity. Additionally, the paper addresses the economic considerations, efficiency, and limitations of RPA technology, providing insights for future research, policy development, and investment strategies. The findings suggest that integrating RPA into agricultural practices offers significant potential for advancing sustainability goals.

Keywords: RPA, Sustainable Agriculture, Automation, AI, Drone.

1. Introduction

Agriculture today relies largely on engineering, technology, and biological and physical sciences. Agriculture has become more efficient and productive due to the automation of many laborious tasks [1]. Innovations in agricultural operations are required to ensure sustainability in light of the growing global population and the resulting rise in food consumption. The application of robotic process automation (RPA) to agricultural systems is one example of such innovation. With RPA, routine and highly repetitive tasks that are typically completed by humans are automated through the use of software robots, or "bots." Planting, crop monitoring, irrigation, pest control, harvesting, and data analysis are some of the tasks involved in agriculture. The three pillars of sustainable agriculture are environmental conservation, social equity, and economic profitability.

These pillars can be supported by RPA by automating labor- and resource-intensive procedures. Because of manpower shortages and inefficiencies, traditional farming methods are becoming less and less effective. The RPA if integrated with other digital technologies, like Artificial Intelligence and IoT, can further enhance its potential by making data collection and decision-making possible in real-time. The integration of RPA with precision agriculture technologies such as GPS, IoT, and data analytics enables precise control over agricultural inputs, leading to reduced waste, improved crop yields, and better resource management.

With the advent of smart farming technologies, the role of autonomous vehicles, drones, and robotic systems has expanded significantly. These innovations make it easier to monitor and manage agricultural operations, ensuring timely interventions and efficient resource utilization. This review article looks at the current state of agricultural sustainability through the lens of RPA, investigating its applications, benefits, and problems.

This paper attempts to thoroughly explain how RPA can promote sustainable farming practices by synthesizing recent research.

The following sections will delve into specific applications of RPA in agriculture, the technological advancements driving these applications, and the potential barriers to widespread adoption. Through this analysis, the paper seeks to highlight the transformative potential of RPA in fostering a sustainable agricultural future.

2. Applications of RPA in Agriculture

The fields of agriculture and robotic process automation (RPA) are coming together more and more to improve farming's sustainability, efficiency, and productivity.RPA has been extensively used in various agricultural applications, demonstrating their versatility and potential to enhance farming practices. Key applications include:

2.1 Planting

Planting is the act of putting seeds or young plants into the ground in preparation for the growth stage of the plant. Higher levels of precision are needed for this procedure since different plants need to be spaced apart to maximize output while also promoting optimal growth.

A farmer must manually plant each seed in the ground using the traditional method. This method takes a lot of time and effort since it involves a process that often covers a large agricultural area and demands a great deal of uniformity and precision. For this reason, A planter machine has been developed that allows the farmer to simultaneously sow seed in the soil and operate the equipment.

An autonomous planting technique has been implemented for various crops, including corn. wheat, sugarcane, and vegetables [2]. These systems incorporate advanced technologies such as sensors, GPS, and machine vision to enhance planting precision and efficiency.

2.1.1 Corn Planting

Various autonomous systems have been introduced for corn planting. Notably, an infrared (IR) sensor was used to monitor seed tank conditions and identify planting rows in an autonomous seeding robot that was created utilizing the Agribot platform.

This system demonstrated satisfactory distance accuracy between seeds. Seed metering units have been developed to ensure planting consistency, with a notable improvement in fuel efficiency by approximately 22%. A GPS-based variable-rate seeding control system was found to be a cost-effective solution, achieving an average seeding accuracy of 97.64%[2]. A seed and fertilizer control system has been developed by integrating the Global Navigation Satellite System (GNSS) and the Inertial Measurement Unit (IMU) sensing technologies. It has been shown that this application is effective, with a maximum inaccuracy of 4.91% at 5.8 km/h[3].

2.1.2 Wheat planting

Chickpea, wheat, and alfalfa seed sowing rates in planters are measured using an infrared sensing device that was designed using photo diodes and infrared light emitting diodes (IR LEDs) [5]. The analog output from the light-receiving sensors is transformed for precise planting control.

2.1.3 Sugarcane Planting

The development of seed metering units for sugarcane has shown significant advancements in planting quality and efficiency, contributing to improved fuel savings and operational accuracy [6].

2.1.4 Vegetable Planting

Autonomous systems for planting vegetables have been explored, with technologies focusing on precision seeding and variable-rate applications to optimize planting processes [7].

2.1.5 Technological Innovations in Autonomous Planting

High-speed cameras, such as the Fuji F660EXR, are used to monitor seed trajectories and ensure uniform seed spacing. This technology enhances planting accuracy, particularly at higher operational speeds[4].

2.2 Crop Monitoring and Health Assessment

Critical crop health data is provided by drones fitted with multispectral, infrared, and visible cameras. This enables prompt interventions to address problems including nutrient deficits, pest infestations, and disease outbreaks.

RPAs have been projected for phenology, growth tracking, plant counting, and chlorophyll measuring, among other potential uses.

Additionally, RPAs are incredibly effective in monitoring crops, particularly in steep regions that would be difficult for traditional scouting to cover [10]. Fig. 1 shows an example of a drone with sensors and NIR that collects data from plants, weeds, and soil.

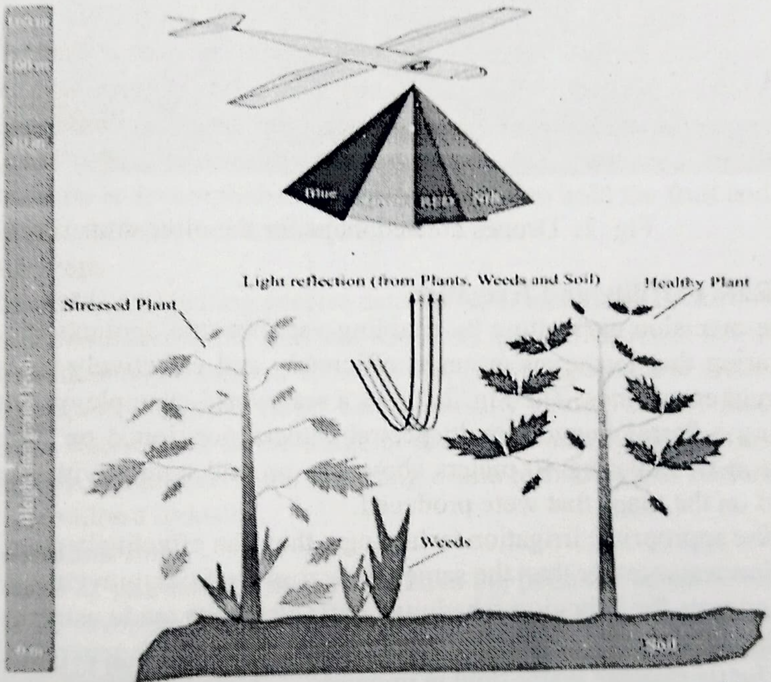

Fig. 1: Drone with sensors and a multispectral camera (with NIR and RGB bands).

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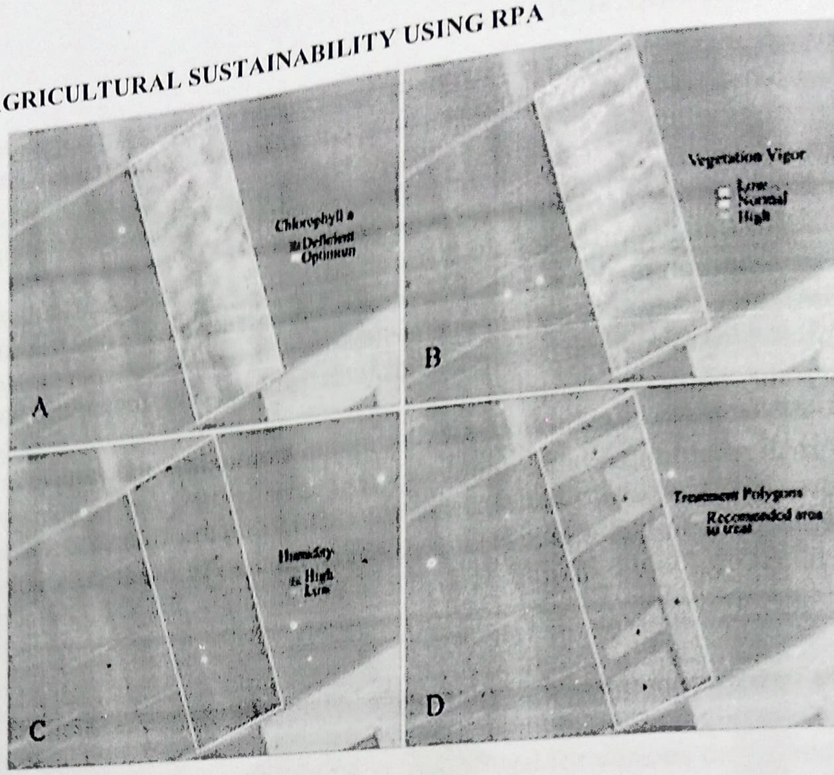

Fig. 2: Drones created maps for the olive crop

2.3 Variable-Rate Fertility and Irrigation

RPAs facilitate precision agriculture by enabling variable-rate applications of fertilizers and irrigation, ensuring that resources are used efficiently and effectively based on the specific needs of different crop zones. The Fig. 2 shows a real-world example of data collected for an olive field using a Parrot Sequoia multispectral camera positioned on a hexacopter drone - Yuneec Typhoon H, hovering 40 meters above the ground, along with suggested treatment locations based on the maps that were produced.

If farmers use the appropriate irrigation technology, they can effectively choose to use different rates of irrigation water rather than the same rate across the field, preventing water waste.[10]. In addition, proposals for irrigation scheduling have also been made using drone data.

RPAs can help detect uneven water absorption and leaks, and generate 3D maps of land topography to better manage water flow in orchards.

2.4 Disease and Pest Surveillance

The ability of drones to cover large areas quickly makes them ideal for monitoring disease spread and pest populations, enabling early detection and management to prevent significant crop losses.

2.5 Soil and Field Analysis

RPAs contribute to soil health monitoring by capturing high-resolution images that can be used to assess soil properties and field conditions, guiding soil management practices and crop rotation decisions. One efficient and green method of managing crop leftovers is to use RPAs to spray decomposing microbial mixtures on them [10].

2.6 Spraying Fertilizers

The main issue with agrochemical spraying is contamination, which poses a risk to human health if appropriate precautions are not implemented. The development and widespread usage of robotic sprayers is occurring in orchards, which include grapes, cherries, apples, and to some extent, greenhouses.These sprayers are developed for target-oriented applications and to enhance input use efficiency [11].

A path toward sustainable agriculture is made possible by the use of RPAs in fertilizer application. When compared to alternative approaches, their operating rate is both cheaper and faster [10].

2.7 Weeds Management

Farmers frequently experience the challenge of not realizing the severity of the weed infestation until after they have harvested their crops.

This issue can be effectively handled by using drones to locate increased weed growth intensity zones and set them off from productive agricultural areas. Additionally, timely weed removal has been suggested as a useful use of RPAs to prevent crop resource depletion.

Two main obstacles stand in the way of using drones to map weeds: (a) separating weeds from crops and bare soil, and (b) distinguishing between the two. To get around these, pre-defined sampling zones are used to extract three different sorts of spectral values: weeds, crops, and bare soil. Data collected by agricultural RPAs can also be used to identify weeds that are resistant to herbicides. Moreover, field robots can be instructed to pull weeds using RPAs[10].

2.8 Harvesting

Efficient harvesting requires not only detachment but also fruit selection. The majority of robotic harvesters are designed to harvest fruits such as strawberries, cherries, citrus, apples, and so on [11]. Nonetheless, a few harvesters were also created for crops like tomatoes and capsicum that are cultivated in greenhouses.

The harvesting of fruits is accomplished by using grippers to hold the fruit and then removing it based on shape, size, colour, and texture[11].

2.9 Insurance for crops

Surveying the vast fields and getting precise data for insurance firms is extremely challenging in a natural disaster. Insurance firms find that RPAs are quite effective in helping them to rank the proportion of field damage, such as 70% or 90%, following a natural disaster [10].

They help to significantly shorten claim time limits by saving lots of labor and material resources. There are also reports of the usage of drones for surveying insurance corporations and state governments. Insurance firms are using drone technology to further their financial objectives in the agriculture industry.

2.10 Mechanical Pollination

One use for robots is as pollinators. Bee robots have the potential to assist real bees, even if they might not be all that helpful. Recently, a startup in New York developed a pollen dump drone that is expected to pollinate crops, such as apples, cherries, and almonds, with high hopes for upcoming sales[10].

In a similar vein, some fruit growers are optimistic about the potential use of RPAs in their orchards[10].

2.11 Livestock Management

Beyond crop farming, drones are also utilized in livestock management for monitoring animal health, behavior, and pasture conditions, which helps in optimizing grazing patterns and ensuring the well-being of livestock. Automatic milking systems (AMS) or milking robots have recently sparked interest on a global scale. In 1992, the company Lely installed AMS in a project in its native Netherlands [9].

3. Agricultural Sustainability

Agricultural sustainability involves a comprehensive strategy that incorporates social, economic, and ecological aspects to ensure that agricultural practices can be maintained over the long term without depleting resources or harming the environment [12]. Key elements of agricultural sustainability include:

3.1 Ecological Aspects

Maintaining the health of ecosystems by preserving biodiversity, reducing pollution, and enhancing soil quality. This includes practices that promote the natural balance and resilience of ecosystems.

3.2 Economic Viability

Ensuring that farmers can profitably engage in agricultural techniques. This involves achieving a balance where farm incomes are stable and not overly reliant on external subsidies, while also being efficient and adaptable to changing conditions.

3.3 Social Equity

Addressing the well-being of all participants in the agricultural system, including fair labor conditions, health, and access to resources. It also involves community integration and maintaining cultural and social values related to farming.

The goal of agricultural sustainability is to create systems that are resilient and capable of enduring through various challenges, while providing for current requirements without sacrificing the capacity of future generations to satisfy their own.

Sustainable agriculture is crucial to preserve ecosystem health and guarantee the long-term sustainability of farming activities. It involves methods that safeguard human communities, the environment, public health, and animal welfare.

Adopting sustainable practices can boost biodiversity, lower greenhouse gas emissions, improve soil health, and increase resilience to climate change. Moreover, sustainable agriculture supports local economies by providing jobs and generating income for rural communities.

4. Impact of RPA on Agricultural Sustainability

RPA can play a pivotal role in advancing agricultural sustainability by automating tasks that are labor-intensive and prone to human error. For instance, automated systems can optimize irrigation schedules based on real-time weather data, ensuring efficient water use and reducing wastage. Similarly, RPA can be used for precision planting and fertilization, which enhances crop yields and minimizes the use of agrochemicals.

Additionally, RPA can facilitate better monitoring and management of livestock. Automated systems can track animal health, manage feeding schedules, and even assist in breeding programs. This not only improves animal welfare but also enhances productivity and profitability for farmers. RPAs have revolutionized agriculture by providing detailed aerial imagery and data collection capabilities that traditional methods cannot match. Their applications in agriculture comprise irrigation management, disease surveillance, soil analysis, and crop monitoring. These applications significantly support the use of sustainable farming methods by enabling precise and timely interventions.

5. Challenges and Future Prospects

It is anticipated that the worldwide market for agricultural robotics and automation systems will increase to USD 40.1 billion by 2028 from USD 13.5 billion in 2023[2].

Increasing labor shortages, population increase, and the need for high productivity have made it possible for agricultural automation and robotics to advance.

Despite the numerous benefits, the adoption of RPA technology in agriculture faces several challenges.

These include the high cost of equipment, the need for technical expertise, and regulatory hurdles. Additionally, there is an absence of standardized protocols for gathering and analyzing data, which may have an impact on the reliability of the information obtained from RPAs.

A few farmers are hesitant to spend their money on technology that could not pay off in the long run. As a result, agricultural researchers must come up with concepts for creating an affordable, multipurpose agricultural robot.

A very resilient modular robotic design is one idea that might be applied to the creation of agricultural robots.

Many agricultural practices have different operational mechanisms and procedures, it is advised that the robot's structure be readily removable and interchangeable with alternative structures in accordance with the operation's particular needs. Therefore, to finish all agricultural tasks, from planting to harvesting, farmers just need to invest in a single primary robotic system with various detachable structure kinds. Because the farmers won't need to purchase separate robots for each sort of agricultural job, the investment cost will be significantly reduced as a result.

Advancements in technology and increased affordability of RPAs are expected to drive their adoption in the coming years. The development of more user-friendly interfaces and automated data analysis tools will make it easier for farmers to integrate RPAs into their operations. Furthermore, ongoing research into improving sensor accuracy and data processing algorithms will enhance the effectiveness of RPAs in agricultural applications.

6. Conclusion

The use of drone technology to agriculture offers significant potential for enhancing sustainability. By providing precise and real-time data, RPA help farmers make informed decisions that improve crop yield and quality while minimizing environmental impact. Although challenges remain, continued advancements in RPA technology and supportive policies will likely accelerate their adoption, paving the way for more sustainable agricultural practices. This review underscores the importance of integrating RPAs into agriculture to meet the growing demand for food production in an environmentally sustainable manner.

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