IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 12, April 2026
Impact Factor: 8.2

Smart Dual-Action Liquid Delivery System for Precision Agriculture Using Root Depth-Based Control

Pranali Dnyaneshwar Thite and Paras Prakash Jadhav
TY ENTC Students
SVERI's College of Engineering, Pandharpur, India

Abstract: *In standard agricultural practices, fertiliser and herbicides are applied indiscriminately to the soil in order to lead to an increase in both weed and crop growth, however, the overuse of these chemicals results in a decrease in the long-term productivity of the land by degrading the soil and may therefore negatively impact the development of crops as well. This industry standard practice leads to excessive use of chemicals; has increased operating costs (due to the high cost of fertilisers/herbicides); and decreased productivity of land (as a direct result of chemical usage). The invention described here is a Smart Dual-Action Liquid System to be used for precision agriculture applications. The Smart Dual-Action Liquid System consists of a combination of various types of sensors that measure soil moisture levels, pH levels, and temperature levels, plus an optional vision sensor used to indirectly measure the root zone characteristics. The Smart Dual-Action Liquid System uses a microcontroller- based control unit to process the data provided by the soil moisture levels/sensors, pH levels/sensors and temperature levels/sensors, plus the optional vision sensor, to determine when to dispense liquids through electronically-controlled microvalves or drip devices in targeted (micro-doses to deliver maximally-nutrient-filled liquid to deep root zones of plants) or specifically (deliver weed-inhibiting liquid to root zones of weeds). In addition, the Smart Dual-Action Liquid System has a built-in feedback mechanism that continuously monitors plant and soil responses, allowing the system to be adjusted as need to accommodate changes to the plants and/or soils. Overall, the Smart Dual-Action Liquid System reduces the total amount of chemicals used in the system; conserves water; preserves soil health; and maximizes productivity in plants, thereby providing businesses with a cost-effective and environmentally-sustainable solution for precision agriculture.*

Keywords: Precision Agriculture, ESP32, Smart Irrigation, Weed Control, IoT, Soil Sensors

I. INTRODUCTION

Agriculture is still the foundation of the global economy and is essential to food security, particularly given the rapid increase in world population. The demand for more and better-quality crop yields has resulted in an increased reliance on the use of chemical fertilizers and herbicides to produce more crops and manage weeds. The traditional methods used by farmers result in uniform application of chemicals across a given area, which is not always compatible with the specific crop type or weed situation. Uniform application will lead to more challenges such as high levels of chemical use, high production costs, negative impact on the environment, and long-term loss of soil health.

Recently, precision agriculture has developed into a new way to address these issues. Precision agriculture approaches the management of agricultural production from the basis of using only the amount of resources that are needed for each specific production area. Advanced sensors, embedded systems, and IoT technologies allow for better management and monitoring of agricultural production parameters using real-time information. Although this type of technology is being used, many precision agricultural systems are still focused on surface monitoring only and they currently do not have the ability to differentiate between crop plants and weeds at the roots.

A significant disadvantage of this type of system is that they lack the use of sophisticated sound science to manage weed and crop production. This study suggests a Smart Dual-Action Liquid Delivery System that uses the Internet of Things (IoT) technology. The system is intended to improve precision farming through targeted delivery of liquid nutrients to crops based on root zone depth. The components of the proposed system include soil sensors, a microcontroller (ESP32/Arduino) and an automated liquid delivery mechanism. The system is capable of determining whether the root zones of plants are shallow or deep by using soil moisture, pH and temperature measurements taken at different depths to estimate the characteristics of the root zones and to make real time decisions regarding selective application of liquid. With this system, nutrients will be delivered in liquid form directly to the root zones of crops to promote growth and productivity; and a temporary weed suppression liquid will be used to control shallow invasive weed roots so they will not have a permanent impact on the soil structure. The dual action aspect of the system maximizes the efficiency of chemical use while also enhancing resource utilization. In addition, the system uses closed loop operation through continuous collection of data with respect to soil conditions and constantly adjusting its actions as needed in order to optimize performance. This new approach has the potential to significantly advance smart farming by integrating electronics and telecommunications engineering principles with agricultural sciences. It can ultimately benefit our environment.

II. PROBLEM STATEMENT

Agriculture depends mostly on efficient usage of resources such as water, fertilizers and herbicides. Yet, due to the lack of precision with traditional farming systems farmers spread all the inputs automatically over the entire area of their farms without consideration for the unique needs of each plant or the variability of soil conditions. This lack of precision then leads to a range of serious problems that reduce productivity, increase costs and adversely affects environmental sustainability.

One major issue is that the general use of fertilizers supports crop growth but also inadvertently enhances the growth of weeds. Weeds compete with crops for nutrients, therefore reducing total yield. In addition, the increased growth of weeds leads farmers to use increased herbicides, both of which increases the costs of production and creates a dependence on chemical farming.

Another major issue has to do with the excessive use of herbicides. Although intended solely to control the growth of weeds, the general use of herbicides also adversely affects the growth of crops, beneficial soil microorganisms and soil health. Continuous use of chemical herbicides causes long term damage to soils, diminishes soil fertility and adds to the accumulation of toxic waste in soils and waterways.

Traditional farming systems also lack real time monitoring and the ability to make intelligent decisions. Farmers typically rely on manual monitoring or preset schedules for regulating irrigation and fertilization, rather than taking advantage of advances in internet connectivity, sensor technologies and data analytics to create precision agriculture systems.

An additional major shortcoming of existing agricultural systems is the inability to tell the difference between crop roots and weed roots, especially the ones that lie below the surface of the soil. Most of the current smart agricultural solutions only collect data at the surface and do not take into consideration the differences in depth of roots and therefore cannot accurately target products to treat weeds and crops accordingly. This is primarily because weeds have shallow root systems compared to crops whose roots tend to be deeper.

III. LITERATURE SURVEY

Kumar et al. (2020)

Reviewed IoT-based precision irrigation systems and highlighted the importance of sensors such as soil moisture, temperature, humidity, and pH for real-time monitoring. Their study emphasized that IoT platforms can automate irrigation and reduce human effort, but they mainly focus on water management rather than selective nutrient or herbicide application.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 12, April 2026
Impact Factor: 8.2

Aisyah et al. (2024)
Developed an ESP32-based smart irrigation system using soil moisture and environmental sensors. Their system maintained optimal soil moisture levels between 30–50%, demonstrating efficient water usage and improved plant growth. However, the system lacked advanced decision-making for differentiating plant types or root characteristics .

Sudarmaji et al. (2024)
Proposed an IoT-based soil moisture control system for horticulture applications. The system continuously monitored soil moisture to determine irrigation timing, ensuring efficient water usage. Although effective in irrigation control, the study did not consider soil depth variation or selective treatment of crops and weeds .

Recent research (2025–2026)
Has introduced machine learning and AI-based smart agriculture systems. These systems use ESP32 and multiple sensors (moisture, temperature, NPK) to predict irrigation requirements and optimize resource usage. While these approaches improve accuracy and automation, they still focus primarily on irrigation optimization and not on targeted weed control or root-depth-based liquid delivery .
Further studies highlight the importance of soil pH and temperature monitoring, as these parameters directly influence nutrient availability and plant growth. Real-time monitoring of these factors allows better soil management; however, integration into decision-based liquid delivery systems remains limited .
Additionally, modern IoT-based agricultural systems utilize wireless sensor networks (WSN) and cloud platforms for real-time monitoring and remote control. These systems improve data accessibility and decision- making but often fail to address the core issue of distinguishing between crops and weeds at the root level

IV. PROJECT DESCRIPTION

The Smart Liquid Delivery System for Precision Agriculture is an innovative project created to deliver water, fertilizers, and herbicides to the zone of the plant only. Its goal is to provide an efficient method of applying inputs and to maximize the yield of crops, all through intelligent controls and selective sprays.
To achieve this, the Smart Liquid Delivery System incorporates modern electronics (embedded in a microcontroller, such as the ESP32 or Arduino), sensor devices to detect the presence of crop plants and sparse areas/weed plants, and automated pumps to deliver a liquid to an area that is either crop or weed into a regulated and predetermined area by targeting the intended application site. The results will minimize the overuse of chemicals applied to crops or unnecessary waste in applications, therefore providing a sustainable solution to agricultural production.
Typically, the Smart Liquid Delivery System consists of a sensor for detecting either soil or plant presence/vegetation type, a computer processor (the microcontroller), and a controlled pump for delivering the liquid to the plant zone. The sensors continuously monitor the presence and type of vegetation or root zone in the application area, and will have parameters, such as moisture level, plant spacing, and signal variability, set to them to set up an application event. Once the data is processed by the ESP32, it will either activate or deactivate the liquid application system.
Pump systems are connected using relay or driver circuits to allow pumping of the needed liquid through nozzles. The use of nozzle direction and activation is determined by the location of crop plants that have been detected, thereby allowing for accurate application of nutrients or irrigation only where crop is growing while providing different treatment options for weed areas or not treating at all.
This system is designed to be able to accomplish what it needs to do in an energy-efficient way, at a reasonable cost, and at a size suitable for small and medium sized farms. There is also an option to use IoT technologies as a way to give remote access and control to operations via mobile devices. This provides farmers with improved ability to make decisions and enhances pedestal for smart agricultural practices.
In summary, the project offers a new approach to improving agricultural productivity through the use of integrated systems, automation and intelligent sensing technologies while helping reduce negative effects on the environment.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 12, April 2026
Impact Factor: 8.2

V. OBJECTIVE OF SYSTEM

The highly intelligent and fully automated Smart Liquid Delivery System for Precision Agriculture's main goal is to create an efficient system that can control the water, fertilizer, and herbicide applications in farming accurately, reduce waste in resource consumption, and promote sustainable agriculture.

The Smart Liquid Delivery System has four specific objectives:

- -To create smart and automated liquid delivery methods that will allow farmers to deliver water or chemicals to only those parts of a field where necessary.
- To minimize the overuse of herbicides and fertilizers by eliminating the need for uniform application of these chemicals through all areas of a field.
- To enable sensor detection of crop plants, weeds, and bare soil and provide methods and techniques for processing the detection of these crop plants using embedded processing methods and techniques.
- To enhance plant yield and health through the exclusive provision of optimal supplies of fertilizers and irrigation only to those crop plants in need of them.
- To create an energy-efficient and affordable embedded system for real-time decisions using microcontrollers like ESP32/Arduino. Development of accurate agricultural practices through the implementation of automation and smart controls into existing agriculture systems Increasing precision agriculture practices by automating traditional agriculture practices; redrawing environmental pollution or soil degradation from excess use of synthetic fertilisers/pesticides. Integration with the Internet of Things, allowing remote monitoring/controlling the system for New, Smart Farming Applications

In summary, the purpose of the system is to provide an efficient, reliable and sustainable solution for Agriculture to improve productivity, decrease operational costs, and reduce the impact on the environment.

VI. ADVANTAGES & APPLICATION

Advantage

1. Lower Chemical Use

Only applies fertilizer, water, and herbicides where necessary to minimize total chemical consumption.

2. Cost-effective Farming

Minimizing the waste of water and agrochemicals allows farmers to cut costs over time.

3. Increased Crop Yield

Delivered to plants in the right amount, at the right time, and in a way that enhances plant growth and productivity.

4. Environmentally Friendly

Reduces nutrient and pesticide spread in soils and waterways caused by the over-application of fertilizers and pesticides.

5. Less manual effort and more automation

No longer requires continuously spraying or checking the fields manually, saving both time and labor.

6. Supports Precision Agriculture

Provides modern-day farming with technology and data-driven agriculture practices.

7. Energy-efficient operation

Uses low-power embedded systems (e.g., any low-power 32-bit microcontroller) and is therefore well suited to rural and off-grid applications.

8. Scalable and flexible design

Can be scaled up to accommodate larger farms or modified for different crop types and growing conditions.

Application:

1. Agricultural Areas

Designed for specific irrigation and individual applications of fertilizers and pesticides and the production of crops.

DOI: 10.48175/IJARSCT-33719

2. Greenhouses
The perfect choice for farming in a controlled environment and delivering accurately measured nutrients.
3. Horticultural Production
Designed to produce fruits, vegetables, and flowers that require precise monitoring and care in their growing processes.
4. Smart Farming (Internet of Things Agriculture)
Enables integration with IoT for remote monitoring and automated management.
5. Research/Agro Lab
Used to research the impact of nutrient sharing on plant growth in a controlled situation.
6. Areas with Limited Availability to Water
Designed to allow for the reduction of water usage in regions with limited supply.
7. Industrial Agriculture
Enhances efficiency and lowers input costs on commercial farms of all sizes.

VII. RESULT

The Smart Liquid Delivery System for Precision Agriculture has effectively shown an intelligent, automated method of controlled irrigation and chemical application, via the utilization of sensor-based detection coupled with micro-controller-based decision making, to manage the delivery of water, fertilizer, and herbicides solely to designated targeted areas of the crop.

The testing phase of this product demonstrated the system's ability to accurately recognize appropriate areas for watering/chemical application by defining the conditions such as the presence of plants, soil conditions, etc. The ESP32/Arduino controller processed the inputs from the sensory devices instantaneously before activating the pump system, only activating when it was required. This selective activation caused a significant reduction in the amount of liquid discharged in the non-target areas such as bare ground or weeded areas.

The experimental results showed a considerable improvement in the efficiency of resources used. There was less water and chemical used than what would have been used through conventional uniform spraying techniques. In addition, the crop zones received adequate and appropriate irrigation, which facilitated better plant health and improved management effectiveness of the entire area being assessed.

The system also demonstrated reliable and stable operation during continuous monitoring conditions; the time response from when the sensor detected something to when the pump was activated was very little, which created the opportunity to deliver liquid in a timely fashion without delay. Also, while monitoring and continuous operation of this system, the system maintained its performance at very low levels of power usage.

VIII. FUTURE SCOPE

The Smart Liquid Delivery System (SLDS) is an innovative technological solution for precision agriculture that has the capacity to continue evolving and being implemented worldwide. With advancements in the areas of embedded systems, IoT and artificial intelligence, we see that this system could quite easily migrate into an intelligent, autonomous agricultural solution.

1. Future integration of artificially based AI and machine learning solutions

In terms of AI solutions, many machine learning algorithms can be utilized to evaluate crop health, identify the condition of soil and assess various environmental factors that may affect the crop being grown, etc. By utilizing machine learning models, the system will be able to analyze past stored data (i.e., historical data) to make better- informed decisions on when and how much liquid(s) should be applied.

2. Future use of the Internet of Things (IoT) for remote monitoring and controlling of the system

The SLDS has the capacity to connect to various cloud platforms, allowing farmers to monitor irrigation/spraying applications remotely and control them with mobile devices (i.e., smartphones / tablets). Real-time information regarding moisture content of the soil, status of the pumps, condition of the field, etc., can all be accessible from any location.

3. Future use of drone technology to deliver liquids

Future versions of the SLDS will have the potential to be integrated with agricultural drones to allow for aerial spraying applications. This will improve the speed of coverage to large fields and allow for targeted application in areas that would otherwise not be able to be accessed.

4. Sensor Integration at an Advanced Level

Integrating more advanced sensors like NDVI (Crop Health Sensors), multispectral imaging, temperature, humidity and nutrient detection sensors into the system can enhance accuracy and improve the decision-making capability of the system.

5. Fully Automated Smart Farming Solution

By adding robotics and embedded systems to the automated process will allow for the expansion of a Fully Automated Farming System which uses automated systems to accomplish Irrigation, Fertiliser Application, Weed Detection, and Pest Control without the use of humans.

IX. CONCLUSION

In conclusion, by integrating automated systems, embedded sensors, and real-time decision-making, the Smart Liquid Application System provides an efficient and innovative method for modern farming by overcoming many of the limitations that exist in traditional agriculture; where a lack of either evenly irrigated fields and/or uniformity with respect to chemical application results in inefficient water and chemical use as well as harm to the environment.

The Smart Liquid Application System enables targeted and selective delivery of water, fertilizer, and/or herbicide through the utilization of microcontroller-based control (i.e., ESP32/Arduino) thus allowing farmers to maximize the amount of resources that they apply to the crops. Furthermore, the use of microcontrollers permits for real- time decision making and increases the accuracy, responsiveness, and reliability of the Smart Liquid Application System when used in a field. Experimental implementation of the Smart Liquid Application System has conclusively demonstrated that it greatly reduces water and chemical usage while simultaneously maintaining or improving the overall health and productivity of the crops. In addition, the Smart Liquid Application System minimizes human labor, decreases dependency on labor, and promotes sustainable agricultural practices.

In addition, the Smart Liquid Application System provides a foundation for continuing advancements within precision agriculture by enabling integration of IoT, AI, and smart sensing technologies; thereby providing for adaptation to future smart farming environments characterized by automation and data driven decision making. In summary, this project provides a practical and scalable means for increasing the efficiency within agriculture, decreasing the negative impact on the environment, and facilitating progress toward a smarter and more sustainable agricultural systems.

REFERENCES

[1]. Pereira, G. P., Chaari, M. Z., & Daroge, F.“IoT-Enabled Smart Drip Irrigation System Using ESP32” IoT Journal (MDPI), 2023

[2]. Awawda, J., & Ishaq, I. “IoT Smart Irrigation System for Precision Agriculture” Intelligent Sustainable Systems (Springer), 2023

[3]. “Hasib, A. S. M., et al. “An IoT-Based Smart Plant Monitoring and Irrigation System with Real-Time Environmental Sensing” arXiv, 2026.

[4]. Kunt, Y. E. “Development of a Smart Autonomous Irrigation System Using IoT and AI” arXiv, 2025.

[5]. Gunawan, T. S., et al. “Automatic Watering System for Smart Agriculture using ESP32 Platform” IEEE ICSIMA Conference, 2022.

[6]. Kumari, M., et al. “Smart Irrigation System Using IoT” IJRASET Journal, 2023.

[7]. Taueatsoala, K., et al. (2026). TinyML-Enabled IoT for Sustainable Precision Irrigation. arXiv.

[8]. Singh, D., & Verma, P. (2023). Smart Agriculture System using Embedded Systems and IoT. Elsevier Procedia.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 12, April 2026

Impact Factor: 8.2

[9]. Zhang, L., et al. (2024). AI-Based Precision Irrigation Systems for Sustainable Agriculture. Computers and Electronics in Agriculture.

[10]. Patel, R., & Shah, M. (2022). Smart Farming System using ESP32 and Soil Moisture Sensors. International Journal of Engineering Research

[11]. Chatterjee, S., & Mukherjee, S. (2023). Precision Agriculture using Wireless Sensor Networks and IoT. Springer Proceedings.

[12]. Sarkar, A. S. M. A., et al. (2026). Cloud-Based Smart Irrigation with Environmental Sensors. arXiv.

[13]. Hanfoug, S., et al. (2026). IoT-Enabled Smart Irrigation System Using LoRa Technology. ResearchGate.

[14]. Bharadwaj, S. S., et al. (2025). Agrisense: Automated Irrigation and Smart Seeding System. IJRASET.

[15]. Lee, Y., et al. (2025). SPADE: Soil Moisture Pattern Recognition for Precision Agriculture. arXiv.

[16]. Chatterjee, S., & Mukherjee, S. (2023). Precision Agriculture using Wireless Sensor Networks and IoT. Springer Proceedings.