

Smart Agriculture in Irrigation and Fertilization Productivity Using IoT

Dr. Sudhir Kadam¹, Snehal Mane^{2*}, Pritam Dadasaheb Desai³, Vishal Maloji Patil⁴,
Dr. Poonamkumar Hanwate⁵, Priyanka Nalawade⁶

¹School of Engineering, Ajeenkya D Y Patil University, Pune, India

²Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune, India (Corresponding Author)

Email: scmane@bvucoep.edu.in

³Dr. D Y Patil Pratishthan's College of Engineering, Salokhe Nagar, Kolhapur, Maharashtra, India

⁴Department CSE-MIT School of Computing, MIT ADT University, Pune, India

⁵School of Engineering, Ajeenkya D Y Patil University, Pune, India

⁶Computer Engineering (Software Engineering), MIT Academy of Engineering, Alandi (D), Pune, India

Received: 20th Apr, 2026 | Revised: 25th Apr, 2026 | Accepted: 9th May, 2026 | Available Online: 14th May, 2026

ABSTRACT

This research presents life in a technologically sophisticated civilization where technology and digitization are omnipresent. With every day that goes by, the significance of technology in agriculture becomes increasingly clear. India's agricultural sector is losing ground every day, which has an impact on the ecosystem's capacity to produce. Addressing this and getting it back to higher growth is becoming more important. To increase the farmer's profitability and agricultural output through improved management, which applies to both big and small farms? This research aims to automate water flow monitoring and fertilizer control. Agriculture in India is practiced in conventional ways. It is made even more unpredictable by the fact that most of our farmers are ignorant. A lot of farming and agricultural operations are based on the forecasts which sometimes fail. Farmers lose colossal sums of money, and at times they end their life. The mentioned factors should not be ignored since we know the benefits of sufficient soil moisture and quality, quality of air, and irrigation on crop growth. Consequently, we have come up with a new idea of smart farming and crop monitoring utilizing an Arduino and GSM module.

Keywords: Flow Monitoring, Soil Moisture, Fertilizer Control, Arduino.

How to cite this article: Kadam S, Mane S, Desai PD, Patil VM, Hanwate P, Nalawade P., Smart Agriculture in Irrigation and Fertilization Productivity Using IoT. *Int J Drug Deliv Technol.* 2026;16(5): 967-974; DOI: 10.25258/ijddt.16.5.92

1. INTRODUCTION

Paragraph: One of the few sectors where technology has not been widely embraced is agriculture. The perilous situation of many farmers in India and other developing nations is one of the causes of this. Overpopulation and urbanization are the two main issues causing the growing shortage of agricultural supplies. While urbanization has led to the conversion of many agricultural lands into non-agricultural fields (NA) for infrastructure construction near metropolitan centers, overpopulation increases the overall demand for agricultural products. In essence, the amount of agricultural land is decreasing daily, and thus, farming activities are also decreasing, potentially leading to a decline in agricultural production.

- The motivation of this project is to introduce technology in the farming sector, which in turn will work for the betterment of the farmer and to increase the production of crops and quality.
- The role that Technology must play in the agriculture sector is becoming increasingly visible each passing day.
- In the given project we are aiming to automate the Control of fertilizers, monitor the water flow.

To address this scenario, farmers apply fertilizer to crops after a specific period (typically several days). However, the issue with this strategy is that, at times, crops do not require fertilizer so early, resulting in

excessive fertilizer consumption, while other crops may need fertilizer slightly earlier.

To resolve this issue, this research proposes an autonomous system that can precisely determine the amount of fertilizer required for soil and crop health. This helps prevent over-irrigation, which not only wastes water but also increases the risk of crop diseases. Also, the system minimizes the unnecessary use of fertilizers [1]. Excessive application of fertilization may result in heavy metal build-up, eutrophication and accumulation of phosphates and nitrates. Water may have excess phosphorus which may pose a danger to the water quality. Indians still practice farming using traditional methods. This is further complicated by the fact that most of our farmers are ignorant, making the process far more certain. Farming and other agricultural activities involve a significant number of predictions which most times do not go according to plan. This means that the farmers end up making big losses and in some unfortunate moments, some of them are influenced to commit suicide. One cannot overlook the importance of such elements of crop growth as soil moisture, soil quality, air quality, and irrigation [2]. To address these challenges, we have designed a new concept of smart farming and crop monitoring based on Arduino and GSM module. Due to its reliability and ability to do remote monitoring, we believe that our approach will be a norm in the Agri industry. Our concept will focus on digitalizing farming and agriculture processes, allowing farmers to know crop needs and growth by projecting the growth. This innovation can contribute to their productivity, profitability and success in business to a great extent. The effectiveness of such a project, though, will heavily require the creation of awareness among farmers, which, in our opinion, will become possible in view of the many benefits of the system [3]. India is an agrarian nation and second on a global scale in terms of agricultural production. At present, farmers are using hand irrigation to irrigate their farms at periodic intervals. Agriculture consumes the most amount of water, and the irrigation sector incurred more than 70 water consumption worldwide. Industrial and household sectors on the other hand constitute 20 percent and 10 percent of the total, respectively but the levels vary widely across countries.

With population swelling daily the demand of food is also increasing. Some of the factors that influence crop yield are environmental problems like unpredictable weather conditions that incur losses to crops and farmers being unwilling to adopt new technologies that can increase profitability in agriculture. Even with these difficulties, agriculture has been an important source of livelihood and is the most important in socio-economic development of India. To solve these problems and overcome the existing situation, we should use technology in more intelligent and effective applications [4].

To do this, there is a need to boost productivity of farming. Although domestic and industrial sectors have 10% and 20% of water consumption, agricultural water consumption is expected to rise in the world by approximately 20 percent in the future without an improvement in efficiency. In a developing nation such as India, farming is the major activity with 47 percent of the population involved in the business. Additionally, agriculture contributes 18% to India's total GDP.

2. RESEARCH GAP

Our concept's dependability and remote monitoring make us think it will set a standard in agriculture. For farmers to monitor crop needs and make precise growth predictions, our concept aims to digitize farming and agricultural operations. This idea would undoubtedly help them grow their business and make more money at the same time. Due to its many benefits, we think it will be easy to raise awareness among farmers, which is crucial to the project's execution. The persistent problem was addressed by a few other people working on related problems prior to the proposal of this model.

The study describes the technological limitations and problems that need to be resolved when implementing a low-scale pilot project based on the Internet of Things in the field of agriculture. All phases of agricultural product development, including food production, processing, distribution, and retail, are conceptually outlined in this study [5]. An indigenous, low-cost, time-dependent microcontroller-based irrigation scheduler with a number of sensors for temperature, wind, and moisture measurement is presented by P. A. Bhosale and V. V. Dixit. This method creates suitable actuators (relay, solenoid valves, motor) based on these parameters. The recorded data is saved on a

memory card and transmitted to the user via an SMS via the GSM module [6].

Developments in controlled environment agriculture and greenhouse automation: A shift to plant factories and urban agriculture describes how different environmental elements work together to enable plants to flourish under different conditions [7]. The suggested solution examines the use of system on a chip (SoC) in WSN for monitoring and controlling greenhouse parameters. The author also discusses how wireless networks have advanced and how this has led to the creation of traditional sensor nodes that have an I/O interface [8].

Since then, agriculture has contributed significantly to India's economic development and will do so going forward. Throughout the agricultural process, farmers face numerous challenges. By managing agricultural labor instead of spending most of one's time on crop production and maintenance, the study aims to address the problem. This will allow farmers to spend more time with their families and improve the socioeconomic standard of society. Without requiring human intervention, the proposed system may automate the entire watering and fertilizer channeling operation at a precise moment. The proposed method offers a wide range of potential applications as one of the potential results of using technology in agriculture [9].

The uses are infinite as it depends on our imagination and thoughts in this particular field. As human beings, it is our duty to come up with mechanisms and technologies that will help and contribute towards the optimization of the utilization of the available resources to meet the needs of the human beings in food production. Applications are unlimited as it is our prerogative to apply our imagination and thoughts in this particular field. As human beings, it is our responsibility to come up with mechanisms and technologies that will be helpful and useful in the maximization of the utilization of resources at our disposal to meet the needs of humanity in food production.

- But given the current situation, if traditional farming methods are to be used, any increase in production will put a strain on the ecosystem.

- But with the advent of improved farming technology that aims to lower costs, increase farming productivity, and produce high-quality, high-quality products, smart farming promises a better future.
- It is believed that smart farming will bridge the distance between small and big farms in developed and developing countries. Smart farming will likely close the divide that exists between large and small-scale farmers in both the developing and developed nations.
- Agriculture is one of the few industries, where the technology has not been adopted on excessive scale, one of the reasons why this is the state of most of the farmers in India or any other developing nation. □
- The value of these technologies is known to different countries which is why most countries are keen on enhancing the adoption of the new farming methods that involve use of technology.

3. PURPOSE OF THE STUDY

The challenge is to minimize the farmer's involvement in the fertilization process while making effective use of it. One of the few sectors where technology has not been widely embraced is agriculture. The perilous situation of the majority of farmers in India and other developing nations is one of the causes of this. Overpopulation and urbanization are the two main issues causing the growing shortage of agricultural supplies [10]. While urbanization has resulted in the conversion of many agricultural lands into non-agricultural fields (NA) for infrastructure development close to metropolitan centers, overpopulation increases the overall demand for agricultural products. In essence, farming operations are declining along with the daily shrinkage of agricultural land, which could result in a decline in agricultural output.

To address this scenario, the only solution is to increase agricultural output by intelligently employing resources. Precision agriculture emerged from the need to minimize waste of readily available resources. The traditional irrigation process consists of a time-controlled fertilizer dispersion system, whereby farmers will spread fertilizer following a

LCD screen displaying parameters such as "Channel 1" and "ML" (possibly representing volumes in milliliters).

Solenoid valve and flow sensor system

As seen in the previous figure, the green pipe connects the solenoid valve and the flow sensor, which is important for flow control and measurement.

5.1.3. Combination of features

Multiple wired connections connect the components, meaning sensors, actuators and micro-controllers are integrated for automatic control.

This system may be designed to provide an accurate amount of water (chemical) in an irrigation system or similar.

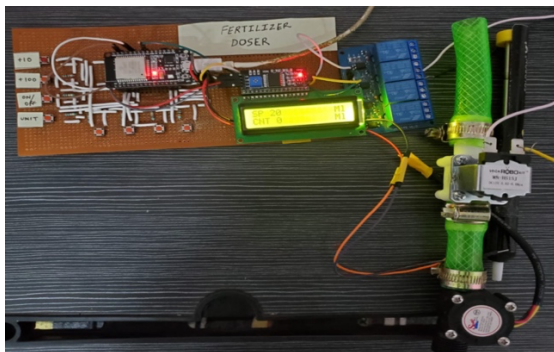


Figure 2. Prototype of fertilizer dispenser.

This is the way that the proposed method fertilizes the field exactly. The technology will help farmers to apply the required amount of fertilizer or water only, and the farmer will not overuse the fertilizer, which may bring problems.

5.1.4. Solenoid Valve

Figure 3 shows an arrangement involving green plastic pipe, which is secured with a metal hose clamp. It is seen connecting an electric solenoid valve (left) and a flow sensor (right). These components can be part of a water management system, perhaps for water or other liquids. A solenoid valve controls the flow rate, while a sensor measures the flow rate or quantity.



Figure 3. Solenoid valve for fertilizer dispenser.

6. SMART FERTILIZER CONTROLLER

This figure 4 appears to be another view of the fertilizer dosing system setup. Here's a detailed analysis:

6.1.1. Fertilizer Container

Clearly labeled "FERTILIZER (N.P.K.)", it acts as the source reservoir for the liquid fertilizer.

The green pipe is connected to extract the fertilizer for dosing.

6.1.2. Electronics Board

The custom PCB with a micro controller and relay module is central to controlling the system. The LCD screen shows operational parameters, likely related to flow rate, volume, or dosing control.

6.1.3. Dosing Mechanism

The green pipe integrates the solenoid valve and flow sensor, ensuring controlled delivery of fertilizer.



Figure 4. Smart Fertilizer Controller.

7. SMART FERTILIZER PUMP WITH CIRCUIT INTEGRATION

System figure 5 shows displaying all components in a functional layout.

7.1.1. Flow of fertilizers

The pipe system (green tube) is connected to a flow sensor and a solenoid valve, monitoring and measuring the flow rate. The black bottom of the output shows leakage, possibly after calibration and control.

7.1.2. Resources Used

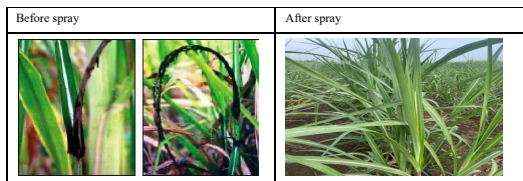
The control PCB, as seen earlier, contains a micro controller, a relay, and an LCD screen. The LCD continuously displays operating information, which may include flow rate, volume, or system status. Fig: - Flow Chart Of the Fertilizer dispenser



Figure 5. Smart Fertilizer Pump with Circuit Integration.

8. RESULT AND DISCUSSION

In this proposed work we have upgraded the previous research done of the paper Automation in Agriculture and IoT in which various sensor were used to check the condition of the soil and to find the lacking nutrients required for sowing the soil, and also to check which nutrients are in excess so that we can adjust the dispensing of the said nutrients to have balance. What we have done in this proposed system is build the automation system for dispensing of the required fertilizer and the various nutrients. This system can be combined with the previous papers to fully automate the whole process from checking the requirement of the nutrients and fertilizer in the soil to plan the when to provide the fertilizer to the soil.



Nitrogen (N): The actual amount of nitrogen dispensed was constantly less than what was needed. In Week 1, the mistake was 3.8%, and in Week 5, it was 20.5%. This implies that there were calibration issues at higher loads since the system became highly under-dispensing at increasing fertilizer demands.

Phosphorus (P): Phosphorus had the largest percentage change at 12.5% (Week 1) to 22.2% (Week 5). Each week the system incorrectly dispensed P significantly, which highlights the need to have more control mechanisms that are more accurate to achieve a perfect dosing of low-quantity nutrients.

Potassium (K): Potassium dispensing was relatively more precise as compared to N and P. The error variability was 3.3% in Week 1 to 12.5% in Week 5. Even under-dispensing, the system was more in line with requirements than Phosphorus.

The proposed system has largely utilised the hardware component and do not involve the IOT in depth that could have rendered the entire procedure complete with remote device which would be a mobile phone. The reason we have not included the Wi-Fi module component of the ESP32 is simple because of lack of the infrastructure required to use the Wi-Fi module. The presence of the Wi-Fi module will have the prerequisite of 24 hours electricity which is still an issue in the rural area of India. As a result, the proposed system still requires the presence of the farmer.

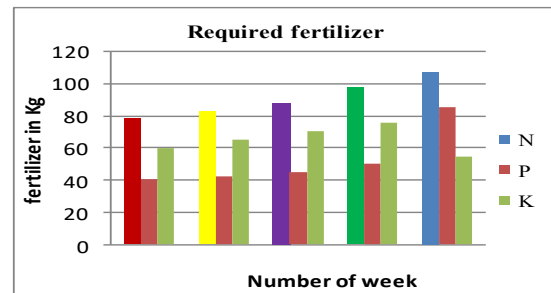


Figure 7. Number of week vs required fertilizer in Kg.

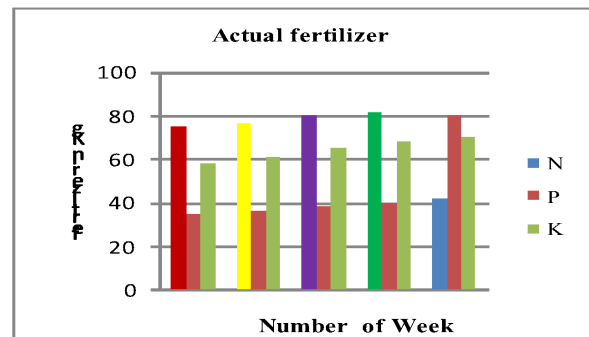


Figure 8. Number of week vs Actual fertilizer in Kg.

Table 1. Weeks VS required and actual fertilizer

Time (Week)	Required fertilizer in Kg			Actual fertilizer in Kg		
	N	P	K	N	P	K
Week 1	78	40	60	75	35	58
Week 2	83	42	65	77	36	61
Week 3	88	45	70	80	38	65
Week 4	98	50	75	82	40	68
Week 5	107	85	54	42	80	70

Trend Analysis: The error percentage increased with growth in fertilizer demand of all the three nutrients. This suggests that as the load on a system increases the accuracy of the system decreases and this may be due to lack of feedback correction or the constraints of the dispensing mechanisms.

CONCLUSION

By partially automating fertilizer application, the suggested hardware-based automation system shows promise in lowering farmer intervention. But by Week 5, it starts to under-dispense nutrients, particularly phosphorus and nitrogen, with mistakes exceeding 20%. Although it was still erratic, potassium delivery was relatively more dependable. Consequently, the proposed technology makes it possible to automate fertilizer application in the field without requiring human intervention. The proposed approach is a first step in the vast field of fusing technology and agricultural practices to create better methods that will help farmers increase crop productivity and make the most use of available resources. Demand can only be met in light of the rapidly growing population if we enable both large and small farmers to profitably adopt improved agricultural practices that make use of technology. Since farming area is limited and cannot be expanded

due to the growing human population, the desire for more food has forced us to search for ways to increase agricultural productivity. Therefore, the proposed approach was developed to provide a solution to the issue farmers face when applying fertilizer to crops, freeing them up to concentrate on other aspects that would help increase output.

Reference

1. Saratkar, P., Pawar, M., & Singh, A. (2025). "Enhancing Agricultural Sustainability Through IoT-Based Smart Irrigation Systems for Soil Monitoring, Water Management, and Machine Learning Applications". Proceedings of RAMSITA 2025. https://doi.org/10.2991/978-2-38476-246-4_8.
2. Badoni, R. P., Kumar, V., & Singh, S. (2024). "How the Internet of Things Technology Improves Agricultural Efficiency: A Comprehensive Review." Artificial Intelligence Review. https://doi.org/10.1007/s10462-024-11046-0.
3. Bariman, N., Rahman, M., & Ismail, A. (2024). "Development of IoT-Controlled Irrigation and Fertilization System for Fertigation Farming". Southeast Asian Journal of Technology and Science, 5(1), 15–22. https://doi.org/10.21009/sajts.2024.05.01.03.
4. C. Brewster, I. Roussaki, N. Kalatzis, K. Doolin, K. Ellis, "IoT in Agriculture: Designing a Europe-Wide Large scale Pilot", IEEE Communications Magazine September 2017
5. Hlioui, F., Baccar, M., Terki, R., et al., "Smart Sensing System for Soil Fertility Estimation Incorporating IoT and Machine Learning", Intelligent Systems with Applications, DOI: 10.1016/j.iswa.2023.200351.
6. Begum, S., Nur, R., "Machine Learning-Enabled IoT for Smart Agriculture Marketplace" A Systematic Review and Open Issues, Internet of Things and Cyber-Physical Systems, DOI: 10.1016/j.iotcps.2024.12.002.
7. Hlioui, F., Baccar, M., Terki, R., et al., "Smart Sensing System for Soil Fertility Estimation Incorporating IoT and Machine Learning", Intelligent Systems with Applications, DOI: 10.1016/j.iswa.2023.200351.

8. Afzaal, H., Farooque, A. A., Abbas, F., Acharya, B., & Esau, T. (2020). Precision Irrigation Strategies for Sustainable Water Budgeting of Potato Crop in Prince Edward Island. *Sustainability*, 12(6), 2419. <https://doi.org/10.3390/su12062419>.
9. Akkaş, M. A., & Sokullu, R. (2017). An IoT-Based Greenhouse Monitoring System with Micaz Motes. *Procedia Computer Science*, 113, 603–608. <https://doi.org/10.1016/j.procs.2017.08.300>
10. Aslam, S., Khalid, A., & Javaid, N. (2020). Towards Efficient Energy Management in Smart Grids Considering Microgrids with Day-Ahead Energy Forecasting. *Electric Power Systems Research*, 182, 106232. <https://doi.org/10.1016/j.epsr.2020.106232>
11. Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E.-H. M. (2019). Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. *IEEE Access*, 7, 129551–129583. <https://doi.org/10.1109/access.2019.2932609>
12. Benke, K., & Tomkins, B. (2017). Future Food-Production Systems: Vertical Farming and Controlled-Environment Agriculture. *Sustainability: Science, Practice and Policy*, 13(1), 13–26. <https://doi.org/10.1080/15487733.2017.1394054>
13. González-Briones, A., Castellanos-Garzón, J. A., Mezquita Martín, Y., Prieto, J., & Corchado, J. M. (2018). A Framework for Knowledge Discovery from Wireless Sensor Networks in Rural Environments: A Crop Irrigation Systems Case Study. *Wireless Communications and Mobile Computing*, 2018(1), 6089280. <https://doi.org/10.1155/2018/6089280>
14. Chang, A., Jung, J., Maeda, M. M., & Landivar, J. (2017). Crop Height Monitoring with Digital Imagery from Unmanned Aerial System (UAS). *Computers and Electronics in Agriculture*, 141, 232–237. <https://doi.org/10.1016/j.compag.2017.07.008>
15. Ojo, O. I., & Ilunga, F. (2018). Geospatial Analysis for Irrigated Land Assessment, Modeling and Mapping. In B. R. Rustamov, S. Hasanova, & M. H. Zeynalova (Eds.), *Multi-purposeful Application of Geospatial Data*. InTech.