Hindawi
Journal of Food Quality
Volume 2022, Article ID 8285969, 8 pages
https://doi.org/10.1155/2022/8285969

Research Article

Application of IoT and Cloud Computing in Automation of Agriculture Irrigation

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Received 7 December 2021; Revised 24 December 2021; Accepted 28 December 2021; Published 18 January 2022

Academic Editor: Muhammad Faisal Manzoor

All living things, including plants, animals, and humans, need water in order to live. Even though the world has a lot of water, only about 1% of it is fresh and usable. As the population has grown and water has been used more, fresh water has become a more valuable and important resource. Agriculture uses more than 70% of the world's fresh water. People who work in agriculture are not only the world's biggest water users by volume, but also the least valuable, least efficient, and most subsidized water users. Technology like smart irrigation systems must be used to make agricultural irrigation more efficient so that more water is used. A system like this can be very precise, but it needs information about the soil and the weather in the area where it is going to be used. This paper analyzes a smart irrigation system that is based on the Internet of Things and a cloud-based architecture. This system is designed to measure soil moisture and humidity and then process this data in the cloud using a variety of machine learning techniques. Farmers are given the correct information about water content rules. Farming can use less water if they use smart irrigation.

1. Introduction

Water is an important natural resource for agriculture, but it is limited [1–3]. A large portion of water in a country like India is needed for irrigation [4]. Crop irrigation is a significant component in influencing crop productivity, as it is affected by a variety of environmental factors such as air temperature, soil temperature, humidity, and soil moisture [5]. For harvesting fields, farmers rely heavily on human supervision and experience [6]. The field's water supply must be maintained [7]. Water scarcity is a major concern in today's world. People all throughout the world are already suffering from such scarcity [8, 9]. In the future years, the situation may worsen.

Rainwater, subsurface water, and surface water are the primary sources of natural water resources. The oceans contain 96.5 percent of the planet's water. The remaining water in the world is available as 1.7 percent in groundwater, 1.7 percent in glaciers and ice caps, a minor fraction in other bodies of water, and 0.001 percent in the air as mist, clouds, and precipitation [10]. In summary, the ocean, which is salt water, contains the majority of the world's surface water. As a result, overall fresh water availability is a rare resource.

Furthermore, fresh water is a critical natural resource that is required for the survival of all ecosystems. However, from a global viewpoint, just 2.53 percent of the entire water body is now available as fresh water [11]. According to a new analysis by ecologist Dash and Dash [12], the majority of the world's population may suffer a water crisis by 2025. On the other hand, the bulk of fresh water is used for irrigation and industrial purposes, which has a significant influence on downstream ecosystems. As a result, the use of finite fresh water resources must be carefully regulated in order to prevent having a negative influence on water availability for future generations.

According to Hegde [13], Figure 1 shows that 81 percent of India's fresh water is used for irrigation, 13 percent for industry, and 6 percent for domestic use. Human water consumption is expected to increase by up to 26% by 2025 [14].

This data demonstrates the poor use of water resources, particularly in agriculture [15]. As a result, there is a critical need to develop strategies to increase the efficiency of fresh water utilization in agriculture. Agriculture is the backbone and most significant gift to human life not only in India, but also across the world. However, the bulk of the world's cropland suffers from a severe lack of irrigation water. Drip irrigation systems have been created by researchers in such a scenario to minimize water use in arid locations. This is due to the lack of standards and systematic approaches for utilizing water and power in a positive manner. As a result, farmers' overheads for conventional drip irrigation have increased, and they must personally visit and monitor the farms on a regular basis.

The same technologies are now being used in Pennsylvania to figure out how much work will be done. A lot of research has been done in the past to make the process of figuring out how many grapes, wheat, or fruit to make easier. Most of these studies use computer vision and other technologies that work with them. The most important thing about PA is that real-time information can be found. Before harvesting crops, a production estimate creates a very important production database.

Such a database allows PA to be used for more than its original goals. It can be used for resource management, harvesting workforce estimation, harvesting time, postharvest problems, storage, and transportation. In addition, production counts have been found to help with financial decisions like figuring out how much to charge for a product, when to sell it, and how much profit or loss it will make.

A crop requires a set amount of water at defined times during its growing period. Irrigation aids crop growth in agriculture. Irrigation is the technique of artificially watering crops. This approach is especially useful in locations with little or inconsistent rainfall. Water is essential to the survival of plants in a variety of ways. Understanding the soil-water-plant link is required to comprehend the various water management strategies under different climatic situations.

There are several types of soil, such as sandy, silty, and clay. Each soil type has its own set of pros and downsides. The sandy soil, for example, has a high drainage capacity. The nutrients, on the other hand, are quickly taken away by the drain. However, because the particles in silty soil are tiny, they may store water for a considerably longer amount of time. However, this soil has a limited capacity to drain water. As a result, for effective agricultural techniques, the soil must be good in all aspects, such as drainage, nutrient retention, and water retention. As a result, it is critical to understand the soil qualities in order to regulate the water requirements.

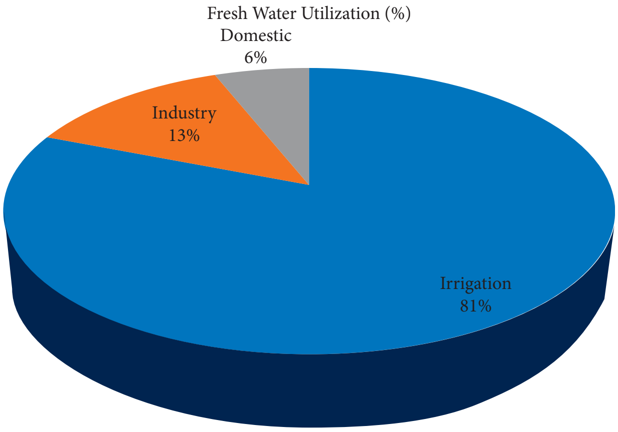

Figure 1: Fresh water utilization [13].

Furthermore, data mining techniques can substantially benefit the decision-making process for many agricultural tasks. The application of association rule regulations to manage the amount of water in agricultural areas is one of these operations. In addition, wireless sensor networks have evolved as a new precision agriculture approach. In current irrigation systems, smart sensor networks are used to collect field values for optimal plant irrigation. In many industries, including agriculture, healthcare, and logistics, machine learning [14] is an important method. This article also uses a machine learning-based system to reduce fresh water waste.

2. Literature Survey

2.1. Review of WSN in Agriculture. Wireless sensor networks (WSNs) play an important role in a variety of industries, including military and agricultural uses in everyday life. Tsai et al. [15] investigated the lifetime property of WSN, which is the time it takes for the sensor to run out of energy. They also explored a metaheuristic approach and how it deals with the WSN lifetime problem. They suggest a metaheuristic algorithm that operates in three phases: transition, evaluation, and determination, which aid in the selection of the best solution to the issue.

It is obvious from their explanation that understanding the different field parameters and domain expertise linked to the longevity problem are required for executing the metaheuristic method. Many scholars have already researched numerous metaheuristic algorithms. Even if the adoption of these techniques improves the performance of the WSN, there are still some outstanding concerns that require additional investigation. When contingency is considered, for example, the number of sensors or cluster heads might be minimized. Furthermore, while most metaheuristic methods are designed with optimization in mind, they may not perform well when used to solve lifespan problems.

WSN node deployment must be both efficient and significant. Li et al. [16] introduced a novel approach for effective sensor node deployment in wireless networks, dubbed the Efficient Dynamic Deployment Approach of Sensor Nodes (EDSNDA), in which the needs of sensor node connection and coverage are considered by reducing node size as much as possible. The algorithm is compared to two other methods: Max-Cov and Min-Cov. Both of these methods are well known, and they employed four dynamic programming models for four distinct circumstances to demonstrate that their suggested technique outperforms the other existing models.

WSN nodes in mobile network architecture are utilized for communication when a large quantity of frequency is required. Hassan et al. [17] explored frequency reuse, which involves reusing a frequency for industrial, scientific, and medical (ISM) applications. Their debate is based on frequency reuse, which is done at sensor nodes located along busy pathways. The CR algorithm was utilized to disperse the load to the macrocells. Their suggested model has a reduced collision domain and can accommodate a larger number of users.

For farmers to enhance their yield, precision farming is vital. In such situations, the use of WSN may be very helpful in determining suitable decisions that support the irrigation requirements and crop output projections by farmers and other agricultural players, such as government irrigation agencies. A self-contained agricultural precision system based on central pivot irrigation systems was established by Dong et al. [18]. The technology uses an underground sensor network to monitor field characteristics such as soil humidity and temperature. This ensures that the sensors are installed and power adjustments are made for the input configuration and regular energy maintenance.

The use of wireless sensors for efficient irrigation planning was addressed by Vellidis et al. [19]. A sensor array system is used in their design to measure soil temperature and moisture so that watering requirements may be predicted in real time, merging the sensor array with sensor network-based accuracy technology.

In irrigation systems, data transmission requires more energy and hence energy conservation in order to enhance irrigation efficiency. According to Nesa Sudha et al. [20], the use of the Multiple Access Time Division allows more efficient transmission of data into WSN irrigation systems (TDMA). Energy is conserved in two ways: from the node to the sink node direct transfer and the addition of data. The network's performance is also improved via TDMA.

Goumopoulos et al. [21] suggested a novel automated zone irrigation system based on wireless sensors or actuators coordinated through an ontological approach. Precision agriculture, which is employed in this approach, is based on speaking plants in order to save more water. This system detects node failures in the network and uses various machine learning methods to improve system performance. Many end-user apps have been created in the past to improve the automation and user friendliness of irrigation tasks.

Vellidis et al. [19] created a technique for optimum cotton crop irrigation. The soil-water balance was computed in their method using data sets from a variety of cotton producing sites. Using the data sets, the authors created an Android mobile application. Furthermore, their application was designed to collect weather data from weather stations in and around the places where it was utilized. The program estimated the irrigation requirements and automatically planned the irrigation systems using the in-built data and the downloaded meteorological data in order to enhance cotton production.

Abbasi et al. [22] examined wireless sensor network applications and their need in the agricultural arena. They spoke about numerous criteria for the agriculture industry that is dependent on time variation features. Furthermore, they offered a quick study in the form of a table containing several types of sensors utilized for agriculture-related variables. Finally, they compared communication systems with varying capacities and features.

López et al. [23] suggested globally developed wireless sensor network architecture to monitor horticulture crops and ensure a high degree of sensor node power. This architecture is heavily reliant on the Berkeley Medium Access Control (B-MAC) protocol, and it takes into account various components such as base station, gateway, soil mote, water mote, and environmental conditions, and it interconnects the properties in order to achieve better throughput and reduce delays.

According to Kodali et al. [24], data accumulation in the gateway and processing will result in some warnings in the form of messages or emails indicating that the measured variables have passed the threshold, which boosts field productivity by lowering agricultural input. They focused on a number of sensor types that were used to determine statistical characteristics of agricultural fields, and they offered an elaborative description of the sensors and their specifications connected to commercial goods while keeping precision agriculture in mind. In addition, the model took into account soil water content sensors, soil moisture content sensors, soil electrical conductivity sensors, PH sensors, weedseeker sensors, temperature sensors, and wind speed sensors.

Because of a lack of decision support systems in the precision agriculture industry, Kassim et al. [25] created an eco-friendly WSN solution called the intelligent greenhouse monitoring system to address difficulties such as farming resource optimization, decision support, and land monitoring. Their approach optimizes the use of water and fertilizer while also increasing the output of the system's crops. They discussed the environmental elements that influence plant development.

Jao et al. [26] created a prototype model of wireless sensor networks for precision agriculture to gather soil moisture content while using a restricted battery supply. Sand soil with varying water amounts was utilized in their model to demonstrate outcomes using off-the-shelf hardware components.

Deepika and Rajapirian [27] conducted a survey of wireless sensor networks in precision agriculture, explaining both current and innovative technologies. For plant monitoring, this model is considered field programmable gate array-based control.

Imam et al. [28] offered an assessment of design difficulties for wireless sensor networks and smart humidity sensors for precision agriculture, with the goal of maximizing farmer advantages. They conducted a comparison study on the utilization of microcontroller families and sensor node units in precision agriculture. Furthermore, they defined and tabulated the needs of the relative humidity sensor, as well as modeling and interface methodologies.

2.2. Reviews on Water Conservation.

Water conservation is critical in agriculture. As a result, several scholars conducted studies in order to discover novel strategies for water conservation. Abubaker et al. [29] conducted trials in several seasons for sessional analysis based on dry and wet seasons, as well as studying the impact of five water collecting systems. Their model took into account the moisture content of the soil in three seasons, namely, sowing, midseason, and after harvest, at four different depths, and they demonstrated that their technique is effective for reducing water usage and improving productivity.

Gutierrez et al. [30] created an algorithm for successful plant soil temperature management, which was written on a microcontroller. It makes use of a solar cell and a communication link based on a cellular Internet interface. The authors conducted the studies for 136 days, and the results showed that their proposed irrigation approach reduced water use by up to 90% when compared to typical agricultural methods.

Gajendran et al. [31] used distributed clustering to explain the efficiency and latency of information collecting mechanisms. The algorithm generates the threshold value depending on the transmission distance, and this overall mechanism aids in the development of a robust information delivery mechanism to the base station, reducing packet loss. When compared to traditional agricultural techniques, drip irrigation technology helps to reduce crop water demand.

Grace et al. [32] offered a work based on a wireless control system that was utilized to operate drip irrigation without the assistance of a human. The primary benefit of their model was the ability to acquire rain information.

Gaddam et al. [33] presented a drought monitoring system for wireless networks that would assess meteorological and soil parameters to anticipate and diagnose drought situations. Their model was capable of collecting and analyzing data for optimal water conservation.

Figueroa and Pope [34] introduced three unique methods for determining root system water consumption from soil moisture sensor time series data: Top Rule Pattern, Prevalidated Top Rule Pattern, and Series String Comparison. The authors compared the algorithms to an actual deployed method, Density Histogram.

Li et al. [35] developed a dynamic root design to mimic the interplay of root development and soil water flow. Their suggested model's goal was to realistically describe a three-dimensional root system that could then be connected with a soil model. This model was used to characterize the dynamic interactions of the root system with soil processes such as water transport and local soil characteristics with rooting patterns and tropisms.

Mert and Adnan [36] investigated the effect of thermal behavior on green roofs, popularly known as roof gardening. To assess both the external and internal conditions, data is collected utilizing soil moisture sensors and temperature sensors. Following an analysis of the data produced by the sensors, their green roof system reduced both the summer and winter extreme temperature effects to a certain extent, and the study revealed that extreme temperature fluctuations on the surface of the green roof and the building envelope are reduced by 79 percent by the green roof system.

Vazhachirackal [37] examined many conceptions of city farming as well as technical and nontechnical elements. The author's study on roof gardening in the metropolitan zone gave valuable assistance for urban food production. This approach also has significant social and economic benefits, since it adds to money generation, as well as environmental advantages.

Rao [38] did terrace garden research, which included the ecological value of terrace gardening by balancing out the ecology, exploitation of open space, trash recycling, energy conservation, and several other terrace gardening applications. They demonstrated that green roof or terrace gardening is a necessity in today's environment.

Besbes et al. [39] provided a model of the heat and mass transfer processes that occur on roofs, and the study was carried out using four different types of roofs, each with a different soil type employed for vegetation and thermal movement of the roof. The experiment resulted in diverse behavioral changes on different roofs, and the results revealed that a light roof with no vegetation exhibits high thermal discomfort, whereas growing plants on the roofs exhibits lower thermal discomfort. Similar work is done by researchers in [40, 41]. These all are proving the importance of Internet of Things in making precision agriculture efficient.

3. Methodology

This section presents a framework for smart irrigation. This framework is shown in Figure 2. The main components of this framework are soil moisture and humidity sensor, Raspberry Pi, central cloud storage, soil data set, machine learning techniques, and mobile applications.

3.1. The Major Components of the Proposed Framework

3.1.1. Raspberry Pi.

The core is an ARM11 CPU. A single core 32-bit ARM11 CPU is employed in this system. It has 512 MB of RAM. This board has USB connections, an Ethernet port, an HDMI port, and an SD card slot. It is simple to connect this board to the Internet by utilizing the Ethernet or USB ports. For environmental parameter monitoring, various sensing devices are interfaced with common purpose input output (GPIO). We offer 5 V, 1 A power to the "Raspberry Pi" via the micro-USB port. Essentially, an SD Card with a memory capacity of 8 GB is used to save files such as applications required for the project with the assistance of the operating system [30].

A "Raspberry Pi" board is utilized as a keyboard and mouse through USB ports. For a display, we utilize the "Raspberry Pi" board as the HDMI port, which primarily

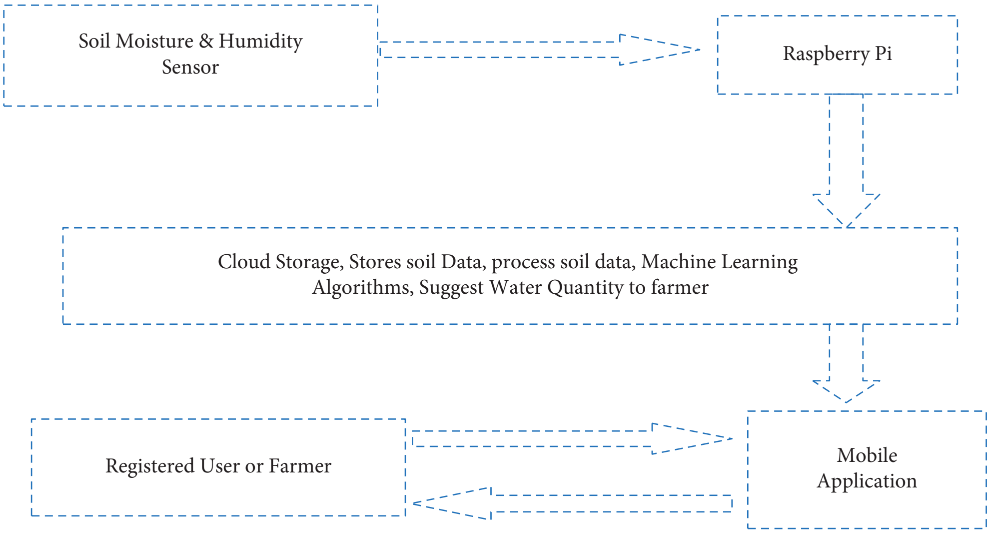

Figure 2: A framework for smart irrigation.

converts HDMI ports to VGA cables. The Ethernet port is used to connect the machine to the Internet through LAN. There is also a normal 3.5 mm small analog audio connector and a regular RCA-type connection on this board. This board also has a 15-pin CSI (Camera Serial Interface) connection for camera module interface and a 15-pin DSI (Display Serial Interface) connection for LED or LCD display interface.

3.1.2. DHT11/DHT22 Humidity Sensor. This is a moisture and humidity sensor. It is used to continually check the amount of humidity and moisture in the soil. This detected data is saved in the cloud via the Raspberry Pi [32].

3.1.3. YL-69 Soil Moisture Sensor. This sensor is used to determine the soil's water content. It is commonly utilized in agriculture, water systems, greenhouses, and other research center activities that need exact estimations of soil water levels. It is separated into two sections: an electrical board that houses the hardware and a dirt mugginess test. The sensor works by producing a potential distinction that is exactly proportional to the dielectric permittivity of water. Variations in voltage can be interpreted as changes in dielectric permittivity and hence as changes in water levels [31].

3.1.4. Cloud Storage. All soil related data is stored in centralized cloud storage. Climate data of that region is also stored in cloud. This cloud has machine learning algorithms like SVM, random forest, and Naïve Bayes. Machine learning algorithms are applied on soil data and climate data to obtain the correct quantity of data required by a particular crop and then this information is made available to registered user by mobile applications. Registered user can view predictions of machine learning. Registered user can set humidity and moisture level for his crop.

3.2. Machine Learning Algorithms

3.2.1. Support Vector Machine Classifier. Support vector machines are associated with learning algorithms which learn from data to decipher patterns in classification and regression analysis. SVM models aim to find fresh water saved in smart irrigation in the different classes as wide as possible so that when a new sample comes in, it is classified based on which side of the gap they fall in.

3.2.2. Random Forests. Random forest is a powerful ensemble learning algorithm often used in classification tasks. It classifies based on the results obtained from the myriad of decision trees it generates while training, where the mode of the targeted outputs from each decision tree is the output of the forest. Random forest generates decision trees on random samples of the training data, thereby reducing the variance in the overall model improving its performance and controlling overfitting.

3.2.3. Naïve Bayes. Naïve Bayes is a probabilistic classifier based on Bayes theorem, with the features being independent of each other. Each feature is considered to contribute to the probability of any given test instance to belong to a particular class.

4. Results

A data set of 330 soil records was created for experimental analysis. This includes soil moisture and humidity details for specific crops in specific regions. Climate data for regions was also part of the data set. In an experimental study, three machine learning algorithms were used: SVM, random forest, and Naïve Bayes.

The accuracy results of machine learning algorithms are shown below in Figure 3: other results are presented in Figures 4 and 5, and Tables 1 and 2.

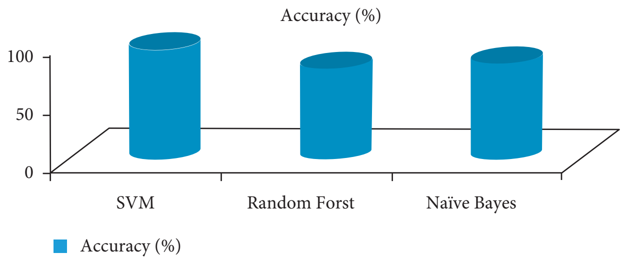

Figure 3: Accuracy of machine learning algorithms.

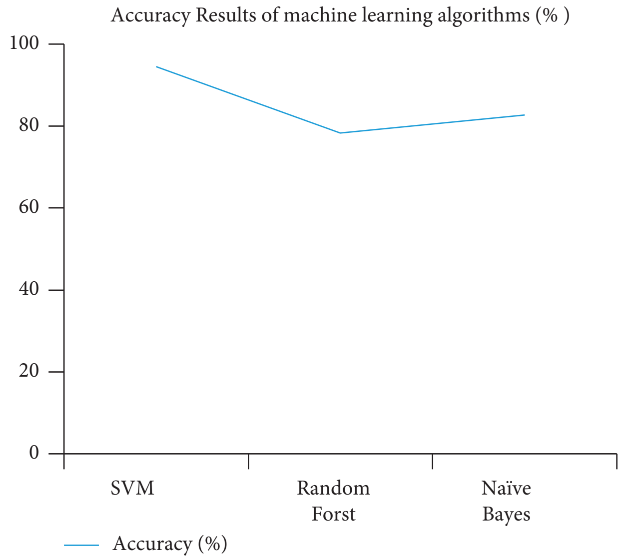

Figure 4: Graphical representation of accuracy results of machine learning algorithms.

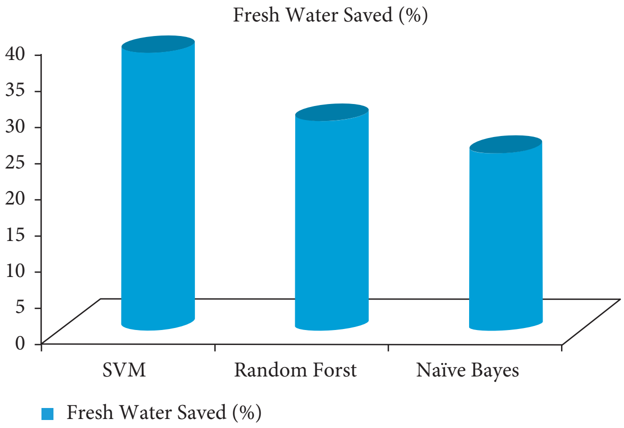

Figure 5: Fresh water saved in smart irrigation.

In this graph, SVM's accuracy result of machine learning algorithms is better than random forest and Naïve Bayes. The result of SVM is more than 80%, but on the other hand, random forest and Naïve Bayes accuracy results are less than 77.5%.

Due to proper water content suggestion for a particular crop, the fresh water saved by algorithms is as follows.

In this graph shown in Figure 6, SVM machine learning algorithms show that fresh water saved in smart irrigation is better than random forest and Naïve Bayes. The result of SVM is more than 35%, but on the other hand, random forest and Naïve Bayes accuracy results are less than 30%.

Table 1: Accuracy of machine learning algorithms.

Accuracy results of machine learning algorithms	
Machine learning algorithms	Accuracy (%)
SVM	88
Random forest	70
Naïve Bayes	76

Table 2: Fresh water saved in smart irrigation.

Fresh water saved in smart irrigation	
Machine learning algorithms	Fresh water saved (%)
SVM	37
RF	26
Naïve Bayes	22

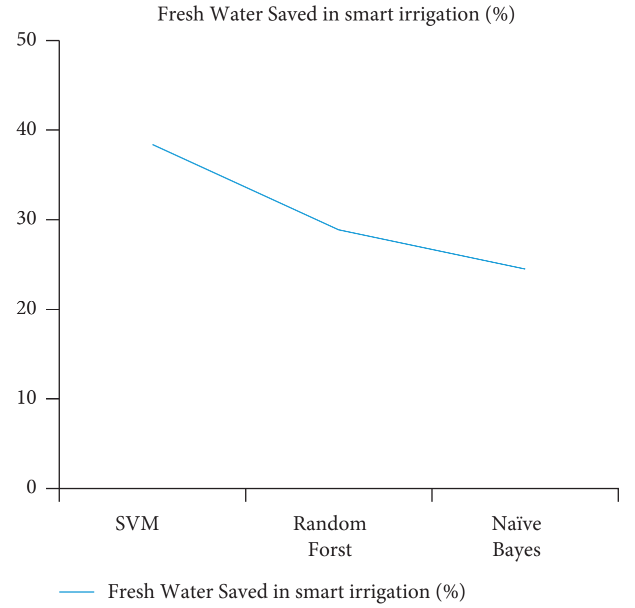

Figure 6: Graphical representation of fresh water saved in smart irrigation.

5. Conclusion

Agriculture, according to the Food and Agriculture Organization of the United Nations (FAO), is not only the world's largest water consumer in terms of volume, but also a low-value, low-efficiency, and extensively subsidized user of water. Because of this, there is an urgent need to increase the efficiency of agricultural irrigation by utilizing technology such as smart irrigation systems. The precision of such a system, on the other hand, is dependent on soil data from that region, as well as climatic data from that region, to be effective. This article describes a smart irrigation system that is based on the Internet of Things and cloud computing architecture. In this framework, machine learning algorithms were utilized to anticipate the proper amount of fresh water required for a crop to be cultivated. As a result, a significant amount of fresh water is saved. The agricultural sector will be transformed as a result of smart irrigation.

5.1. Future Work. Although the systems described in the previous part make the IoT and cloud computing concept practicable, a significant amount of research is still necessary. This section examines the technical issues that now plague IoT systems. Later on, a novel concept of IoT and cloud architecture was developed to meet all necessary parts that are missing in existing architecture. Before the Internet of Things can be extensively adopted and deployed across all sectors, a thorough understanding of industrial characteristics and needs on cost, security, privacy, and risk is required.

Data Availability

The data shall be made available on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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