

Retraction

Retracted: IoT-Driven Model for Weather and Soil Conditions Based on Precision Irrigation Using Machine Learning

Security and Communication Networks

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] D. K. Singh, R. Sobti, P. Kumar Malik, S. Shrestha, P. K. Singh, and K. Z. Ghafoor, "IoT-Driven Model for Weather and Soil Conditions Based on Precision Irrigation Using Machine Learning," *Security and Communication Networks*, vol. 2022, Article ID 7283975, 10 pages, 2022.

Research Article

IoT-Driven Model for Weather and Soil Conditions Based on Precision Irrigation Using Machine Learning

Dushyant Kumar Singh ¹, Rajeev Sobti ¹, Praveen Kumar Malik ¹, Sachin Shrestha ²,
Pradeep Kumar Singh ³ and Kayhan Zrar Ghafoor ^{4,5}

¹Lovely Professional University, Jalandhar 144411, India

²Department of ECE, Nepal Engineering College, Pokhara University, Pokhara, Nepal

³Department of Computer Science, KIET Group of Institutions, Delhi-NCR, Ghaziabad, India

⁴Department of Software & Informatics Engineering, Salahaddin University-Erbil, Erbil 44001, Iraq

⁵Department of Computer Science, Knowledge University, Erbil 44001, Iraq

Correspondence should be addressed to Sachin Shrestha; sachins@nec.edu.np

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To feed a growing population, sustainable agriculture practices are needed particularly for irrigation. Irrigation makes use of about 85% of the world's freshwater resources. Thus, for efficient utilization of water in irrigation, conventional irrigation practices need to either be modified or be replaced with advanced and intelligent systems deploying Internet of Things, wireless sensor networks, and machine learning. This article proposes intelligent system for precision irrigation for monitoring and scheduling using Internet of Things, long range, low-power (LoRa)-based wireless sensor network, and machine learning. The proposed system makes use of soil and weather conditions for predicting the crop's water requirement. The use of machine learning algorithms provides the proposed system capability of the prediction of irrigation need. Dataset of soil and weather conditions captured using sensors is used with six different machine learning algorithms, and the best one giving highest efficiency in predicting the irrigation scheduling is selected. Linear discriminant analysis algorithm gives the best efficiency of 91.25% with prediction efficiency.

1. Introduction

Agriculture is the major portion of GDP in both developing and developed countries. It has been estimated that the world population will be about 10 billion by 2050. To feed the growing population always, food production requires to be increased minimum by 70%. Sustainable agriculture practices are required in agriculture and are keys to ensure food security for growing population. Sustainable agriculture aims to enhance the overall agriculture productivity towards reducing the negative impact on environment due to less efficient agriculture practices. Smart agriculture practices tend to lack behind in research and call for much research and development (R&D) to achieve goal of sustainable agriculture. One of the areas in agriculture, which

needs much attention, is irrigation. Extensive irrigation makes use of 70% of the available freshwater resources. Internet of Things (IoT) and machine learning (ML)-based solution may help in efficient monitoring, controlling, and irrigation scheduling for agriculture fields [1–7].

Many IoT and ML-based irrigation systems have been developed for monitoring and control application. One irrigation system developed integrates sensors and energy module on the top of sprinkler. Another implementation connects soil moisture sensor to Internet for monitoring soil moisture [8], yet another system designed for irrigation uses air temperature, humidity, and air quality for irrigation scheduling and ML for data processing [6].

Ground water is the main source of socio-economic development, but agriculture is using major portion of

ground water for irrigation purpose. Since last two decades, both artificial intelligence (AI) and ML are registering their presence in many application areas including agriculture. ML has been used for predicting river flow and water quality [9].

Water management is of paramount importance due to its scarcity, and this also affects agriculture as major portion of fresh water is used for irrigation. The various methods of irrigation as identified are drip irrigation, spray irrigation, nebulizer irrigation, and most used form of irrigation in India, that is, flood irrigation. Soil moisture, humidity, and temperature are some of the some of the most observed agriculture parameters for irrigation planning. Mainly open-source platforms, specifically Arduino, are utilized as main board in various systems developed for irrigation management [10].

There is a need of sustainable agriculture with minimal impact on environment and maximum productivity, to feed ever growing population and monitor efficient utilization of available limited fresh water in agriculture for irrigation. Conventional less efficient irrigation practices, which focus of past research mainly on monitoring of closed greenhouse environment with low-range technology, high initial cost of weather monitoring systems, and negligible use of intelligent algorithm in irrigation management, has motivated authors to propose the present automated irrigation systems. Recent developments in IoT, wireless sensor networks (WSN), information and communication technology (ICT), and ML have further opened new opportunities to researchers towards agriculture. Proper irrigation planning affects both quality and quantity of agriculture product. IoT and ML along with sensor network can facilitate farmers in proper irrigation planning and efficient utilization of irrigation water.

In the present article, a low-cost long-range irrigation system is proposed. The proposed system uses ML to predict the irrigation requirement by crop. The main contributions of the present article are as follows:

- (1) Long-range soil condition monitoring system. It constitutes as array of sensor with long-range wireless communication module to communicate the soil conditions to weather station.
- (2) Low-cost IoT enables weather station for weather condition monitoring. Weather station collects the soil conditions from various soil sensor nodes and collects the weather information from sensor installed on weather station.
- (3) Best ML algorithm for predicting when to start irrigation.
- (4) IoT-based data storage and remote monitoring of soil and weather conditions. Weather station with soil and weather data sends the data to IoT cloud for storage and monitoring.

The system proposed identified the various communication technologies for their communication capabilities, scalability and power consumption, and the suitable member s selected for the present proposed system. For

making the system intelligent, ML is used, and various algorithms employed in agricultural application are reviewed. The review of ML in agriculture provided the most deployed algorithms for agricultural application, and based on their performance, the system used linear discriminant analysis (LDA) for irrigation requirement for decision-making. The irrigation requirement is affected by the weather and soil parameters carefully selected through extensive literature review. The selected soil and weather parameters are sensed through various sensors and are communications to cloud for monitoring.

The present article is divided into different sections and subsections to present the concept and proposed system. Section 2 presents the state-of-the-art study, identifies the present work on ML, and uses of ML in agriculture, precision irrigation, and the challenges with the past automated irrigation systems. Section 3 presents the design of the proposed irrigation system and provides the testing result and data captured by the developed system and thereafter. Section 4 provides the ML algorithm with for irrigation prediction. In the end, Section 5 concludes the findings of the proposed work.

The present study is important as the proposed system utilizes both soil and weather conditions for irrigation planning to come up with efficient irrigation water utilization strategy in agriculture. Other than farmland irrigation planning, the study also contributes towards improving the economic condition of farmers by reducing higher manual supervision cost and minimizing the negative impact on environment such as freshwater resource pollution and change in soil properties due to less efficient irrigation practices. IoT and long-range, low-power WSN are the most advance technologies in the proposed system and use of ML algorithm that makes the system much effective with predictive irrigation scheduling.

2. Literature Survey

This section presents the status of research in automated irrigation systems and use of machine learning in agriculture.

2.1. Machine Learning. In ML, data-driven prediction is done by programming the system. ML computers are equipped with human learning capabilities to learn from experience, acquire new knowledge, and improve system performance. Basic elements of ML system are raw data, data preprocessing, ML algorithms, generalization, and decision-making [11, 12].

One of the important applications of ML is data mining. The article [13] discussed the supervised learning algorithms in ML, and decision tree, neural networks, and instance-based learning are some of the important supervised learning algorithms. ML learning is faster in making decision as compared to humans. The various methods of learning as described in article are role learning, analog learning, and knowledge discovery. Various applications of

ML are finance, telecommunication, marketing, and analysis of network [14].

ML is a subbranch of AI and gives machines the capability to learn from experience. ML is quite different from statistic method, which is based on likelihood, whereas the ML provides solution based on certain set of rules. Machine learning gains knowledge in the form of experience gathered from historical data. ML techniques are mainly categorized in three categories, namely, supervised, unsupervised, and reinforcement learning. Classification and regression falls under supervised learning, while cluster, anomaly detection, and dimensionality reduction are the applications of unsupervised learning [15, 16].

2.2. Machine Learning in Precision Agriculture. PA also called digital farming is the technology-driven farm management system. PA focused on reducing the production cost and effect on environment while increasing the profit of farmers. ML and IoT are the essential element of future farming. Deploying ML in agriculture helps in controlling, optimizing farm practices, and predicting the weather and rainfall. The various areas exploiting ML are predicting weather conditions, soil properties, and crop yield [12].

In agriculture and other applications, ML offers computational and analytical solutions to different types of datasets. Deploying ML for agriculture is quite tedious due to unavailability of data collecting equipment and unavailability of trained manpower to handle the collected data. Agriculture yield gets affected by many parameters, and some of the important parameters are fertility of soil, climatic conditions, water availability, pests, and crop disease. Rainfall, wind speed, solar radiations, heat flux, evapotranspiration, and temperature are few of the major factors affecting the crop yield [15].

IoT, WSN, and ICT have potential to take care of the various challenges posed to agriculture. AI has been deployed for weather, water usage monitoring, energy, and soil health analysis. AI can be helpful in training robots for harvesting and other similar kinds of labour-intensive agricultural activities. ML is a branch of AI and, along with ICT, is used for smarter data analysis. ML has been used in crop management, livestock management, soil management, and water management. ML does help in predicting crop yield, weed detection, and phenotype classification. The use of AI, IoT, robotics, and WSN is on upswing in agriculture applications. Recent advances in IoT, WSN, and ICT have further triggered their deployment in agriculture. With AI, weather conditions, water usage, and soil condition can be analysed by farmers for better decision [16].

The various agricultural practices where technology is playing an important role are animal welfare, livestock management, yield prediction, disease detection, weed detection, crop quality, species recognition, water management, and soil management. Only 10% of the research has focus on water management, and more than 61% of the research has been focused on crop management. Moreover, water management, that is, water quality and irrigation, plays an important role in crop management. The various

agricultural areas getting benefitted from ML are crop yield prediction, crop disease detection, crop weed detection, livestock welfare, and many more as summarized in Figure 1. Support vector machine (SVM), K-nearest neighbour (KNN), and Gaussian naive Bayes (NB) are some of the ML algorithms, which are used in majority of the agriculture practices [17].

Remote sensing such as satellite and photography is also used to build better decisive system in precision agriculture. The aim of the precision agriculture is to reduce the production cost and impact on environment. Weather conditions, soil properties, irrigation, and fertilization are some of the parameters affecting the crop yield. Much attention is given to ML as being able to process data from various sources and can work with nonlinear data. ML needs minimal or no human intervention and incorporates better knowledge-based system. ML has been used for detecting biotic stress of crop, disease detection in crops, determining physiological and structural properties of plant, and suggesting automatic irrigation. SVM and KNN are the two ML algorithms used extensively in various agriculture applications [18].

2.3. Precision Irrigation Models and Challenges. Traditional irrigation practices result in excessive application of water resulting in field runoff and pollution in freshwater resources. A ML-based algorithm is built with the gathered dataset to predict the allowable time for irrigation. Five different ML algorithms were compared based on mean square error. Ridge regression offers the least mean square error and has been selected as the best match for irrigation prediction [19].

Agriculture sector particularly for irrigation consumes majority of the fresh water. Scarcity of fresh water and use of traditional less efficient irrigation practices in agriculture has ignited the use of advanced and intelligent technologies for irrigation monitoring, controlling, and scheduling. IoT and ML are offering the better techniques in developing intelligent solutions for irrigation. An intelligent irrigation system is developed using Arduino and Raspberry Pi. Soil temperature, humidity, UV radiations, and air temperature are the parameters observed for the developed irrigation monitoring and control system. For communicating the measured parameters, short-range communication technology ZigBee has been deployed. HTTP-based web server and IoT-controlled water pump are the other elements of the developed intelligent system. Soil moisture and need of irrigation are predicted by applying SVM and KNN ML algorithms to soil temperature, humidity, UV radiations, and air temperature, which measured through sensors with weather forecast information [20].

IoT along with WSN, mobile computing, and intelligent agricultural machinery has succoured farmers to adopt various PA practices. An irrigation control system is developed using data from twenty-two soil sensors for a period of two years to develop ML algorithm. Various regression and classification methods were applied to the dataset. Out of the ML algorithms selected, Gradient Boost Regression

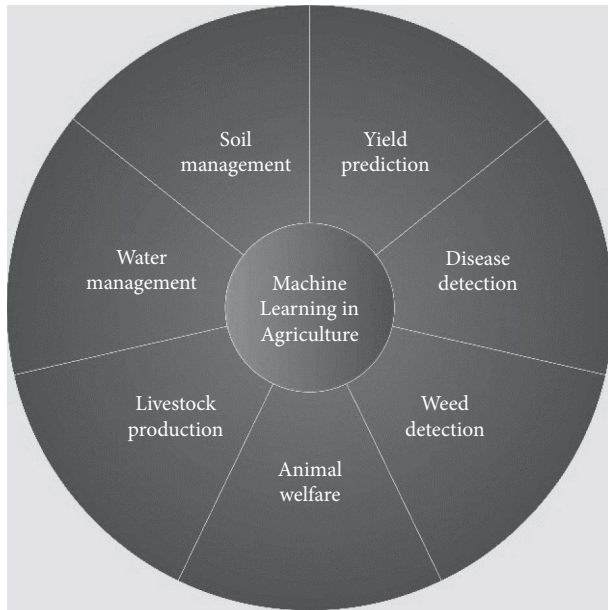


FIGURE 1: Applications of machine learning in agriculture [1, 13].

gave 93% of accuracy in prediction and the best performance was given by Boosted Tree Classifier with 95% of accuracy in predicting the irrigation requirement. Evapotranspiration, the indirect method for estimating the crop's water need, was used to estimate the irrigation requirement using wind speed, humidity, and solar radiations to measure through sensors [21].

Eighty-five percentage (85%) of fresh water is utilized by agriculture particularly for irrigation [22]. For the efficient use of fresh water in agriculture, intelligent IoT-based irrigation systems are required for monitoring, controlling, and scheduling of irrigation. Based on short-range communication technology, AI, ML, and remote sensing, different intelligent irrigation models have been developed. Few of the developed smart solutions of irrigation are summarized in Table 1. In Table 1, the last column also provides the challenges in the developed system, which needs to be addressed to develop a better solution for intelligent irrigation system.

3. System Design and Testing

As mentioned in Table 1, the challenges faced with present automated irrigation systems are short range, complex design, limited use of knowledge-based ML techniques, and filtering out of certain important agriculture parameters. The system proposed in the present article focuses to address majority of the challenges. The proposed intelligent irrigation system comprises soil monitoring sensor nodes, IoT-connected weather station, IoT cloud for data storage and monitoring, and ML algorithms for the prediction of irrigation need. The agriculture parameters observed, as identified from literature survey section, for proposed irrigation decision support system, which are soil temperature, soil moisture, air temperature, relative humidity, wind speed, and wind direction.

Putting together Internet of Things (IoT) which is scalable long-range, low-power wireless communication, and machine learning algorithm in the proposed system make it more advanced and reliable. System uses multiple soil sensor nodes for farmland monitoring. Soil sensor nodes are equipped with soil moisture sensor, soil temperature sensor, and LoRa wireless communicating module. With the LoRa technology, soil sensor nodes can be installed upto a range of 1 km to 1.5 km [28–30], although the module deployed claims range upto 8 km and enables to monitor the larger farmland.

Weather station other than capturing the local weather conditions also acts as a central unit between IoT cloud and soil sensor nodes. Weather station observes air temperature, relative humidity, wind speed, and wind direction. Weather and soil conditions (from soil sensor nodes) are sent to IoT cloud for storage and monitoring. ThingSpeak IoT cloud is used being available with no cost for upto 8 channels and provides good data visualization in graphical form. Figure 2 gives the block diagram of the proposed system.

The system is tested with two soil sensor nodes, as shown in Figure 3, and weather station, as shown in Figure 4.

The weather station uploads the soil and weather condition data to ThingSpeak IoT cloud. ThingSpeak IoT cloud provides data visualization in graphical form, and data uploaded can be downloaded in ".csv" form for analysis. The mobile interface for data visualization is shown in Figure 5.

The captured weather station data are compared with the weather data from <https://www.worldweatheronline.com> as shown in Tables 2 and 3.

From the three days of observation, maximum difference in temperature from the two sources of data was 1.4°C. For humidity, the difference between the two sources of data was measured as 2% and wind speed differs by maximum of 1 kmph. The developed system performs satisfactorily, as the observed data in within the limits of sensors [10].

4. Machine Learning Modelling for Precision Irrigation

The dataset contains 500 observations of soil and weather conditions (100 rows and 5 columns), with 100 entries for each observed parameter. "AirTemperature," "Humidity," "WindSpeed," "Volumetric Moisture Content (VMC)," and "SoilTemperature" are the five columns of measurement for soil and weather conditions, respectively. The data store is expanded to include a sixth column, "Decision," which contains 0s and 1s depending on whether irrigation is necessary or not based on soil and weather conditions suited for rice and wheat [31–33]. Figure 6 depicts the various characteristics of the libraries utilized to execute ML algorithms.

Six different ML algorithms are applied to the weather and soil information in order to discover the best ML techniques for the current application. Machine learning techniques such as linear logistic regression (LR) and nonlinear K-nearest neighbour (KNN), classification and regression trees (CART), Gaussian naive Bayes (NB), and support vector machines (SVM) are the methods used in

TABLE 1: Precision irrigation systems and challenges.

| Reference | Description | Challenges |
|-----------|---|---|
| [7] | Soil moisture, air temperature, humidity, and light intensity of the farmland were observed to estimate the irrigation need. IoT is implemented for data monitoring and transmission of data takes place through short-range ZigBee technology. | (i) Soil temperature and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of ZigBee limits the design for shorter fields as being short-range technology and limited in scalability if very large farmland needs to be monitored. |
| [8] | Arduino-based IoT enabled irrigation system. The developed system used temperature, pH, soil moisture, and humidity to estimate the irrigation need. | (i) Soil temperature and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of Arduino makes IoT design complex. (iii) ML irrigation prediction is not part of system design. (iv) System uses short-range wireless communication technology, which limits the utilization of system in larger fields. |
| [23] | An IoT-based automated irrigation system is designed. It uses temperature, humidity, and soil moisture to estimate the irrigation requirement. | (i) Soil temperature and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of Arduino makes IoT design complex. (iii) ML irrigation prediction is not part of system design. |
| [24] | Based on soil moisture, an automated IoT enables irrigation system, which is proposed. The system enables the farmer to monitor the soil moisture and initiate the irrigation when required. | (i) Soil temperature, air temperature, and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of Arduino makes IoT design complex. (iii) ML irrigation prediction is not part of system design. |
| [25] | An IoT-based automated irrigation system is developed. Soil moisture, humidity, and temperature are the parameters observed to make decision regarding irrigation. Indirect method of estimating the crop's water needs; that is, evapotranspiration has been used for irrigation scheduling. Developed system uses short-range RF communication technology for data transmission. System claims to be about 92% more efficient in comparison with tradition irrigation techniques. | (i) Soil temperature and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of Arduino makes IoT design complex. (iii) ML irrigation prediction is not part of system design. (iv) System uses short-range wireless communication technology, which limits the utilization of system in larger fields. |
| [26] | IoT-based irrigation system is developed by observing soil moisture and uses GSM technology for monitoring and Arduino as development platform | (i) Soil temperature, air temperature, and wind conditions are important factors in irrigation planning but neglected in design. (ii) Use of Arduino makes IoT design complex. (iii) ML irrigation prediction is not part of system design. (iv) Use of GSM makes system complex and costly as require placing mobile phone at site with active SIM. |
| [27] | An intelligent Raspberry Pi-based irrigation system is developed. Soil moisture and air temperature are the observed farm parameters. KNN algorithm is applied to observed farm parameters in order to make prediction for irrigation requirement by the crops. | (i) Soil temperature and wind conditions are important factors in irrigation planning but neglected in design. (ii) The system developed does not discussed regarding sensor network for monitoring larger fields. (iii) The design does not make any effort to identify the best ML algorithm for the irrigation application based on observed parameters. |

current experimental analysis. Agriculture applications frequently employ the support vector machine (SVM), K-nearest neighbour (KNN), and Gaussian naive Bayes (NB) algorithms. The multivariate plot is shown in Figure 7, and the link between the various soil and weather variables can be seen there. For example, air temperature and soil temperature are directly associated with various extents, although the air temperature and VMC graph display scattered dots.

The available soil and weather dataset is divided into two parts (80% and 20%), and 80% of data segment is used for training, evaluation, and selection of best ML algorithm, whereas the other 20% of data segment is used for the

validation of the ML algorithm. LDA gives the accuracy of 91.25%, highest amongst all the six ML algorithms, while SVM accuracy is minimum with only 63.75%. The accuracy of all six ML algorithms is provided in Table 4.

Bayes' theorem is used to estimate probabilities in LDA models. They create predictions based on the likelihood that a fresh input dataset will fall into one of the classes. The output class is the one with the highest probability after which the LDA provides a prediction.

Bayes' theorem, which calculates the probability of the output class given the input, is used to make the prediction. They also utilize the likelihood of each class as well as the probability of the data in each class



FIGURE 2: Block diagram of the proposed irrigation system.



FIGURE 3: Soil sensor node.



FIGURE 4: Weather station.

$$P(Y = x|X = x) = \frac{[(Plk * fk(x))]}{[(\text{sum}(PlI * fI(x))]}, \quad (1)$$

where x is input and k is output class. $Plk = Nk/n$ or the training data's base probability for each class. In Bayes' theorem, it is also known as prior probability. $fk(x)$ represents estimated probability of x belonging to class k [34].

After the calculation of accuracy of ML algorithms based on the training and validation process, the selected model is LDA

with 91.25% of accuracy. The selected ML algorithm is tested with four instances, numbered as 1, 2, 3, and 4 in Figure 8.

Instances 1 and 2 are the soil and weather conditions from dataset itself giving decision 1 and 0 for irrigation. When instance 1 and instance 2 outputs are compared with the expected output, it is found to be correct. In instance 3 and instance 4, the selected ML model is provided with the random values for the soil and weather conditions without looking to the dataset values. The decision for instance 3 is 0 and for instance 4 is 1. When the decision is compared for the



FIGURE 5: ThingSpeak data visualization interface on mobile phone.

TABLE 2: Weather conditions from <https://www.worldweatheronline.com>.

| | Time | Friday | Saturday | Sunday |
|-------------|----------|---------|----------|--------|
| Temperature | 3:00 AM | 12°C | 12°C | 11°C |
| | 12:01 PM | 21°C | 22°C | 22°C |
| Humidity | 3:00 AM | 50% | 44% | 33% |
| | 12:01 PM | 26% | 22% | 20% |
| Wind speed | 3:00 AM | 4 kmph | 9 kmph | 8 kmph |
| | 12:01 PM | 10 kmph | 8 kmph | 9 kmph |

TABLE 3: Weather conditions from developed weather station.

| | Time | Friday | Saturday | Sunday |
|-------------|----------|---------|----------|--------|
| Temperature | 3:00 AM | 13.4°C | 11.9°C | 12.3 |
| | 12:01 PM | 22.1°C | 20.6°C | 20.8°C |
| Humidity | 3:00 AM | 52% | 46% | 31% |
| | 12:01 PM | 25% | 23% | 18% |
| Wind speed | 3:00 AM | 5 kmph | 10 kmph | 7 kmph |
| | 12:01 PM | 11 kmph | 8 kmph | 8 kmph |

```
>>>
Python: 3.7.6 (tags/v3.7.6:43364a7ae0, Dec 18 2019, 23:46:00) [MSC v.1916 32 bit (Intel)]
scipy: 1.7.3
numpy: 1.21.5
matplotlib: 3.5.1
pandas: 1.3.5
sklearn: 1.0.1
>>> |
```

FIGURE 6: Attribute of ML libraries.

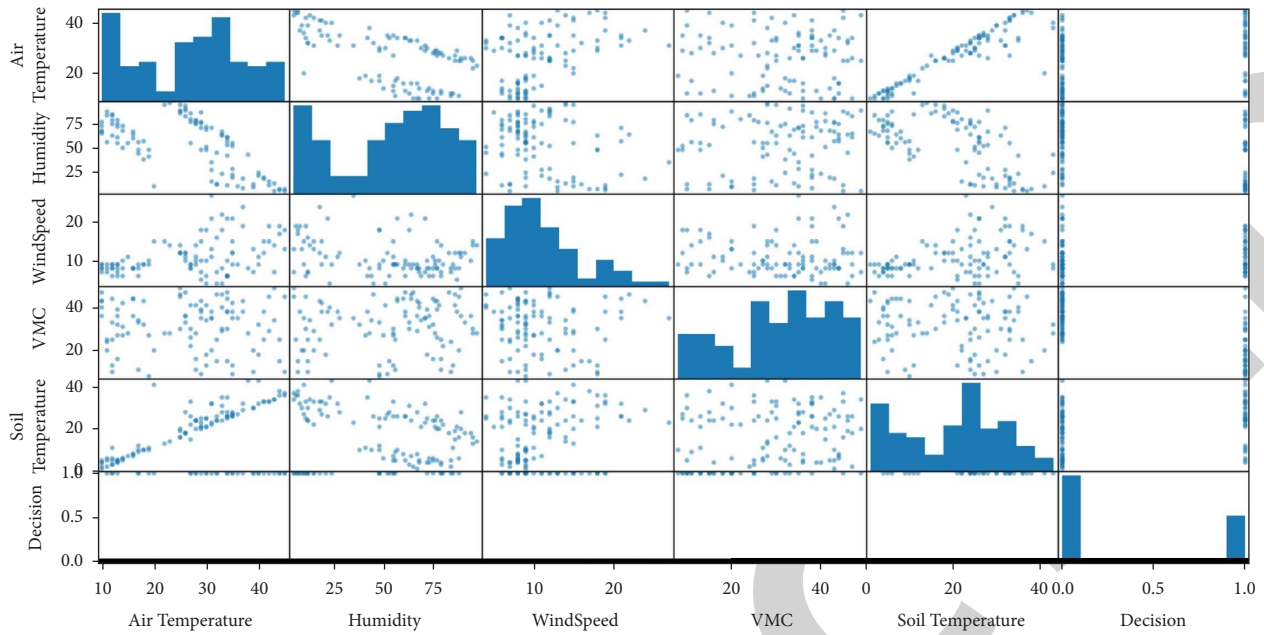


FIGURE 7: Multivariate plot for soil and weather conditions.

TABLE 4: Algorithms comparison for accuracy in prediction.

| S. no. | ML algorithm | Accuracy in prediction |
|--------|--------------|------------------------|
| 1 | LR | 0.825000 (82.5%) |
| 2 | LDA | 0.912500 (91.25%) |
| 3 | KNN | 0.837500 (83.75%) |
| 4 | CART | 0.850000 (85.0%) |
| 5 | NB | 0.850000 (85.0%) |
| 6 | SVM | 0.637500 (63.75%) |

```

Soil and weather parameters from data set for decision 1: 1
[[36, 10, 9, 35, 27]] [1]
Required irrigation and system is activated

Soil and weather parameters from data set for decision 0: 2
[[35, 19, 9, 42, 27]] [0]
Irrigation not required and system is deactivated

Random soil and water condition Case 1: 3
[[40, 70, 10, 50, 30]] [0]
Irrigation not required and system is deactivated

Random soil and water condition Case 2: 4
[[40, 58, 5, 26, 30]] [1]
Required irrigation and system is activated
>>> |
    
```

FIGURE 8: Testing of the LDA model for intelligent irrigation system.

TABLE 5: Cost analysis of commercial weather stations.

| S. no | Weather station product | Cost/unit | Make | IoT feature | Source |
|-------|---|-----------|-------------------------------------|-------------|---|
| 1 | Automatic weather station, for industrial: ATM1136 | 70,000 | Advance Tec India Private Limited | No | https://www.indiamart.com/proddetail/automatic-weather-station-12477572848.html |
| 2 | V tech ultrasonic weather station for agriculture: VT-UWS01 | 120000 | V TECH | No | https://www.indiamart.com/proddetail/ultrasonic-weather-station-19054403862.html |
| 3 | Portable weather station: 110-WS-18 | 325000 | Auro Electronics Private Limited | No | https://www.indiamart.com/proddetail/portable-weather-station-4539296991.html |
| 4 | Automatic weather station, usage: industrial: RK900-01 | 143000 | Infinity Enterprise Private Limited | No | https://www.indiamart.com/proddetail/automatic-weather-station-18244123933.html |
| 5 | Automatic weather station, for official | 500000 | Nevco Engineers Private Limited | No | https://www.indiamart.com/proddetail/automatic-weather-station-13513226588.html |

expected outcome based on dataset, it is found out that the ML model selected is able to correctly predict the irrigation requirement.

5. Conclusion

Scarcity of freshwater resources and ever rising world population needs modernization of agriculture. For food security to increased population, reducing impact on environment and efficient utilization of irrigation water agriculture needs to adapt modern technologies. IoT, ICT, WSN, and ML provide intelligent solutions to agriculture practices including irrigation. Many irrigation models have been developed, but they neglect one or the other important aspects of either technology or agriculture. An advanced knowledge-based long-range scalable irrigation decision support system is proposed in the present paper. The proposed design tries to address some, or all the challenges faced in present automated irrigation systems and providing the cost-effective solution. The cost comparison of developed weather station with some of the available commercial weather stations is provided in Table 5. Weather stations with the cost of eve as high as Rs 32500/- are not supported with IoT. The weather station developed for the proposed system cost 50%–60% less than as mentioned weather stations in Table 5.

Weather and soil conditions are observed for the proposed irrigation support system. The use of scalable long-range, low-power communication technology in soil sensor nodes gives systems the ability to monitor larger fields with more accuracy. IoT cloud is used for weather and soil data visualization eliminating the requirement of local storage and display. Knowledge-based ML technique is used for making decision regarding irrigation. Six different linear and nonlinear ML algorithms are used with the observed dataset, and their accuracy in predicting irrigation is calculated. The best efficiency of 91.25% was observed with LDA algorithm. After selecting the efficient ML algorithm, the selected algorithm is tested for the different soil and weather conditions for decision-making. The intelligent irrigation decisive support system was successfully able to monitor soil and weather condition of farmland using IoT and makes correct decision regarding irrigation.

Data Availability

Any specific data are not generated. All results are included in research paper itself.

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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