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# A Low Cost Smart Irrigation Planning Based on Machine Learning and Internet of Things

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**Abstract**

In an agriculture system major issues of irrigation systems for plants water supply is a critical factor. A significant amount of freshwater is required for this task but after the utilization of water in the irrigation process it is being polluted. In addition, the excessive use of water during the irrigation process can negatively affect crop production. Therefore, we need to provide a balanced amount of water for effective crop production and conservation of water. In this paper, we proposed low-cost irrigation planning with two key aims: first is to reduce the installation and maintenance costs of data collection in innovative irrigation systems and second is to control the valve for water supply automatically. In this context, we first provide a review of recent irrigation systems based on the Internet of Things (IoT) and Machine Learning (ML). Next, we introduce a working plan to collect crop water requirements using a soil moisture sensor. Then, an algorithm is proposed to decide the water supply for water treatment. Finally, the experiments are conducted on the samples collected from the farmland of wheat crops. Additionally, two different scenarios are considered to collect the water requirement samples. Based on the experimental and theoretical analysis of water requirements the proposed irrigation system can reduce the water demand by up to 25% as compared to traditional ways of irrigation. Moreover, in comparison of popular valve automation system the proposed multiple valve based system reduces the amount of water wastage up-to 22%. Therefore by utilizing the advance computational techniques (IoT and ML), we can reduce the cost of irrigation system and planning.

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**Keywords**

Agriculture Automation;
Food Security;
Machine Learning;
Smart Irrigation;
Water Conservation;
Water Management Plan.

## Introduction

Water is essential for all living things. However, the entire world is covered with 75% of water, but only 1% of it is fresh and usable.[1] The population is growing worldwide, and the requirement for water and food is also growing. Therefore, we need to concentrate on advanced techniques of agriculture by which we can increase the production of food

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crops and also reduce the need and wastage of fresh water. In this context, Machine Learning (ML) techniques and network technology become very useful for making effective utilization of water in agriculture.[2] The ML techniques are utilizing the historically collected farm data and recover the essential insights which may useful for making effective water management and planning of irrigation. The ML techniques are able to analyze the large amount of data and find the similar pattern and possible consequences.

However, the ML techniques will help to analyze and predict the future possible consequences and insights, but for live change in farm conditions we need the sensor technology to collect instantaneous data.[3] Therefore, we can utilize the Internet of Things (IoT) and Sensor technology to sense and communicate the current farm conditions to server. The server utilizes these sensor hints to verify the predicted results by the ML algorithms. In our context, we can save water and also enhance the productivity of the crops by utilizing these technologies. Therefore, in this paper, we proposed to investigate and develop an enhanced irrigation system for optimizing water requirements. Additionally reduces the installation and maintenance cost of smart irrigation systems.

The paper provides the following contributions in order to demonstrate the required irrigation model

1. A review of recent techniques developed for smart irrigation systems
2. An overview of the IoT-based device to collect samples from farmland
3. The planning of providing a water supply system for reducing implementation of sensors and water requirements
4. The decision-making algorithm for making the water supply decisions by automating the water valves.

**Literature Review**

In this review we investigate the recent development in water conservation in agriculture. Thus we have considered 45 articles among 25 most relevant to have been selected for review. The summary of the studied contributions are reported in table 1. Additionally, the essential keywords used in different research articles are given in table 2. Table 1 highlights the key contribution of the articles. Then the method of data collection and analysis methods are discussed. Next considered parameters or attributes are listed. Finally, the consequences of the article are highlighted. Therefore, table 1 highlights the key components used for designing the technique to effectively utilize the water in agriculture. Next, table 2 consists of the key terms or abbreviations used in the research articles. The conducted review is keenly interested to explore the studies of better utilization of water and improving the agricultural yield.

**Table 1: Review Summary**

| Ref | Key contributions | Data source | Attributes | Consequences |
|---|---|---|---|---|
| [1] | monitoring water utilization, estimate growth | Soil moisture sensors | soil moisture, pH levels, humidity, and temperature | (1) Decide the amount of water to trigger the irrigation system. (2) Capture plant image and notify the farmer. |
| [2] | Maintain health of crops, Required water and nutrients | | cost, time, and care | Soil preparation and planting, growth requires attention. Process for detecting and solving plant health issues. |
| [3] | predict soil moisture and manage water according to rain | Raspberry Pi, edge nodes with actuators and sensors, Heroku | MongoDB | regression + clustering, XGBoost + k-means, Avoiding transmission |

| | | | | |
|---|---|---|---|---|
| [4] | control plants watering rate | Arduino and NRF24L01 | soil moisture and user requirement | Manages and monitors the irrigation system, saves employee cost, prevents water |
| [5] | - | sense soil humidity | Deep Learning | wastage. high accuracy |
| [6] | predict water requirements | Sensor, Ontology | KNN | Avoid the burden of the server, reduce latency rate. 50% decision manual and 50% decision relies on sensor data. |
| [7] | precision irrigation for monitoring and scheduling | use of soil and weather conditions | Dataset of soil and weather conditions captured using sensors | Predicting the water requirement. Prediction of irrigation needs. LDA gives 91.25% prediction efficiency |
| [8] | analyses a smart irrigation | | measure soil moisture and humidity | Process data in the cloud using ML. Farmers are given information about water content rules. |
| [9] | Set up an automatic irrigation system | soil moisture sensor | soil moisture | Irrigate precise water needed. A total of 44% water savings, while the plants were healthier than the traditional method. |
| [10] | low cost IoT and weather based controller system, weather prediction | soil moisture | temperature, humidity and rain drop sensors, weather parameters | Control water supply, saves water, remotely monitor soil and control water supply, according to the weather condition |
| [11] | Design and the experiment of a smart farming system | wireless sensor networks | | enables prediction, implementation in three phases, i) data collection, ii) data cleaning and storage, iii) predictive processing |
| [12] | predict the weather condition, predicts whether soil needs water | Sensor Data | Temperature sensor, humidity sensor, pH sensor, raspberry pi or Arduino pressure sensor and the bolt IOT module. | Solve these irrigation problems, predict the weather condition, and make less use of field water. irrigation system and to conserve water |
| [13] | yield prediction and smart irrigation | - | planning schemes, transport, buying mechanisms, storage, and liquidity | Predictions to minimize production cost and maximize yields. Past breakthroughs and AI-based techniques in precision farming. |
| [14] | intelligent irrigation system | soil and weather | Parameters selected by various research articles | Provides a cost-effective solution to local weather monitoring. |
| [15] | SMCSIS to address the excessive irrigation problem | soil moisture sensor and climate prediction | air temperature, wind speed and direction, UV, and humidity | Real-time watering decision, database of characteristics and crop irrigation information, Access control and blockchain |

| | | | | |
|---|---|---|---|---|
| [16] | irrigation system to supervise the paddy field | soil moisture sensor, pH sensor, flow sensor | parameter of soil-moisture and water flow amount | It operates via http protocol to control the water pump. Capable to on/off water pumps. |
| [17] | recommendation system for efficient water usage | IoT devices are deployed | Environmental and ground details, Raipur crop dataset | Applies ML approaches to analyze and suggest irrigation. |
| [18] | DLiSA, a feedback integrated system | LSTM | Soil moisture for a day ahead, irrigation period, water required | The simulation results that DLiSA uses water more wisely than state-of-the-art models. |
| [19] | automating agriculture using WSN and weather prediction | weather prediction to minimize water needed | - | WSN efficient than IoT, cost effective micro-controllers, communication modules and data showcasing |
| [20] | Smart & Green framework | prediction of soil moisture, without sensors | data monitoring, pre-processing, storage, fusion, synchronization, irrigation | Outlier removal allows precise irrigation. Save on average, between 56.4% and 90% of the irrigation water needed. |
| [21] | detail of a smart irrigation system to cover large urban areas | soil temperature/ moisture and air temperature | | Use a radio-planning tool to determine best locations, the Irrigation system is reducing 23% water by weather forecasts. |
| [22] | study and development of an automatic irrigation control | water management, ML algorithms to predict | wireless sensors and actuators network, a mobile application | Best time of day for water administration. Studied Decision Trees, Random Forest, ANN, and SVM, 60% water savings. |
| [23] | IoT-based platform for smart irrigation | Use of ML | - | Facilitating system deployment, providing cost reduction and safer crop yields. |
| [24] | dynamics of decision-making in on-farm household income | six irrigation schemes, across three southern African countries. | ordered probit and ordinary least squares regression | Households make trade-offs b/w irrigation, dry-land, livestock and off-farm. Combined with the impact of small plot size of irrigated land, to result optimal benefits. |
| [25] | Support decision making for on-line control, operational management of water allocation | - | - | Technique for irrigation projects. Provides an increase of productivity and management quality due to automation, optimization for diagnostics of the issues. |

**Table 2: Identified Keywords**

| Keywords | Detail |
|---|---|
| pH | Potential of Hydrogen |
| SMPHA | Soil Moisture Prediction Hybrid Algorithm |
| KNN | K-Nearest Neighbour |
| GSM | Global System for Mobile communication |
| LoRa | Low-Power |
| LDA | Linear Discriminant Analysis |
| AI | Artificial Intelligence |
| SMCSIS | Secure Multi-Crop Smart Irrigation System |
| UV | Ultraviolet |
| IIS | Intelligent Irrigation System |
| NIT | National Institute of Technology |
| DLiSA | Deep Learning based IoT enabled Intelligent Irrigation System for precision Agriculture |
| LSTM | Long Short-Term Memory Network |
| WSN | Wireless Sensor Network |
| LPWAN | Low-Power Wide-Area Network |
| RF | Radio Frequency |
| SVM | Support Vectors Machines |

Among them most of the work focused and recommended to utilize the sensor and IoT technology for data capturing and ML techniques for analyzing the data. But, the systems based on IoT and ML for deployment, management and maintenance. Secondly, different crops have different needs of water and fertilizers. Additionally, due to different climate conditions the weather varies in different locations thus local weather sensing and prediction is essential to improve the irrigation models. In this presented work we are concentrating on designing an effective system which is low cost and effective for better water utilization.

**Data Collection and Sensor Placement**

In order to collect soil conditions in terms of moisture there are a number of different hardware configurations available. Among them ESP32 based hardware is one of the most frequently used techniques. Circuit Diagram for ESP32 is given in figure 1.

**FC-28**

It is a simple method for measuring the moisture in soil and similar other materials. The FC-28 based soil moisture sensor can be directly used with different microcontrollers. The sensor module consists of two pads, which are functioning as information collection units for the sensor, and working as a variable resistor. In this context, when water is available in the soil then it demonstrates better conductivity between the pads, which results in a lower resistance, and a higher AOUT.

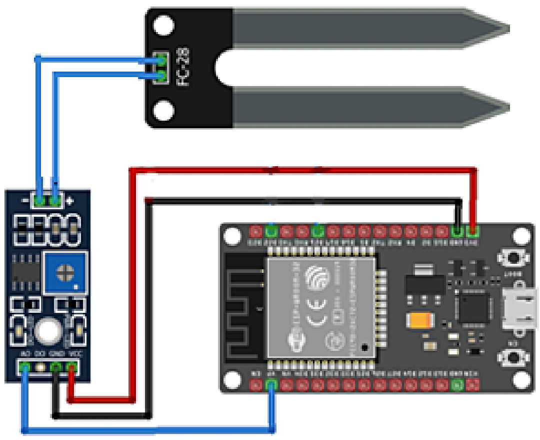


**Fig. 1: Circuit Diagram for Moisture sensor**

**ESP32**

The ESP32 is a feature-rich processor unit or microcontroller (MCU) with integrated Wi-Fi and Bluetooth connectivity. ESP32 is capable of functioning reliably in complex environments, with an operating temperature ranging from –40°C to +125°C. ESP32 can remove external circuit imperfections and adapt to changes in external conditions. ESP32 can perform as a complete standalone system or as a slave device to a host MCU, reducing communication overhead. It can interface with other systems to provide Wi-Fi and Bluetooth functionality. The Station mode (STA) is used to connect the ESP32 module to a Wi-Fi access point. The ESP32 behaves like a computer that is connected to a router. If the router is connected to the Internet, then the ESP32 can access the Internet. Here FC-28 is a soil moisture sensor module, which is connected to the ESP32 module. That combination measures volumetric from the soil. The total cost of the unit is very low and can be organized under

600 INR, and further can be reduced in mass production. But covering the entire field with this node can become expensive therefore we need the effective placement of the sensing devices in the field for appropriate sensing and data capturing. The aim of the sensor deployment is not only to capture data samples from the soil but also to provide a better plan to reduce the sensor deployment cost in farmland. Therefore, we have subdivided the land area into three main parts outer area, middle area, and center area as demonstrated in Figure 2.

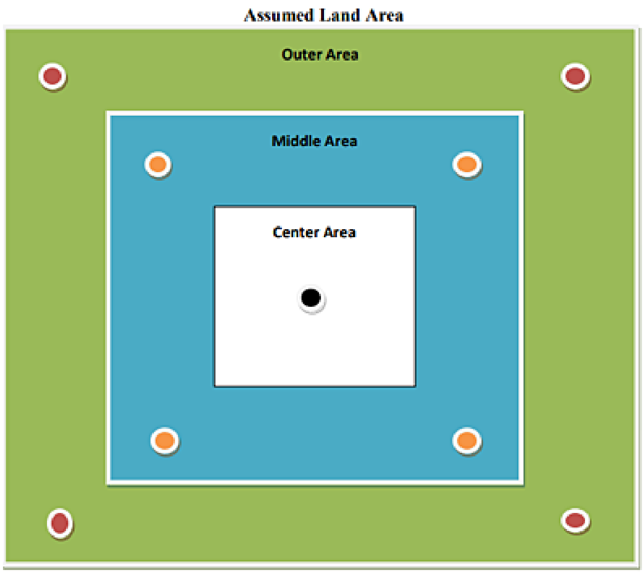



**Fig. 2: Sensor placement plan**

In the outer area, it is assumed that it is always in contact with direct hot air and sun by which the evaporation becomes faster and soil has low moisture. Additionally, the placements of the sensor nodes are denoted as maroon, orange, and black nodes in Figure 2 in the middle area of the categorized areas. Therefore the entire ground is covered with only nine sensor nodes.

### Water Supply Decision Making

According to the given figure 2, the entire area of cultivation is divided into three main parts in the following manner

- A1: Area under the outer bold black line and inner thin black line.
- A2: Area under the thin black line and thin blue line.
- A3: Area surrounded by a thin blue line.

According to the area categorization, we have recommended establishing three water supply pipelines for cultivating these specific areas. But we can use a common motor for water supply with three different valves. Additionally, to operate or enable and disable we need an algorithm. The required algorithm is demonstrated in Table 3. The algorithm accepts the sensor readings in terms of $R_a$, $R_b$ and $R_c$. These readings are consolidated readings of all the sensors established in a particular area. Therefore, the sensors demonstrated in blue color provide information about the outer area which is represented using $R_a$. The consolidated sensor reading for this area is calculated using

$$R_a = \frac{1}{N}\sum_{i=1}^{N} R_i^a$$

Where, N is the number of sensors established to collect data from outer area, and $R^i_a$ is the sensor reading of $i^{th}$ sensor established in outer area. Similarly we are calculating the readings of the sensors established in middle and center area.

**Table 3: Decision making process for valve control**

**Input:** Sensor Reading $R_a$,$R_b$,$R_c$, Operational valves $V_a$,$V_b$,$V_c$
**Output:** Valves V

**Process**

1.for each new reading
a. if($R_a$≤30%)
1. V = Enable $V_a$
b. elseif($R_b$≤30%)
1. V = Enable $V_b$
c. elseif($R_c$<30%)
V = Enable $V_c$
d. End if
2. End for
3. Return V

**Single Valve vs Multiple Valve**

The proposed work is aimed to preserve fresh water wastage in the agriculture process. In this context, we have implemented a moisture sensor and compared it with the traditional water irrigation system. However the proposed method theoretically preserves the water up to 25%, but in literature there are some other kinds of water supply management systems that are also available which are reducing the water requirements in agricultural use. Among them the two popular water supply systems are frequently used, among them grid organization and concentric circle ways are much popular at Indian agricultural scenarios. But in both the cases the common valves are used for operating the entire system. The figure 3 demonstrates the traditional and new organization of the water supply systems.

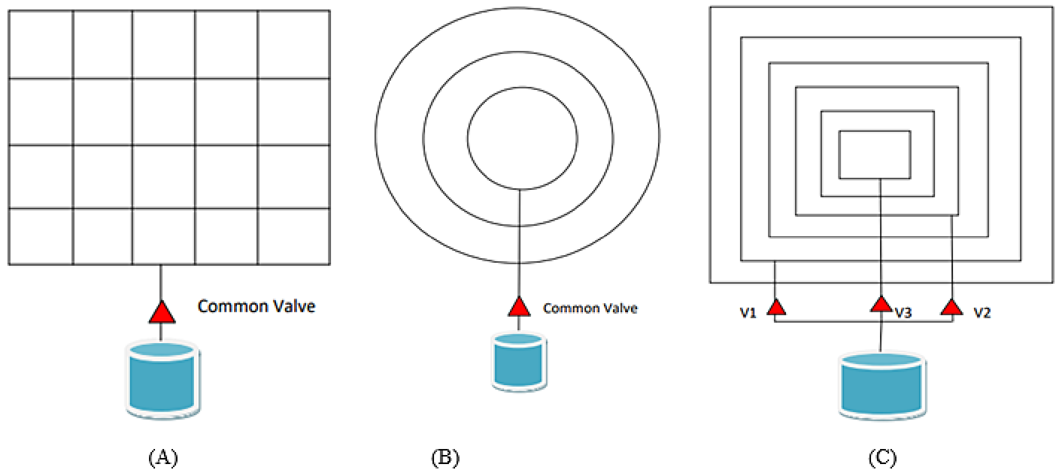



**Fig. 3: shows the water supply systems (A) Grid based single valve supply (B) concentric circle based single valve system and (C) proposed water supply system using multiple valve**

Figure 3(A) shows the grid organization of the water supply system operated using a single valve. This system is developed to provide water supply to the entire farm land equally and uniformly. However, this system is a popular way to irrigate a farm but this technique is suitable for the farms where crops are planted in a distance and require similar or uniform amounts of water. Mostly this technique is adopted in indoor methods of farming. On the other hand the figure 3(B) demonstrates the concentric circle based process of water treatment using the single valve. In both the traditional approaches the water supply is provided in a uniform manner to the entire farm. However the limited water supply needs to cultivate the farm but requires excessive water to be produced.

On the other hand using the multiple valves we reduce the water requirements according to the farm's moisture level. Therefore, only those valves are being operational when the specific area of the farm requires the water treatment. In this context, the proposed method of multiple valves and a decision making function will reduce the water requirements more as compared to the traditional method of water treatment using a single valve. The required organization of the multiple valve based water irrigation system is demonstrated in the figure 3(C). In this diagram valve V1 is connected to the outer area of the farm and valve V2 connected to the middle area and center area is connected to the valve V3. Based on the collected data samples on the basis of real world scenarios and an open farm, we calculated the water requirement for the given three methods of water supply.

**Results Analysis**

In this work the aim is not to identify the performance of a circuit, but the aim is to identify the key insights which will help to improve the irrigation system. Here the improvement indicates how much water we can preserve. Therefore, using a use case we performed a study practically in the field by which we found some essential insights. In this context, we performed two set of experiments such as

**Scenario 1**

measuring the moisture content first time after seeding. In this scenario all the fields are flat and need an equal level of water supply for the first time.

**Scenario 2**

In this experimental scenario we have collected the samples after 30 days of crop growth. In this time the plants are grown up and then we measure the moisture of the field.

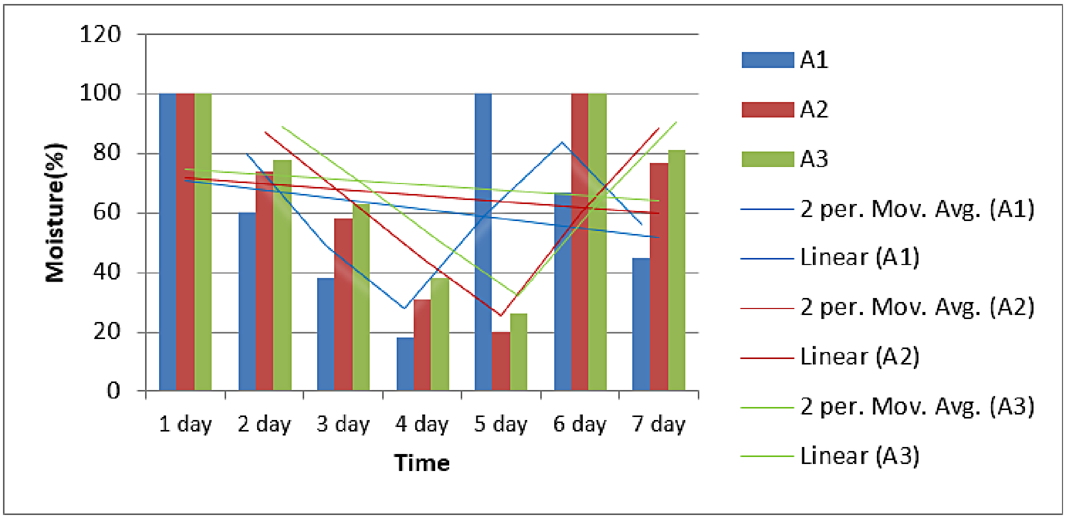



**Fig. 4: Moisture contents after first time crop seeding**

The figure 4 provides recorded average moisture readings at the end of day. The readings are taken in the winter season after seeding of wheat crops and first time water supply. During this scenario the entire field is cultivated and at the time of reading the initial reading of sensors is 100% moisture. Therefore, in figure 3 first day reading is given as 100%. Next, for four days the moisture content is frequently dropped. After that we can only cultivate the outer area of the land to preserve the water. And on the sixth day we need to cultivate the inner part of the land.

On the other hand after 30 days when we collected the sample we found a major difference in pattern. In order to find the difference among the patterns we requested to cultivate the entire field completely and then we started collecting the samples. The figure 5 shows the collected sample. According to the collected samples we found the evaporation process is reduced for grown crops. Additionally, at the outer area we need the water supply after the fifth day, at the middle area after the sixth day and at the center area require the water after the eighth day.

According to the discussion with the farmers who are utilizing the traditional method of irrigation, the wheat crop requires 90-120 days of work from their seeding to harvesting. Among first 3/4 days needs care about the crop irrigation. Additionally, there are mostly forth days they need to cultivate the entire crop for better growth. Therefore, if we assume that each time we need x quantity of water to irrigate the field. Then if 90 days life cycle is considered then we need T_w amount of total water.

$T_w$=(x*90)/4

Additionally, when we consider the proposed scenario of irrigation then for outer area we need.

$$T_o = \frac{1}{3}\left(\frac{x*90}{4}\right)$$

For middle area

$$T_m = \frac{1}{3}\left(\frac{x*90}{5}\right)$$

And for center area

$$T_c = \frac{1}{3}\left(\frac{x*90}{6}\right)$$

Thus we need a total of

$$T = T_o + T_m + T_c$$

$$T = \frac{x*90}{3}\left(\frac{1}{4}+\frac{1}{5}+\frac{1}{6}\right)$$

$$T = \frac{3x}{4}$$

Thus total preserved amount of water is

$$P = T_w - T$$

$$P = 25\%$$

Therefore the proposed method will save 25% of water as compared to traditional technique of crop irrigation. The performance of preserved water is given in figure 6.

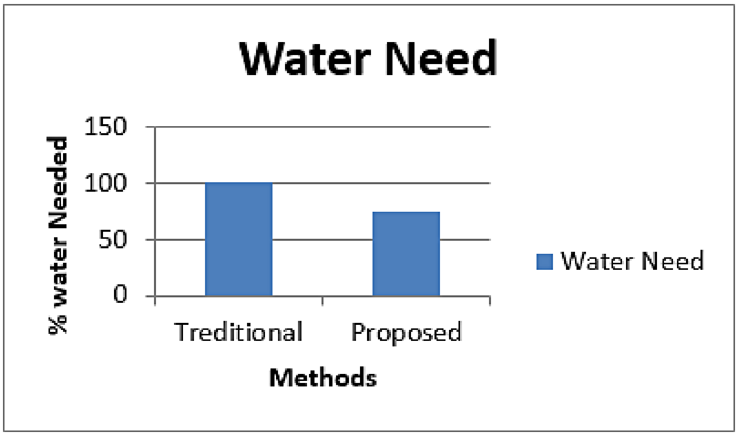


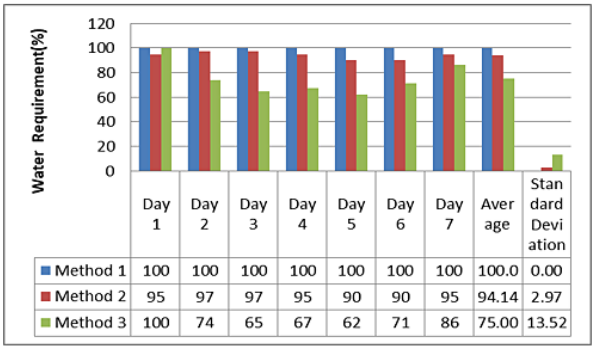

**Fig. 6: Amount of preserved water**

For a week we measured the water requirements for all three scenarios of water supply valve operation and presented them in figure 7. The X axis of this diagram is presenting the days and the total water requirement by the methods is given in Y axis. According to the obtained observations we found the grid method requires a significant amount of water as compared to concentric circle based method and proposed multiple valve based method. In order to provide a clear vision about the water requirements we also measured the mean water requirements for all the experimental methods. Figure 7(B) demonstrates the mean water requirements of the methods in a week, which is calculated using the following equation.

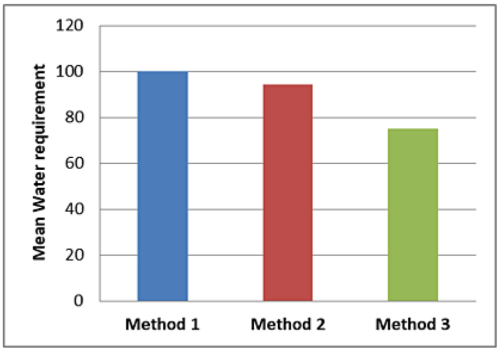
$$W = \frac{1}{N}\sum_{i=1}^{N} T_i$$

Where N is the number of days in observation, in this work we assumed N=7, T_i is the total water supplied in ith day.

This experimental outcome is based on the consideration of 50m X 50m land area, and a water supply tank of 5000 litre water storage tank. All three configurations are applied one by one to the same place and the observations are made.




(A)




(B)

**Fig. 7: shows (A) water requirement in one week period of time and (B) daily mean water utilized by the methods**

Additionally the results are given terms of percentage (%) water consumed during the irrigation. The experiments are conducted during the winter season in January month. Based on the obtained values in experiments we can say the proposed method of irrigation system and valve management will reduce the amount of water requirements.

## Conclusions

In the agricultural process a significant amount of freshwater is used. Additionally this water recycling needs a significant amount of time and is an expensive process. Therefore fresh conservation is a challenging task. Therefore in this paper we are working to minimize the utilization of water without affecting the crop yield. Thus, first we designed a low cost moisture sensor to collect the data. Additionally a sensor placement method is also employed to reduce the deployment cost of sensors. Further for automating the water supply the sensor reading based valve triggering algorithm is proposed. Finally experiments have been carried out in two different scenarios of wheat crops. Additionally the samples are collected for water supply. Based on the experimental data collection and the discussion with farmers a theoretical analysis of water requirement has been performed. Based on the analysis of results we have found the proposed technique can reduce the water consumption up to 25% with respect to traditional irrigation systems. Additionally we found the outer area of the crop field has been losing the moisture more frequently as compared to the inner part of farmland. However, this experiment is conducted on a plain land but the moisture content is also affected by the type of surface and the season of crop also. Therefore, in the near future we are also trying to study the effect of surface and weather conditions of irrigation systems.

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**Conflict of Interest**

All authors have participated in Conception, implementation, and analysis. Drafting the article critically for important intellectual content Approval of the final version. This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue. The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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