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

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Abstract— **In the farming process irrigation time and the amount of water supply is a critical factors. 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. Based on the experimental analysis the theoretical analysis has been carried out to estimate the reduction in water requirements. The results indicate the effectiveness of the proposed irrigation system by reducing the water demand by up to 25% as compared to traditional ways of irrigation.**

Keywords — Smart Irrigation, Irrigation Automation, Machine Learning, Water Conservation, Food Security, Water Management Plan.

I. 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. 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 crops and also reduce the need and wastage of fresh water. In this context, machine learning techniques and network technology become very useful for making effective utilization of water in agriculture. By effective water management and planning of irrigation, we can save water and also enhance the productivity of the crops. 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.

II. 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 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 the table 1 highlights the key components used for designing the technique to effectively utilize the water in agriculture. Next, table 2 consist 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 amount of water to trigger irrigation system. (2) Capture plant image and if problem found, 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 irrigation system, save employee cost, prevent water wastage.
[5]	-	sense soil humidity	Deep Learning	high accuracy
[6]	predict water requirements	Sensor, Ontology	KNN	Avoid the burden of 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 need. LDA gives 91.25% prediction efficiency
[8]	analyses a smart irrigation		measure soil moisture and humidity	Process data in cloud using ML. Farmers 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	Prediction to minimize production cost and maximizes 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 and 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 water pump. Capable to turn 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, 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 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 of 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 are 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 is much expensive for deployment, management and maintenance. Secondly, different crop has the different needs of water and fertilizers. Additionally, due to different climate conditions the weather is varies in different locations thus local weather sensing and prediction is essential to improve the irrigation models. In this presented work we are concentrated on designing an effective system which is low cost and effective for better water utilization.

III. DATA COLLECTION AND SENSOR PLACEMENT

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

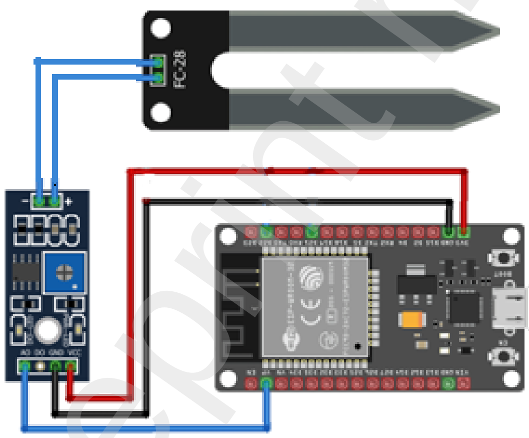


Figure 1 Circuit Diagram for Moisture sensor

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 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 demonstrate better conductivity between the pads, which result in a lower resistance, and a higher AOUT.

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 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 with the ESP32 module. The total cost of the unit is very low and can be organized under 600 INR, and further can reduced in mass production. But for covering the entire field with this node can become expensive therefore we need the effective placement of the sensing devices to 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 provide a better plan to reduce the sensor deployment cost in a farmland. Therefore, we have subdivided the land area into three main part outer area, middle area and center area.

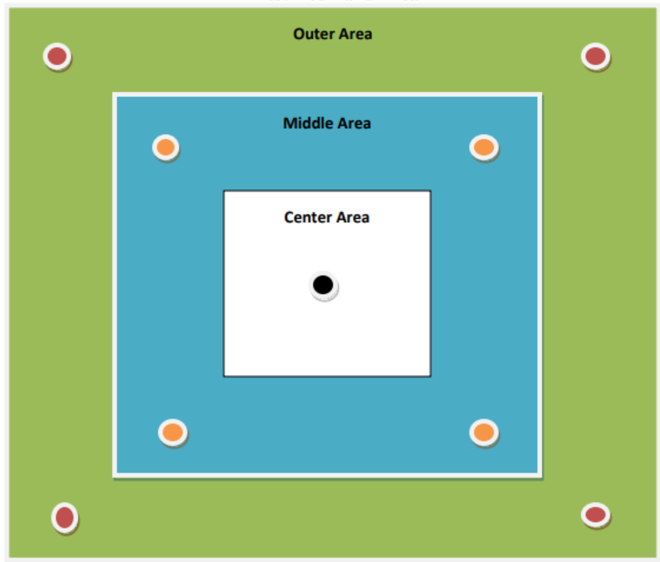


Figure 2 Sensor placement plan

In the outer area, it is assumed that it is always in contact of direct hot air and sun by which the evaporation is 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 at the middle area of the categorized areas. Therefore the entire ground is covered with only nine sensor nodes.

IV. 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 thin blue line.

According to the area categorization we have recommended to establish 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 reading of all the sensors established in a particular area. Therefore the sensors demonstrated in blue color provides the 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 Algorithm 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. $if(R_a \leq 30\%)$
      i. V = Enable V_a
   b. $elseif(R_b \leq 30\%)$
      i. V = Enable V_b
   c. $elseif(R_c < 30\%)$
      i. V = Enable V_c
   d. End if
2. End for
3. Return V

V. 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:

1. **Scenario 1:** measuring the moisture content first time after seeding. In this scenario all the field is flat and need an equal level of water supply for first time.
2. **Scenario 2:** In this experimental scenario we have collect 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.

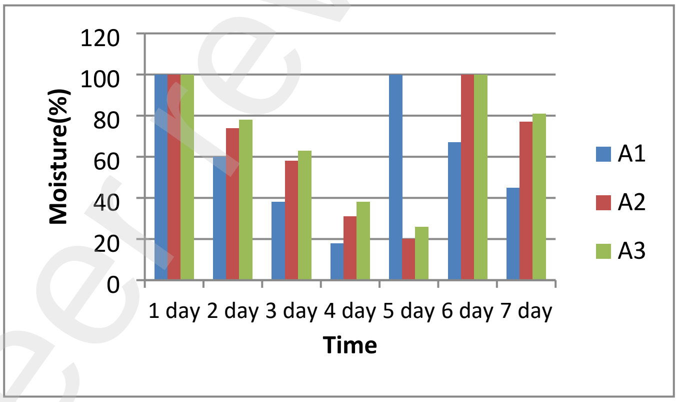


Figure 3 moisture contents after first time crop seeding

The figure 3 provides recorded average moisture readings at the end of day. The readings are taken in winter season after seeding of wheat crop and first time water supply. During this scenario 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, four day the moisture content is frequently dropped. After that we can only cultivate the outer area of the land to preserve the water. And at sixth day we need to cultivate the inner part of the land.

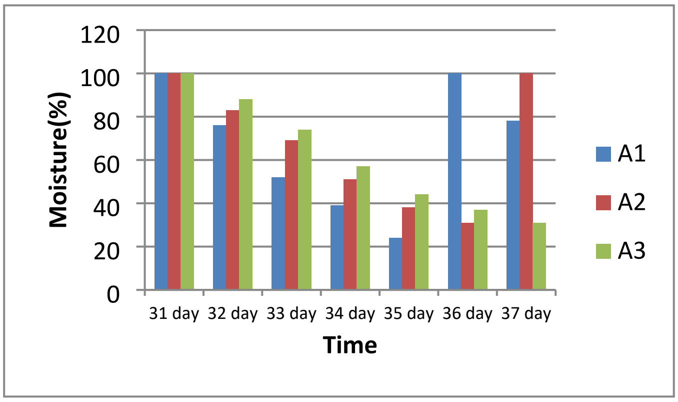


Figure 4 moisture contents after 30days of crop growth

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 pattern we requested to cultivate the entire field completely and then we start collecting the samples. The figure 4 shows the collected sample. According to the collected samples we found the evaporation process is reduced for grown crop. Additionally, at the outer area we need the water supply after fifth day, at middle area after sixth day and at the center area required the water after 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 day 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:

$$T_w = \frac{x * 90}{4}$$

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:

$$T = T_o + T_m + T_c$$

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

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

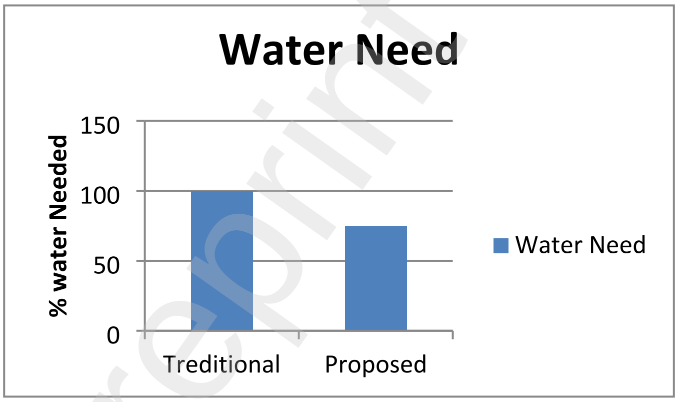


Figure 5 Amount of preserved water

Thus total preserved amount of water is:

$$P = T_w - T$$

$$P = 25\%$$

Therefore the proposed method will save 25% amount of water as compared to traditional technique of crop irrigation.

VI. SINGLE VALVE VS MULTIPLE VALVE

The proposed work is aimed to preserve fresh water wastage in agriculture process. In this context, we have implemented a moisture sensor and compared 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 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 way are much popular at Indian agricultural scenarios. But in both the cases the common valves are used for operating the entire system. The figure 6 demonstrates the traditional and new organization of the water supply systems.

Figure 6(A) shows the gird organization of the water supply system operated using 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 required similar or uniform amount of water. Mostly this technique is adopted in indoor methods of farming. On the other hand the figure 6(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 uniform manner to entire farm. However the limited water supply need to cultivate the farm but requires excessive water to be produce.

On the other hand using the multiple valves we reduce the water requirements according to farm's moisture level. Therefore, only those valves are being operational when the specific area of farm requires the water treatment. In this context, the proposed method of multiple valve 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 6(C). In this diagram valve V1 is connected to 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 scenario and an open farm, we calculated the water requirement for the given three methods of water supply.

For a week we measured the water requirements for all three scenarios and presented 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 gird method requires significant amount of water as compared to concentric circle based method and proposed multiple valve based method.

Additionally the results are given terms of percentage (%) water consumed during the irrigation. The experiments are

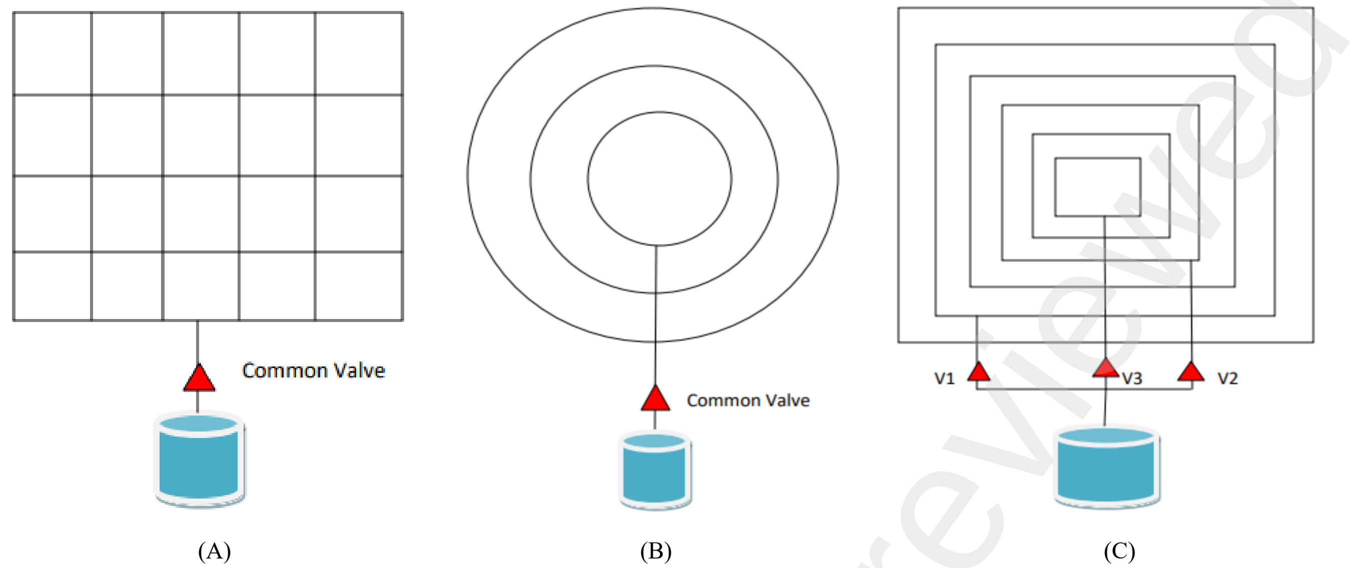


Figure 6 shows the water supply systems (A) Grid based single valve supply (B) concentric circle based single valve system and (C) proposed water supply system using multiple valve

conducted at 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.

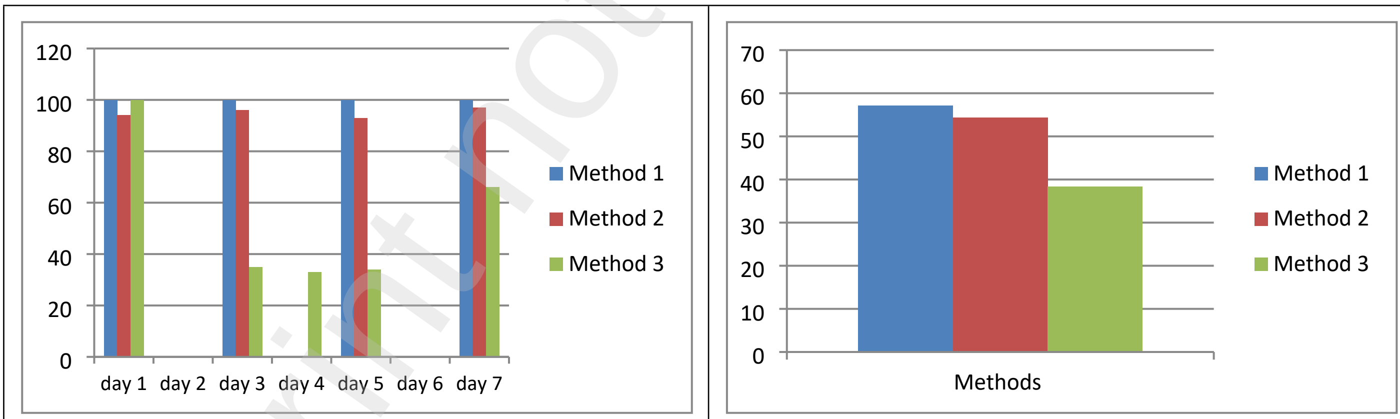
In order to provide a clear vision about the water requirements we also measured the mean water requirements for all the experimental methods. Figure 7(B) demonstrates the mean water requirements of the methods in a week, which is calculated using the following equation:

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

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

VII. CONNECTIVITY AND SENSOR PLACEMENT

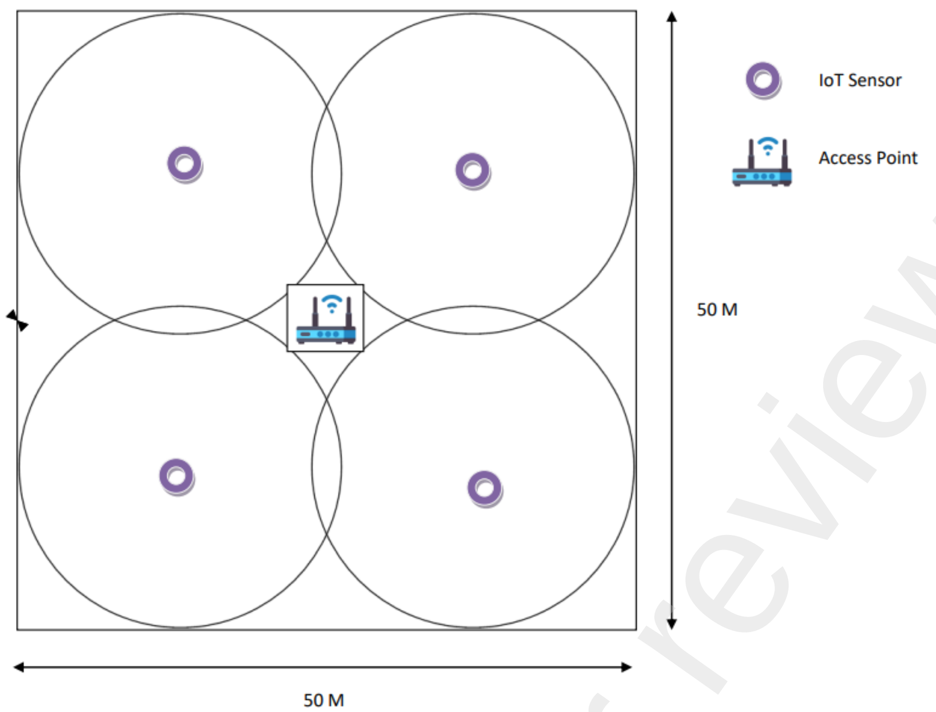
In our proposed work, the considered area is monitored using the IoT sensors for collecting the water moisture level.



(A) (B)

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

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



VII. CONCLUSIONS

In agricultural process a significant amount of fresh water is used. Additionally this water recycling needs a significant amount of time and 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 wheats 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 system. Additionally we found the outer area of crop field has loosing the moisture more frequently as compared to 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 near future we are also trying to study the effect of surface and weather conditions of irrigation system.

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