

BROACHING UNCOUTH WATER LEVEL SNAG IN UNDERGROUND AGRICULTURE FIELD THROUGH WIRELESS SENSORS

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Abstract

The major problem faced by the agriculture industry is the growth of seeds at optimal fertility. Such uncouth fertility occurs when either no water reaches under soil seed or some obstacles prevent it. This issue degrades agriculture growth at an aggravation level and consequently barren the land. A wireless sensor-based communication model has been developed to notice the accurate status of the water level reaching seeds of various crops such as wheat, maize, barley, and cotton with soil types Loamy, Silty clay, and Black soil. In the proposed model, 'Broadening Uncouth Water Level Snag in Underground Agriculture Field with Wireless Sensors' (BUWLN), the water level would be measured in real time and the data would be transmitted to a base station accordingly. The 8 sensor nodes and a base station would be deployed accompanied by an Arduino package in an area of 90 × 30 square feet to monitor water levels efficiently. The study will keep track of water levels, and the farmer will be informed of the water level so they may manage water resources more effectively. In addition, farmers will also be aware of the field if water is distributed uniformly so that the crops yield increases. The performance of the proposed BUWLN model has been compared with Remote water-level monitoring system (RWMS), Low cost wireless sensor network (LCSN), and Ensemble groundwater level prediction (E-GWLP) by conducting simulation using PROTEUS. result showed that the proposed BUWLN model has enough potential for future growth.

Keywords: Base Station, Detection, Monitoring Proteus, Sensor Node, Water Level

Introduction

Agriculture is the art and science of sowing seeds, growing crops, and producing food for a country. Agriculture leads to the production of different animal and plant products. It also results in food and fabric production. Before agriculture, people searched for food and spent their lives hunting and

searching for food. With the growth of crops and fields, the breeding and herding of wild animals also increased. Farmers are the main heroes in agriculture as they work a lot for the growth and development of crops and the agriculture industry (Rajasekaran and Anandamurugan, 2019). They use

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different tools and machines for their work and work day and night for the betterment of this industry. By current methods and techniques, water is not available for all crops and some parts stay barren and plant growth may be sparse. A barren land cannot give proper growth of crops and vegetation but using latest technology and the management one can lessen the infertility of soil to improve the poor growth of plants and agricultural fields (Ashraf, 2019). A wireless sensing element network was created for an agriculture field within which various crops were selected, and their water consumption in line with soil and time was measured. Using wireless sensor networks the WIFI signals detect the water level and sent it to the bottom station. Every crop and soil is deeply studied and the relevant time was studied to produce results. Four different soils, i.e., loamy soil, silty clay loam, and loam soil black soil and crops, i.e., barley, cotton, maize, and wheat, were thought-about and then an analysis was done about water level consumption and the behavior with soils. Per hour watering time and depth of each crop with relevant soil were considered to obtain the results.

Deployment of sensors in under-surface fields will yield crops better growth and more generation of products for agricultural industry. Three comparative strategies, i.e., Remote water-level monitoring system (RWMS), low-cost wireless sensor network (LCSN) (Calderwood *et al.*, 2020a), and ensemble groundwater level prediction (E-GWLP) (Iqbal *et al.*, 2021), were used for comparison and generating results. The Arduino system (Ashraf, 2021), would communicate to sensors and actuators wirelessly and signals were transmitted and received through an RF transmitter and receiver. The world's first entirely machine-operated crop was harvested in 2017 (Aderemi *et al.*, 2021). Still, later on, it felt like an essential part of the agriculture field. Every country decided to improve its agriculture industry through artificial intelligence, digitalization, mobile technologies, the internet, and many other ways. Information Technology is used in agriculture to make a company more productive and increase food growth. Moreover, it helped farmers do their work efficiently, informed them, and made timely and sound decisions. It is an unseen resource in the soil or rocks beneath the surface of the earth that is scarce. As well as providing safe water for living beings worldwide, water plays an influential role in industrial development and economic growth.

Use of Sensors in the Agriculture Field

The usage of wireless sensor in agriculture field has brought significant improvements in crop production. The sensors are used for many purposes

to keep the farmer updated about different aspects of the area. The sensors provide data to the farmers through which they get assisted, and then they make the required changes in the system. This intelligent technology is continuously growing and enlarging. Three sensors are used in innovative agriculture industries, and their detail is discussed further.

In this study, the sensors work as the main component that helps to sense the current conditions of soil and crops according to their needs and then work wirelessly. The sensors can be deployed under or over the surface but here they are present underground so that they are safe from unfavorable climatic conditions. Sensors used in previous research works were mostly wired and that created difficulty and destruction in the field but in this study the sensors work wirelessly so that so that there is no as such technical or non-technical issue faced by the farmers and the respective workers in the field. The number of sensors are classified as

Ph Sensors

The presence of nutrients and chemicals in an agriculture field must be monitored continuously as deficiency of nutrients, and excess chemicals can be harmful to the crop. Ph sensors provide nutrients and chemical feedback and details related to the soil. These sensors detect hourly, daily, weekly, monthly and yearly variations of Ph level in soil and thus help improve the technology (Li *et al.*, 2020a).

Humidity and Temperature Sensors

When healthy plants are the main objective, the most critical element to be monitored is 'WATER'. To survive, plants require specific soil, light, air, water, temperature, and humidity conditions. Humidity is present in the air, and different temperature changes in the environment also must be kept in view as divergent plants need other weather conditions to survive. The temperature and humidity sensors (Alfandi *et al.*, 2020), monitor the temperature and humidity changes in the environment and inform the farmer about the latest variations. Despite the surrounding conditions, keeping track of the equipment installed in a field is also necessary. The temperature sensors are also asset sensor that senses the faults in gear so the defect can be resolved.

Accelerometer Sensor

Some equipment, e.g., nozzle sprays in the field, require tracking of their movement, and a fault in its movement must be detected; otherwise, it may destroy the whole system. The accelerometer resembles the temperature sensors as both draw out the apparatus's faults. The accelerometer sensors detect abnormal movements and vibrations and then

inform the farmer so that it can be managed (Saleem *et al.*, 2020).

A part from these sensors there are some other allied components that work together such as GPS, used to keep tracking the activity of various happenings. It provides an automatically guided system that needs no assistance and saves time and resources like water (Wang and Ming, 2021). The smart cameras are another essential component which is quite different from analog sensors but has extensive use in the smart agriculture industry. Intelligent cameras act as an eye for the farmers. Through them, they can watch out for different issues like pests' growth, lightning issues, obstacles, and damaged apparatus and thus can also remove other sensing devices as they show a complete image of the field.

Importance of wireless sensors in agriculture

In agricultural land the wireless sensor are used to observe different physical and immaterial conditions. These sensors send the signals in the form of sounds, vibrations, indications to the remote server machines wherever information is being collected. Indeed, it is a non-conventional method and some way to urge a less faulty system because it is troublesome to a central system with wires (Ahmad *et al.*, 2020). Data collection for agriculture monitoring is affected by a number of factors, including the particular location of the study, the climate and the weather, the proximity of markets and the infrastructure for transportation and storage, as well as agricultural methods, and activities specific to each person. The use of sensors in agriculture is crucial in order to get the rapid real-time data. A mechanism for gathering data such as this can produce an immediate change in an agri system, allowing to monitor agri-parameters in real-time with high accuracy. As a result of the availability of so many data sources in such a short time period, it is difficult to make the appropriate decision as a result of the influx of data. It is pertinent to understand that recent developments in agriculture have not only been driven by the amount of data that has been collected in various ways. Additionally, the data has been collected with a high level of security. Several security threats can alter information and network structure, including eavesdropping, disruption, and physical attacks. The source node must establish a security model in the communication network and application where data is processed and stored to ensure that data is authenticated, unchanged, and protected (Saleem *et al.*, 2020).

Wireless sensors in agriculture: challenges and solutions

There are numerous challenges for wireless sensor network in the agriculture field. As sensor nodes sense the data and perform the further processing in the line of transmission and the routing. All these activities cannot be accomplished sans using energy. Therefore, the biggest challenges seems the energy consumption and an efficient energy management strategy becomes indispensable to enhance the life time of the batteries (Ashraf *et al.*, 2020). In addition to using renewable energy sources such as solar power or kinetic energy, it is also possible for sensor nodes to be powered by solar energy.

It is usually necessary to collect data from sensor nodes and transfer it to a central base station. This consumes a huge amount of battery power, when using traditional WSN approaches. In order to prune the energy loss by reducing the amount of data transferred by employing techniques such as aggregation and compression, it is necessary to use techniques such as real-time data transfer and event-based applications (Ahmed *et al.*, 2020).

Ecological factors usually cause data transmission failures. Data transmission is usually limited to a short range by most wireless sensor communication technologies, requiring additional sensors and routers to create a wireless sensor network (Sumit *et al.*, 2022). In addition to multi-tire networks, ad hoc networks and mesh networks can be used to extend communication range.

Besides spoofing, sinkhole attacks, Sybil attacks, Denial of service attacks, and jamming (Sybil Attack - an Overview | ScienceDirect), there are many types of threats that spoil the integrity of data. These threats include man-in-the-middle attacks, phishing attacks, and malware attacks, which can all be used to intercept data and inject malicious code into a network. Additionally, replay attacks can be used to intercept and re-transmit data, thus corrupting it. A wide range of access control mechanisms and anomaly detection techniques are available for securing sensed information in a WSN (Khan *et al.*, 2021).

Similarly, fault tolerance (Saleem *et al.*, 2020), cannot be ignored in wireless sensor communication. These factors can have devastating effects on the performance of a wireless sensor network, such as reduced coverage, increased latency, and decreased throughput. Furthermore, these problems can be compounded, as the effects of one problem can lead to the manifestation of other problems as well. In order to increase the reliability

of WSNs, a variety of fault tolerance mechanisms have been employed such as redundancy-based mechanisms, clustering-based mechanisms, and deployment-based mechanisms.

Somehow, placement of the nodes is important because it affects the accuracy of the data collected. If the nodes are too far away from each other, then the data may not be as accurate. Additionally, if the nodes are too small, then they may not be able to collect enough data to be useful (Afnan *et al.*, 2020). In order to deploy a sensor node, its size must be small and suitable. Sensor nodes play a major role in WSN performance and lifetime. There are two main types of deployment methods for WSNs: random and deterministic (Hepsibha and Sanjiv 2013). In large scale open environments, random deployment strategies are used, and in small-scale environments, deterministic deployment strategies (point to point).

Contribution

In this study, the water level in underground agricultural field has presaged, reassuring that each seed has direct exposure to enough wetness for best fertility. The contributed remarks are given therefore.

- The deployed sensor nodes sense the water level and transmit the signal to base station.
- The base station collects data from all sensors and sends the status of water level to user through GSM.
- Various soils and the crops are tested and the outcome is compared with other systems.
- The simulation has been conducted using PROTEUS(PCB Design and Circuit Simulator Software), to analyze the output of proposed BUWLN model with other models.
- The results of proposed BUWLN model vouched the suitability of the system and maximum fertility would be possible.

The rest of the work is arranged as. A comprehensive literature review is presented in Section 2. The ground reality about the proposed method is addressed in Section 3. The proposed layout is discussed in Section 4. The simulation performance has been bassesse in Section 5. The conclusion and future research expectations are presented in Section 6. Results and discussion are presented in Section 6.

Literature Review

There is an associated redoubled variety of agriculture-related analyses and works over the last 2 decades. several researchers worked within the agriculture trade for its betterment. The literature review determined that each study has numerous

limitations and challenges which led to the proposal of this study for each crop and soil.

Lorena Parra *et al.* (Parra *et al.*, 2015), presented an innovative study to improve the utilization of resources and reduce the emission of harmful gases in urban environments through the integration of Information and Communications Technology (ICT). They conducted a study in which they explored the issue of sustainability of groundwater resources and how it is affected by a number of factors. Moreover, it discussed the development and testing of a specific sensor for monitoring the salinization process of groundwater. To obtain the most accurate correlation between induced voltage and electric conductivity of water samples, several prototypes are tested to determine the most effective combination of electrical coils. It was decided to perform a first test to determine which sensors were most suitable in terms of size, cost, and maximum possible voltage. A minimum cell volume is determined for the selected prototype. Additionally, a mathematical equation has been obtained that correlates the sensor signal (induced voltage) with the electric conductivity of water through a calibration process with more than 30 samples. It was not possible to monitor the water level for the specific crop in this study.

Another approach had presented by Engr *et al.* (Engr *et al.*, 2018), which reviewed various instrumentation techniques that were applied in groundwater level determination. New and experienced researchers who are not familiar with this particular area of research will find this work to be an inspirational and educational resource. There is a possibility that the data may not be adequate to model groundwater hydrology or to understand how hydrologic regimes affect groundwater. As well as being labor-intensive, manual measurements are time-consuming, especially in remote areas where frequent measurements are needed. Groundwater level monitoring has also been done with ultrasonic, radar, capacitive, and optical sensors, but all have limitations. There are lots of problems with other methods of measuring pressure, but pressure sensors avoid them. It's possible to connect them to conditioning circuits that record measurements only when water levels change, or at intervals from hours to days.

Similarly, Mehmet c. vuran *et al.* (*Internet of Underground Things in Precision Agriculture: Architecture and Technology Aspects - ScienceDirect*), proposed underground communication between UTs. It's important to analyze underground-to-upper surface communication links as well as vice versa due to the soil-air interface. Additionally, field experiments show the path loss. We have developed a comprehensive architecture

for precision agriculture-based IOUT. The main components of IOUT are sensing and communications. An overview of the challenges associated with realizing IOUT is presented, as well as a design for a testbed for realizing IOUT. Wireless UG communication has also undergone recent advances in theory and application. It is highly challenging to integrate SM sensors with communication equipment due to the availability of a variety of SM sensors. In order to seamlessly integrate different types of sensors into communication devices in IOUT, a standard protocol is required.

Wei Li *et al.* (Li *et al.*, 2020b), focused on the development of a remote measurement system for monitoring environmental parameters in agricultural fields using portable wireless sensor networks. Additionally, it addresses the problems associated with current plans, including their cost, availability, and accessibility to the outdoors. Sensing soil moisture, pH, humidity, and temperature, the intelligent sensor-driven irrigation system regulates irrigation practices. Users of the proposed system are provided with user-friendly mobile applications for monitoring and regulating their farmland. By controlling and monitoring the water pressure and input voltage, sensor-based irrigation protects water pumps against any harmful damage. The demand for sensor-based irrigation is increasing day by day, and it is expected to have a significant impact in the future. By controlling soil moisture levels, it reduces human error and saves time. Precision agriculture refers to a method of increasing productivity, efficiency, and profitability through sensor-based applications. This resulted in a serious shortcoming due to the absence of any water level detection.

For environmental monitoring, Ian F. Akyildiz *et al.* (Akyildiz and Stuntebeck, 2006), monitored soil properties and toxic substances. The sensors were deployed completely underground. Agricultural soil monitoring is one application of underground sensing. As a result of this research, WUSNs demonstrated that they are superior to current sensing solutions in terms of overall network concealment, ease of deployment, and timeliness of data collection. Surface sensors are used for monitoring sports fields and gardens. These benefits enable new and broader underground sensing applications. Water levels may also have been affected by other factors such as rainfall, soil moisture content, and groundwater table levels, but none of these factors indicate a significant change.

According to Xiuhong Li *et al.* (Li *et al.*, 2011), a field sensor module, a base station module, a data center module, and a WEB release module are included in the mechanism. Despite the absence of

wind and solar, this intelligent power management system can still operate in gear. The system takes steps to protect itself, such as reducing sampling frequency or cutting off high-energy sensors. Using a self-developed embedded ZKOS operating system, the portable wireless water-level monitoring system is expandable, real-time, and affordable. By synchronizing satellites through GPS chips, the system timer is revised or adjusted to ensure synchronicity among systems located in different locations. In order to facilitate remote updating of the system, a program has been developed to enable most of the sites to be in the field. A remote server also has software for monitoring and controlling the system's frequency. Therefore, users' inquiries can be taken into account when designing this system. As of now, Poyanghu Lake's water levels are being monitored using this system. However, in this work, wires were used which caused disturbances.

Do-Hyeun Kim *et al.* (Kim *et al.*, 2007), considered the boreholes and their drilling data. It is used to keep the drilling data of the groundwater and then uses techniques to manage its efficiency. Moreover, it is used for sustainable water resource management. Its main focus is to manage the boosting and bagging of groundwater through boreholes. Using borehole-log data to predict GWL for sustainable water resource planning and management, an ensemble prediction model based on boosting and bagging was presented. A data model and a predictive analytics model are the two core modules of the proposed research study. By processing borehole data and investigating hidden hydrogeological characteristics, the data analytics module assisted in increasing the efficiency of future boreholes by uncovering hidden characteristics. Borehole data were therefore analyzed using a variety of data analysis techniques, including statistical and time-series analyses based on soil colors, land layers, and stratum layers, among others. Other data, however, was unknown since only drilling data was saved.

An article by Nalina Suresh *et al.* (Goyal *et al.*, 2019), describes a smart system for monitoring water levels on farms and providing cost-effective solutions for farm management. In order to improve the way farmers manage their water resources, it monitors water levels regularly and stores the captured data in a database. To send out alerts to farmers, the researcher used Nexmo SMS API instead of a GSM shield. In order to test the SWLMS, the researcher needed to use different phone numbers and email addresses when Nexmo reached its limit of SMS alerts it could send. The SWLMS is using the demo version of the Nexmo API. A valid email address is required to register with the SMS API. In the course of the testing

process, the researcher had to make countless dummy email accounts. Additionally, farmers must access the web portal via the internet to view water status. SMS alerts sent through the Nexmo API require the internet. Further, the consumption of water was not specified in advance, only after it had been consumed.

Banjo Ayoade Aderemi *et al.* (Aderemi *et al.*, 2021), focused on groundwater management by using different techniques and methods of providing water and using IoT-based systems to lessen water use. They used a groundwater aquifer and designed a model that can save water reservoirs. Groundwater in the aquifer moves slowly and dynamically. Due to two main reasons, it responds to hydrological stress such as climate change, land use, and abstraction in two ways (Afnan *et al.*, 2020). Alternatively, an equilibrium state is achieved by balancing the re-charge and discharge of an aquifer system, which allows the aquifer to exist indefinitely, or, secondly, when the hydrological stress exceeds the equilibrium state, aquifers will only survive for a limited period of time. It was not assumed that water usage would be determined before work started.

The relationship between the volumetric water content of the soil, the node depth, the signal frequency, and attenuation during transmission was discussed by Xiaoqing Yu *et al.* (Xiaoqing Yu, 2012). An increase in burying depth is also accompanied by an increase in the soil path, resulting in higher attenuation. WUSN is feasible in agricultural applications based on the results of the experiment. Due to the effects of reflected rays from the underground-air interface at the surface, the burial depth is crucial for WUSN tests. Crops weren't measured separately for seed depth.

A groundwater levels were monitored over a critical portion of the South American River Sub-basin, which may accommodate flood-based managed aquifer recharge by Andrew J. Calderwood *et al.* (Calderwood *et al.*, 2020b). Except for occasional battery changes, the installed groundwater pressure transducers and telemetry are fully automated, as is the open-source data pipeline that processes sensor data and visualizes it. Data is sent over a cellular network via Solinst Level Senders and Solinst Level Loggers. In Situ TROLL Link 201, Campbell Scientific CR300, and others are available from several companies. To send data from the telemetry units across a cellular network to the local server hosting an open-source SQLite database, you need sufficient cellular service. Using the cellular reception of two different networks, we chose the one with the strongest signal across all the monitoring wells in our site. This allowed us to decide which monitoring wells to connect and

which cellular network to use. Telemetry is installed in metal wellheads, so some antennae have been mounted directly to the housing to improve cellular reception, however the battery system was causing problems.

Dongzhi Wang *et al.* (*Simulation Test of Wireless Underground Sensor Network in Stadiums*), proposed an underground wireless sensor network, and proved the results using NS2 network simulation. In order to achieve the optimal monitoring coverage and node setting combination, to measure the moisture of a field in a stadium, the model is installed as the main control chip and the wireless sensor network is built. With magnetic induction communication, signals get transmitted by an induction coupling created by the sending and receiving coils. This is different from electromagnetic wave communication technology and can work in extreme soil conditions. By applying the round-trip time-ranging network model to the positioning of patrol personnel and robots in venues, this paper proposes the AMW-SMC algorithm to accurately and fast position multiple moving targets using the AMW-SMC algorithm. AMW-SMC locates moving targets through an adaptive adjustment and multidimensional scaling based on the adjusted sequential Monte Carlo framework. With the help of the distance measurement value acquisition platform, the algorithm was verified through simulations and experiments. Different network topologies are used to simulate and evaluate the routing algorithm's performance. In this case, the moisture level was detected and the water level wasn't.

For assessing groundwater sustainability, Steven W. Evans *et al.* (Evans *et al.*, 2020), used an open-source web application called Groundwater Level Mapping. A simple, low-cost approach to groundwater level mapping was developed in this study to improve accuracy. Its contributions were 1. An open-source web-based assessment tool 2. Groundwater data imputation method 3. Aquifer storage change estimate. Using both temporal and spatial interpolation, they developed an open-source Python-based web app to visualize and quantify groundwater resources. Using correlations between wells in the aquifer, we temporally interpolate time series data to generate groundwater level maps at selected time steps. Only one crop was tested with the technique.

A topographic survey of groundwater had presented by P.J. Sajil Kumar (Kumar, 2022), Using GIS-based geostatistical modeling, we're trying to understand groundwater-level fluctuations and their geographical distribution. There were 22 wells surveyed and selected for future research. In our study, we excluded wells that normally dry in the

summer months. It's critical to choose wells to get a good spatial representation of the area. Marking the latitude and longitude of the study area was done with a handheld GPS (GARMIN GPSMAP® 86i). The measurements were taken before and after the monsoon season (July 2016 and January 2017). Soils were not specifically mentioned in the study.

Using different types of soil to test the sensor's versatility, Jaime Lloret *et al.* (Lloret *et al.*, 2021), identified the appropriate sensor for further development. For every sensor, they looked at maximum linearity. The behavior of the sensor with a universal substrate differs from that demonstrated with beach sand or cultivated soil, another significant aspect to emphasize. Among the components included in the design are the sensor as well as the power circuits that are required to generate biphasic signals for driving the coils. A message exchange algorithm and an algorithm for operating an efficient water management system are presented in the paper. Lastly, the entire system is tested in a real environment to ensure that soil moisture measurements and network performance are as expected. There was no mention of different crops, only different soils.

Using a wirelessly-connected pressure sensor network, Srikanth Anumalla *et al.* (Anumalla *et al.*, 2005), proposed a model for a groundwater monitoring system. Groundwater researchers and decision-makers were hoping that the proposed solution would provide fast access to groundwater data with a minimum of effort and expense. Sensors, integrated circuits, and wireless communication infrastructure are all incorporated into the proposed infrastructure. Data acquisition, data transfer, and data processing are all important to this design. While maintaining the accuracy and reliability provided by proprietary solutions, they prioritize minimizing the system's total cost. Adaptable to other areas of environmental measurement, too. An environment sensing system based on Field Programmable Gate Arrays and IEEE 802.11 wireless networking is synthesized in our system.

A quick summary and the proposed solution for all previous studies are given in Table 1



Figure 1. Unfertile seeds result in barren field

Ground reality and proposed method

Human civilization cannot survive without agriculture. Food and supply shortages and sustainability issues have been caused by an increasing population, resource shortages, and degradation of the ecological environment (Ashraf, Saleem *et al.*, 2020). The majority of farmers in developing nations still practice traditional agriculture, which leads to flaws in agricultural production and leaves most of the land unproductive. Figure 1, illustrates the unfertile land condition due to the usage of old traditional methods. These methods can not sure whether all seeds have gotten substantial amount of water or not therefore, at early stages most of the seeds cannot grow up and consequently a very spacious area of land remains unfertile. Similar cases can be seen over the time for numerous crops and in different soils. In some cases, the uncouth water distribution causes land to barren when no water reaches to seeds as shown in Figure 2.



Figure 2. A barren agricultural field from a close perspective

Farmers use traditional farming methods to cultivate their crops, which are inefficient in terms of harnessing resources such as manpower and water. In fact, traditional agricultural monitoring results in high costs and destruction from man. BUWLN is an alternative way to use water efficiently to grow crops at the highest level. Through real-time monitoring, minimal use of manpower, time, accurate estimation of water for irrigation, and protecting the crop from disasters like disease, floods, etc., this study addresses the limitations of traditional farming. The proposed frame work would ensure that each seed in agriculture field will get a plausible amount of water necessary for initial growth. Figure 3, depicts the outcome of this study where each seed has gotten enough water and the initial growth has been achieved at large.

Table 1. Summary of Related Work

Available studies	Details	Limitations	Proposed solution
Lorena Parra et al.	underground water was maintained at different rates and levels based on different factors	neither the crop's water level nor its soil moisture were monitored	specific crops and soils are considered
Engr. Ajayi Isaac Ayodele et al.	the formation of groundwater levels was solely considered	implementation was plagued by numerous impeaches	on the basis of comparative output, the best results are chosen
Mehmet c. vuran et al.	it was shown how air interfaces with soil and how underground communications work	communication system is lacking	plausible communication has been made from sensors to base station and base station to users
Wei Li et al.	wireless sensors measured the environment	detected factors without measuring water level	sensor nodes measure the water needed for each crop
Ian F. Akyildiz et al.	through wireless sensors the environmental factors are identified	underground water level was not detected	for particular seeds, it aims to detect underground water levels
Xiuhong Li et al.	mainly detects various environmental effects with moisture and generates early warning of events	lacks underground water level detection	water level detection is performed in underground agriculture field
Nalina Suresh et al.	water usage was only measured and data was provided to farmers	no water level was considered	based on crop type and soil type, water level would be detected
Banjo Ayoade Aderemi et al.	a groundwater aquifer is used to lessen the use of water	no assumptions are considered about the water levels	on the basis of pre-collected data for each crop the water level would be determined accordingly
Steven W. Evans et al.	an improved technique was developed to map groundwater levels.	only developed the technique, not implementation	groundwater level mapping would be done with observed values of different crops
Jaime Lloret et al.	the behavior of sensors for different soil were used while soil linearity was also checked	different crops were not mentioned only different soils were considered.	undertake the specific crops and its attributes for better water level detection
srikanth Anumalla et al.	underground water pressure was measured through pressure sensors wirelessly.	focused only pressure but not the water level	the underground water level was measured wirelessly with water level sensors
Xiaoqing Yu et al.	soil and node depths were measured and shown that higher burying depth matters	depths was not measured for every crop separately	seed depth would be measured through water level detection
Dongzhi Wang et al.	the moisture of the field above the ground is detected through simulation	only moisture level at upper ground surface was detected and no underground detection is performed	the underground water level of different crops would be taken into account using proteus

**Figure 3. Improved seed fertility is the outcome of the proposed method**

Proposed layout

The proposed layout consists of wireless sensor nodes and a base station. The sensor nodes are deployed under the agricultural field at

particular positions i.e, 11 feet apart away from each other as shown in Figure 4. The base station receives data packet from each sensor node and then transmits this data to the end user through GSM network to the appropriate gadgets. These sensor nodes have been tested with various crops and the soils as well. Initially, properties of each crop and soil was deeply studied and water flow for each crop and the soil was pre-examined. Three different soils were taken such as Loamy soil, Silty clay loam soil and Black soil. The crops such as wheat, barley, maize and cotton are taken into account. A meticulous analysis was performed regarding water level consumption and its behavior with soils. Further, a per hour watering time with depth of each seed was considered because each crop has different seed depth.

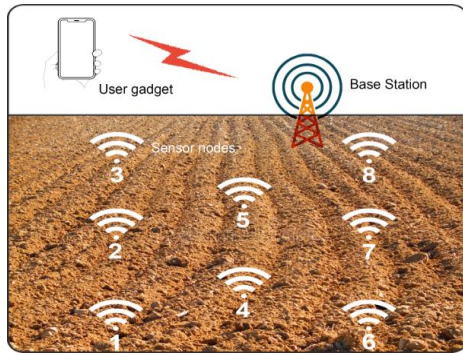


Figure 4. Proposed topology with deployments

The entire field area has a total measurement of 90×30 sq-ft, where 8 sensor nodes have been deployed. During each experiment, the type of soil and crop is chosen separately, but the area remains the same. The water pipe having five inch diameter has been installed that supply the water to entire field. Sensors 1 and 6 were deployed 11 feet away from the end of the pipe, while sensors 3 was placed at 13 feet away. The flow of the water in the pipe is laminar and its flow has been calculated according to the Poiseuille equation (Haldar, 2020), as Equation (1).

$$Q = \frac{(\pi D^4 \Delta P)}{8 \mu \Delta x} \quad (1)$$

This equation represents a water flow rate with Q , the diameter of pipe is represented by D , having ΔP as pressure difference between both ends of the pipe, μ is a dynamic viscosity based on length (Δx) of the pipe. It is worth noting that flow of water depends on variable factors such as radius (r) and length (L) of the pipe, pressure gradient (ΔP) and viscosity (η). The pressure gradient (ΔP) can further be defined as difference in pressure between the two ends of the pipe and it is determined by the fact that the water will always flow from the High-Pressure Area (P_1) to the Low-Pressure Area (P_2) therefore, ($\Delta P = P_2 - P_1$). The Equation (1) can be re-written as Equation (2).

$$Q = \frac{\pi D^4 (P_2 - P_1)}{8 \mu L} \quad (2)$$

For proposed BUWLN method, the average speed of the water has been computed according the parameters given in Table 2 and further substituting these parameters in equation 2, the speed of water is obtained using Equations (3, 4 and 5).

$$Q = 3.14 \times (127)^4 (600) 8 \times 0.01 \times 366 \quad (3)$$

$$Q = 3.14 \times (260,144,641) \times (600) 8 \times 0.01 \times 366 \quad (4)$$

$$Q = 1.6 \times 10^{10} \text{ m/s} \quad (5)$$

Table 2. Parameters for speed of water

Length of pipe	366 cm
Diameter	127 mm
Viscosity	0.01 (Pascal seconds)
Pressure	600 (Pascal)

Now, in order to calculate the water flow from the last end of the pipe towards deployed sensor nodes it is assured that water flows under steady-state condition and flow rate in the pipe is the same at any location along the length of the pipe. Therefore, continuity equation can be represented as Equation (6).

$$\text{Flow} = \text{Velocity} \times \text{Area} \quad (6)$$

an area of 30×15 sq ft, has been chosen for this experiment therefore, by substituting the values in Equation (6), the water flow up to the sensor nodes can be expressed as Equation (7).

$$\text{Flow} = (1.6 \times 10^{10}) \times (30 \times 15) \quad (7)$$

The properties of soil and relevant permeability (the ability of soil to absorbed water) with crop types are listed in Table 3 and 4 respectively.

Seeds in each crop requires different soil depth and therefore, Table 5, lists the depth of seed for all crop types.

Table 3. Crop and soil types

Crop types	Type of soil
Wheat	loamy soil
Maize	loamy soil
Barley	Slit Clay loamy soil
Cotton	Black soil

Table 4. Permeability of Soils

Soil types	Permeability
Loamy Soil	0.2 – 0.4 inches/hr
Slit Clay Loamy Soil	0.3 inches/hr
Black Soil	0.6 inches/hr

Table 5. Depth of seeds

Crop	Seed depth
Wheat	1.5 – 2.0 inches
Maize	1.5 – 2.5 inches
Barley	1.5 – 2.0 inches
Cotton	0.5 – 1.5 inches

The growth of every crop requires different environment and the moisture therefore, seeds are also needed to place in such a way that maximum fertility can be assured. Consequently, each underground deployed sensor also requires the different depth in accordance to the crop requirement. Table 6, Shows the variety of sensor depth with respected crop.

Table 6. Depth of sensors

Crop types	Sensor depth
Wheat	2.7 inches
Maize	2.2 inches
Barley	2.7 inches
Cotton	2.0 inches

The sensors have been deployed and categorized into two layers such as upper surface and underground illustrated in Figure 5. Each sensor in the form of complete package either Arduino based circuitry is placed in underground agricultural field with complete measures as not to be destroyed by external factor such as water, moisture, air etc. At upper surface, the signa range is shown where by each sensor would communicate with base station and transmit the data packet as it senses the water level. The base station would execute the receive signal from each sensor node and will generate the report to the end user through GSM mobile network to relevant gadget. The entire agriculture field has been further divided to analyze the water reaching to the sensor nodes shown in Table 7.

Furthermore, Table 8, shows the observed time for water reaching to the seeds in an area of 30×15 sq ft. which has been recorded during the execution process.

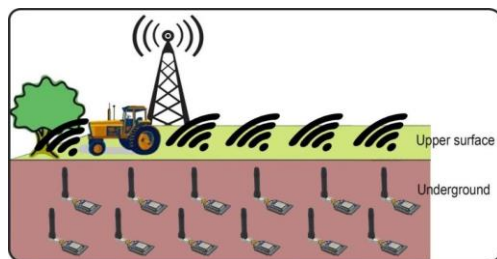


Figure 5. Layers of the deployed underground sensor nodes

The circuit diagram and the attributes of deployed sensors are shown in Figure 6. The deployed sensors are connected to Arduino board which is further connected to a transceiver that sends signal to a base station. The base station then forward signals to user's devices. The sensor nodes

connected with Arduino board are the coil-based sensors that works by adopting the electromagnetic induction of the coils. Each sensor is composed of two solenoid coils wound on the same PVC pipe support. The coil 1 receives the sinusoidal signal generated by the power circuit based on the integrated circuit. Further, coil 1 induces a current on coil 2 which is largely affected by the content of the coil core since the magnetic field is affected by the type of soil and water content inside it. Finally, this current is measured, collected, and stored with an electronic module. The analog multiplexor of four inputs is controlled by using two digital outputs and the system will be able to take measurements from the four soils of water sensors. Each sensor search the receiver of base station within transmission range and when it found the signal is accepted by the base station receiver. The water level sensor model SKU: 400738-25 has been used. Its sensor element is made of Silicone Diaphragm, Wet/ Wet Transducer.

Table 7. Standard time for water flowing

Area (feet)	Assumed time (minute)
15	3.4
30	6.8
45	9.0
60	12.16
75	18
90	24.32

Table 8. OBSERVED TIME ON THE FIELD

Area (feet)	Observed Time (minute)
5.0	1.2
20	4.8
30	6.8

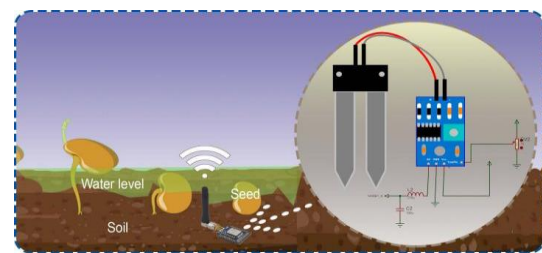


Figure 6. Description of water level sensor deployed in underground field

It is available in different ranges such as 0-3', 0-15', 0-30', 0-60', 0-120', 0-250' but we have used for 3'. It requires minimum 10 ms to warm-up.

Sowing a seed in normal condition causes it to start growing as soon as it is watered for the first time and gradually grows. The soil moisture sensor

has two sections as sensor contains a fork shaped test (Shahzad, 2020), with two uncovered guides that go into the soil or where the water content is assessed. It is a variable resistor with resistance contrasts, as the soil soggy demonstrates. The sensor likewise contains an electronic module that connects the test with the Arduino. The module conveys an outcome voltage as demonstrated by the obstacle of the test and is made open at an Analog Output (AO) pin. A close sign is dealt with to an LM393 High Precision Comparator (Arfeen *et al.*, 2021), to digitize it and is made open at a Digital Output (DO) pin. The module has an understood potentiometer for the modernized yield (DO) responsiveness change. One can set an edge by using a potentiometer; So that when the moistness level outperforms the breaking point, the module will yield LOW anyway HIGH. This plan is gainful when one must set off a movement when a particular cutoff is accomplished. For example, when the moistness level in the soil passes a limit, one can establish a handoff to start siphoning water. The Soil dampness sensor is direct and has 4 pins to relate. AO (Analog Output) pin offers us a bare hint between the stock worth 0v and will be related to one of the specific responsibilities on your Arduino. DO (Digital Output) pin gives the Digital aftereffect of the inside comparator circuit. one can connect it to any modernized nail to an Arduino or directly to a 5V exchange or equivalent device. VCC pin supplies power for the sensor. It is endorsed to drive the sensor between 3.3V - 5V. Either way, assuming no one cares, note that the specific outcome will change depending on what voltage has obliged the sensor. The module gives both straightforward and modernized yield. The soil clamminess would be measured by examining the primary outcome.

Arduino is an open-source device easy-to-use and gears the programming. The signal can directly be sent through numerous headings to the micro-controller (Ashraf *et al.*, 2022). The data packet transmission from source, sensor nodes to the base

station and then from base station to the end user gadgets has been explained via information flow chart in Figure 7. This flow chart has been divided into two sections. First indicates how the sensor node would deal the water level while second section shows the message transmission mechanism from base station to the end user. Initially, deployed sensor nodes in underground field invokes and check whether plausible water level has been achieved through X and Y parameter that is already programmed in arduino and these parameters must be satisfied the condition $X \geq Y$. If it is not a case then a delay would be added into average received time as $t+5 \Rightarrow w$ and sets water level is not achieved. After achieving required water level, signal is transmitted to transceiver that further sends it to the base station. The water level is achieved at time instant "t" at sensor value X. The achieved information and data are transferred through GSM to the user interface. As the data is received by the user, the process ends and same loop remain continues. On the other hand, when water level was not achieved same steps would be followed and message will be communicated to the end user gadget.

Simulation Performance

In fact, sensor nodes measure the volumetric water content; and produces an output voltage according to the resistance. The transceiver is connected to Arduino with directly attached oscillator (Ashraf, 2020). This demodulator/modulator is used to send and receive data to the base station that is battery operated. The base station consists an antenna with a transceiver. A text message is generated about the status of the water level in Arduino programmed and ultimately forward to the end user gadget through GSM network.

The complete network topology is simulated in proteus 8, shown in Figure 8, where eight sensors are placed and connected to Arduino board

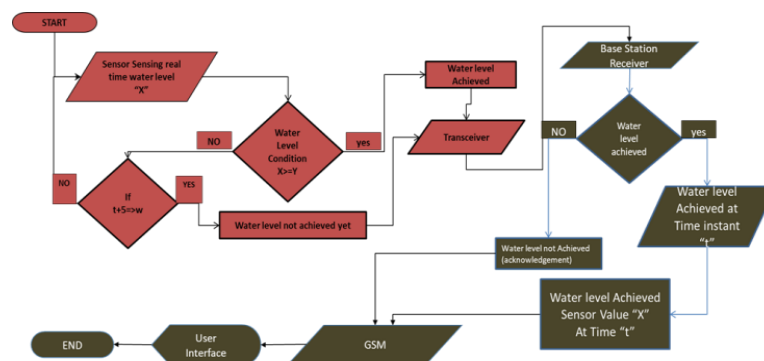


Figure 7. Proposed flowchart

which connected next to the transceiver and communication takes place to the base station from where the user is notified. After setting the sensor parameters as soon as the simulation is executed the output screen appears and indicate the water level illustrated in Figure 9. It can be worth noting that when sensor node sense the water level, this level is send to the Arduino for processing which compares this level to a pre-fixed value. The Y is set as pre-fixed value for water level which changes for each crop while X is a real-time sensed level of the water by the sensor nodes. During execution when $X \geq Y$, the value is transmitted along with the message as 'water level is achieved' to the base station using the transceiver connected to the Arduino. If the condition is not satisfied, then a timer would include the a delay as " $t+5 \Rightarrow w$," where t is the time at which the value is sensed, and w is the specific time pre-fixed in the Arduino. If the sensor cannot sense the water level in the time "w," then the signal will be sent to the base station "water level not achieved yet" using the transceiver. At base station, all signals would be received and will be forwarded to the end user accordingly.

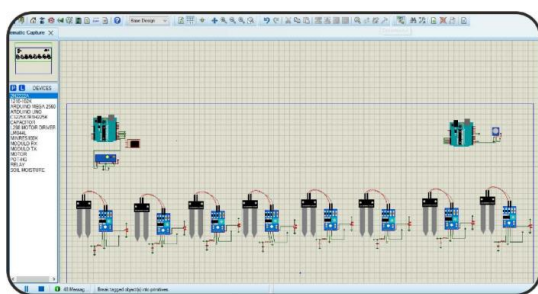


Figure 8. Proposed topology during simulation

The step by step status of water level reaching to seeds for each crop has been tested with all three soils. Figure 9, vouches the water level condition for the wheat using loamy soil and the outcome of this simulation is given in Table 9.

Next, result is obtained for maize and for this loamy soil is used. Figure 10, depicts the outcome and details are shown in Table 10.

For barley, the silt clay soil is used and its simulation progress is shown in Figure 11, while outcome statistics are placed in Table 11. Black soil has been used for cotton and the simulation status is presented with Figure 12, and remaining statistics are given in Table 12.

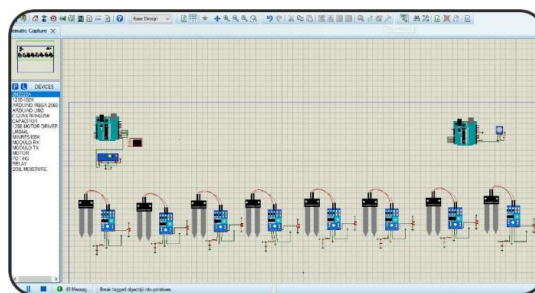


Figure 9. Water level for wheat is being detected by sensors

Table 9. Statistics obtained for wheat

Sensor#:	Sensor deployment (feet)	Sensor Depth (inches)	Time (hour)
1	11	2.7	6:47:50
2	22		6:49:40
3	33		6:51:48
4	44		6:53:50
5	55		6:56:00
6	66		6:59:20
7	77		7:03:30
8	88		7:08:30

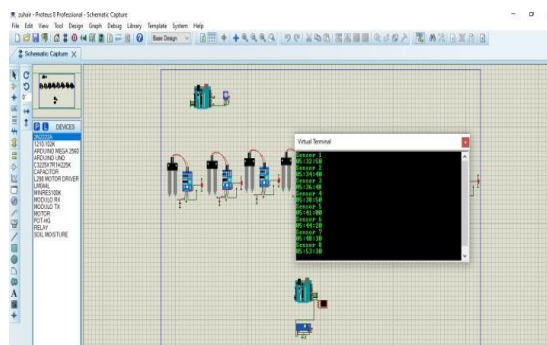


Figure 10. Sensors detect the water level for maize

Table 10. Results devised for maize

Sensor#:	Sensor deployment (feet)	Sensor Depth (inches)	Time (hour)
1	11	2.2	5:32:50
2	22		5:34:40
3	33		5:36:48
4	44		5:38:50
5	55		5:41:00
6	66		5:44:20
7	77		5:48:30
8	88		5:53:30

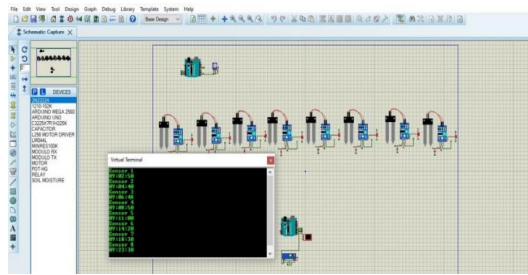


Figure 11. Simulation is in process for barley

Table 11. Results devised for Barley

Sensor#:	Sensor deployment (feet)	Sensor Depth (inches)	Time (hour)
1	11	2.7	9:02:50
2	22		9:04:40
3	33		9:36:48
4	44		9:38:50
5	55		9:41:00
6	66		9:44:20
7	77		9:48:30
8	88		9:53:30

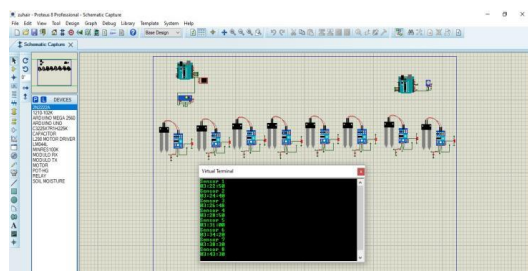


Figure 12. Water level is reaching out for cotton

Table 12. Results devised for Cotton

Sensor#:	Sensor deployment (feet)	Sensor Depth (inches)	Time (hour)
1	11	2.0	3:22:50
2	22		3:24:40
3	33		3:26:48
4	44		3:28:50
5	55		3:31:00
6	66		3:34:20
7	77		3:38:30
8	88		3:43:30

Results and Discussion

The outcome of simulation results are critically analyzed according to the objective of the study which is made in previous sections. Four crops Wheat, Maize, Barley and Cotton were tested in Loamy, Silty clay, and Black soil to ensure the performance of the proposed method for analyzing

the status of water level reaching to the seeds whereas standardized water absorption parameters of the soil were considered too. The outcome of proposed method has been compared with three state of the art studies i.e Remote water-level monitoring system (RWMS), Low-cost wireless sensor network (LCSN), and Ensemble groundwater level prediction (E-GWLP).

Performance evaluation for Wheat

As an area of 90×30 sq.ft, was taken and eight sensor nodes were deployed each having 11 feet distance from each other. The result statistics are shown in Figure 13. It concluded that E-GWL could not detect the water level because this study was mainly focused to detect the underground water level through drilling and such water level encompasses corrugates and changes time to time therefore it detects water level, at node first after passing more than 2 hours and 24 minutes depicted by the curve and has uncouth detection up to the node 8 that has been achieved near about 12 hours. In fact, LCSN came up with the idea that an automatic sprinkler with sensors can better conserve the water but even it could not handle the soil and crop type because every soil has different obsecration level that is why it exhibits an unbalanced output starting from sensor node 1 after passing 3 hours but comparing the performance of RWMS, due to the fact that this system was mainly designed to detect the level of water in rivers through telemetry, it produced a more uncouth detection. As a result, there was no precession in water detection and the resultant curve starting from sensor node 1 to sensor node 8 was able to detect water for up to 13 hours. Finally, the proposed BUWLN method has shown a prudent performance because deployed sensor nodes achieved the water level in timely fashion and responded in full capacity. The detection curve began at 2 hours and completed the entire detection up to the node 8 by less than 7 hours which is the hallmark of shrewd output.

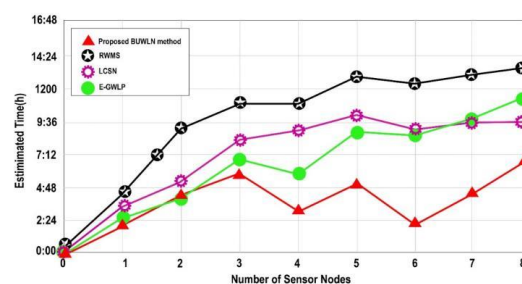


Figure 13. Weighing the level of water detection in wheat

Performance evaluation for Maize

In EGWL the time-series data from the original borehole becomes computationally demanding too in terms of cost (time and storage). The detection curve begins and achieved first water level detection at node 1 in more than 3 hours and extended the detection duration to more than 16 hours at node 8. This shows a huge period and consumed a lot of energy as shown in Figure 14. The RWMS is used to gather, process, and provides more precise groundwater data and it used to create the ground water observatory, that may easily be replicated in new places. No soil type is considered therefore the detection curve achieved final detection at node 8 in 13 hours. The LCSN sensor-based irrigation might reduce external environmental influences compared to traditional irrigation techniques. Its main disadvantage is that it cannot be used for the height crop because it only sparkles the water droplets. Because the water drops remain on the leaves, less water reaches to the ground, resulting in an asymmetrical detection curve occurred from node first to eight in 15 hours. The performance of proposed BUWLN method was standing sound because water level detection is much higher and detection curve achieved water level detection in just 7 hours.

Performance evaluation for Barley

Usually, underground water has different flowing variations therefore, E-GWL normalized the water flow when extracted to the upper surface. During normalization the water flow fail to maintain the pressure level therefore, no scrumptious detection could be achieved and data collection shows that detection curve starting at node 1 by 4 hours reaching to the last node 8, even after 16 hours as illustrated in Figure 15. On the other side, moisture and soil properties does not match to detect the continuous water corrugate therefore LCSN could not perform even near to the proposed BUWLN method and detection curve began at node 1 after passing more than 3 hours showed the

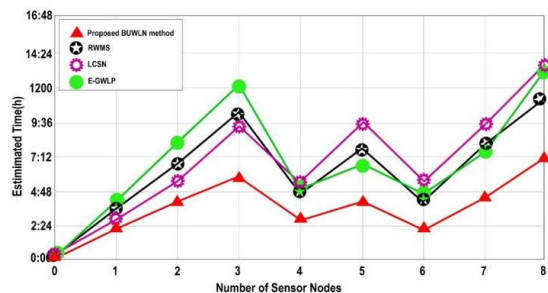


Figure 14. Comparing maize water level detection with other methods

trembling output detection and achieved the water level detection at last node 8 after passing more than 13 hours. Nearly, same condition happened with RWMS where first detection at node 1 was occurred after 3 hours and reached at last node 8 after spending 12 hours and during the detection cycle it exhibit the unbalanced output.

The proposed BUWLN method gave a clear difference how the expected flow time and the observed flow time of water are closely correlated and therefore, from node 1 to node 8, water level detection has been achieved within 7 hours.

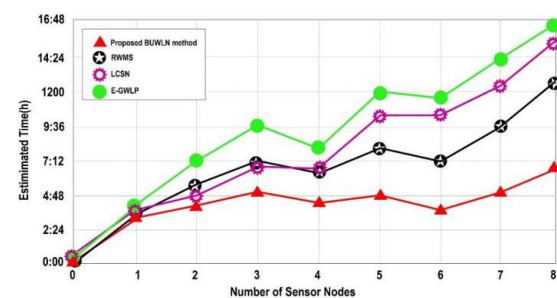


Figure 15. For barely, water level detection comes out more precisely

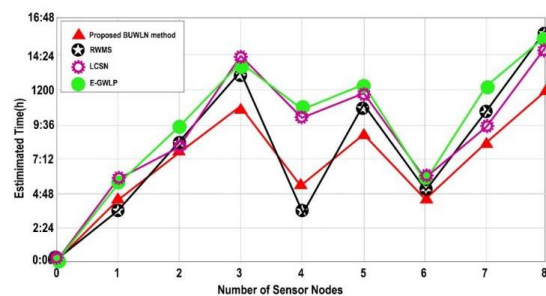


Figure 16. Cotton comes up with better statistics

Performance evaluation for Cotton

Sensor nodes are deployed based on the type of crop that is being grown. Showing Figure 16. EGWL patterns and behaviors for spotting diminishing the water levels and being aided by a time series analysis of groundwater level data. Searching for and discovering variances and dissimilarities in time-series data in a meaningful context is difficult because time-series borehole data are noisy and variable because of this reason the detection curve achieved first detection at node 1 after passing 3 hours. RWMS handle the massive amount of data that is accessible to enhance the drilling, in the presence of ambient noises, and this technique has been proven to be significantly insufficient for detecting water level, that is why the

detection curve achieved all levels up to node 8 in 15 hours. In the case of LCSN, the sensors used in sprinkler irrigation and hoard the data on the current state of the environment. Despite the fact that the sensor is only able to measure the humidity, it unable to determine whether the water reaches the roots of the plants, or if their growth is affecting the physical conditions of the land or crop. Because of this specific reason, the detection curve is unbalanced starting from node 1 to node 14 and achieved entire detection in more than 14 hours. The better performance has been seen for proposed BUWLN method because it maintained the observed time curve near to the standard time therefore, the detection curve up to node 3 is linear then it slightly changes according to the positions of the deployed nodes and finally, completed the whole detection process at node 8 in just 12 hours seconds.

Conclusion

In order to determine the water level detection by each sensor node in an underground agriculture field was main objective and this study has accomplished all detections very shrewdly as compare to all other studies such as Remote water-level monitoring system (RWMS), Low cost wireless sensor network (LCSN), and Ensemble groundwater level prediction (E-GWLP). According to the findings, applying BUWLN to an agriculture field can increase the fertility of seeds, improving the growth of crops. Although only four crops i.e wheat, maize, barley and cotton while three soils loamy, silty clay, and black soil was tested for this experiment; In the future more crops can be tested, which would increase productivity and contribute to the GDP of the country.

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