

Efficient Smart Water Management Techniques to Enhance Crop Productivity for Maize

Abstract

Maize is known as “Queen of Cereals” due to high yielding cereal crop. Water scarcity is a major problem, where agriculture consumes a significant portion of freshwater. Smart Irrigation is one of the intelligence irrigation systems using Internet of Things technology that can help farmers maximize crop production and adequate management of water. The field experiment on Sensor based drip Irrigation and Farmer Practice was conducted in the research field to enhance growth, yield and water efficiency. The experiment comprised of eight treatments such as T1 : IoT based Drip Irrigation at 60% depletion level, T2 : IoT based Drip Irrigation at 80% depletion level, T3 : Drip Irrigation at 60% PE, T4 : Drip Irrigation at 80% PE

T5 : Drip irrigation as Normal Practice, T6 : Surface Irrigation at 0.6 IW/CPE ratio, T7 : Surface Irrigation at 0.8 IW/ CPE ratio and T8 : Flood irrigation as Farmer’s Practice. The proposed systems IoT based Drip irrigation at 60% depletion level can be recommended for hybrid maize to augment higher grain and straw yield. The highest water saving recorded in IoT based Drip Irrigation at 60% depletion level (46.88%) followed by IoT based Drip Irrigation at 80% depletion level (40.63%).

Introduction

Maize is the dominant cereal crop cultivated both for food and economics purposes. The world’s population is rapidly increasing, and as the population grows, the demand for food increases. The FAO forecasts more than 60% increase in food production by 2050. In agricultural cropping system requires to use available water and land resources efficiently do meet the requirement of increased population. Irrigation management is a part of precision agriculture, in which the exact amount of water applied to the field to satisfy the crop needs for the various stages. Based on the soil moisture and crop evaporation conditions, IoT based smart irrigation management detect when to irrigate, the amount of water needed and the irrigation frequency for the maize crop. In agriculture industry, new technologies are required to fully satisfy the increasing needs and requirements [1–3]. Smart irrigation technology is

used to increase agricultural productivity while reducing its environmental impact. Advanced agricultural operations generate data from a various sensors, leading to a better understanding of both the operational environment[4–7]. The SMART irrigation system is an emerging technique that automates irrigation systems and conserves water usage. This technique adjusts irrigation based on actual soil and weather conditions, therefore it allows farmers to meet their demand with a new adopted technique which conserves the water for irrigation process [8-9].To avoid loss of productivity caused by water stress farmers applying more water than the required water. This leads to waste of water and reduced productivity. Precision irrigation is a methodsallows water to be used more efficiently and effectively, avoiding both under- and over-watering. The smart management of water for precision irrigation in agriculture is essential for increasing crop yield and decreasing costs, while at the same time contributing to environmental sustainability.

The Internet of Things (IoT) emerges as the natural choice for smart water management applications, even though the integration of different technologies required for making it work seamlessly in practice is still not fully accomplished. The emergence of IoT is a phenomenon that owes to the conjunction of several factors such as inexpensive devices, low-power wireless technologies, availability of cloud data centres for storage and processing, management frameworks for dealing with unstructured data from social networks, high-performance computing resources in commodity platforms, and computational intelligence algorithms to deal with this monumental amount of data(Big data analytics).The main objective of the project is to reduce the water used in irrigation and to maximize yield.

Water is the lifeblood of plants. It is also a precious resource to be used wisely by the agricultural industry. Measuring the water balance of the plant is the best way of determining when and how much to irrigate. As it stands, farmers must go out into the field to take measurements by hand. Farmers that find this to be too inconvenient and inefficient can look to environmental and meteorological data.

Currently, there are some challenges to be overcome the traditional method. The solution for the above problem is IoT based smart irrigation. Sensors have installed on the soil to measure the soil moisture level in real-time. Wireless transmitters send these readings to a gateway, which forwards it to a cloud. AI-driven software factors other information into the equation such as the weather forecast and the phenological state of the crop. It provides farmers with an irrigation recommendation that takes all the variables into account, including the particulars of the plantation, the type of crop, and the farm's water supply.

Traditional irrigation method has changed to the software development for IoT-based smart applications, such as irrigation for agriculture, is not yet fully automatized. Secondly, advanced IoT software platforms are missing, for automating part of the process and integrating different technologies such as IoT, big data analytics and cloud computing for the deployment of applications for smart water management. Thirdly, the integration of heterogeneous sensors requires adequate standards and information models. The project is proposed to develop and assess an IoT-based smart water management platform for precision irrigation in agriculture. The main objective of the project is

- To assess the temporal soil moisture using sensor and actuator technologies and communication technologies.
- To develop and design software components for data acquisition, data storage, processing, and distribution.
- To assess the water-saving potential of IoT based smart irrigation system.
- To study the effect of IoT based smart irrigation system on crop yield.

Methodology

A field experiment “IoT Based Smart water management to enhance the crop productivity” in maize was carried out during summer 2023 in the research farm of Agricultural College and Research Institute, Madurai [9°58.22 N & 78° 12.25 E] in 2023 with an elevation of 147m above mean sea level. The farm is situated in Southern agro climate zone of Tamil Nadu.

Experimental Design and Treatment Details

The experiment was laid out in a randomized block design with 8 treatments with three replications. The test crop used was maize hybrid COH(M) 8 with a spacing of 60 x 25 cm.

The treatment details are as follows:

T₁ : IoT based Drip Irrigation at 60% depletion level

T₂ : IoT based Drip Irrigation at 80% depletion level

T₃ : Drip Irrigation at 60% PE

T₄ : Drip Irrigation at 80% PE

T₅ : Drip irrigation as Normal Practice

T₆ : Surface Irrigation at 0.6 IW/CPE ratio

T₇ : Surface Irrigation at 0.8 IW/ CPE ratio

T₈ : Flood irrigation as Farmer's Practice

Soil Characteristics

The experiment field soil is sandy clay loam in texture. The soil samples was collected randomly in five different places of field at depth of 0-15cm. The physiochemical properties of soil are pH -6.81, Nitrogen – 285, Phosphorus-15.2, Potassium - 418in kg ha⁻¹

Crop Management

Preparation of the seedbed included ploughing with disk plough, cultivator and rotavator. Formation of ridges and furrows enables saving of irrigation water in maize. The spacing of maize is 60 x 25cm. Each treatment has 5 rows of maize. Each Lateral length 26m long and the distance between the laterals is 120 cm.

Land Preparation and Manuring

A well-prepared ridges and furrows which has given 4-5 deep ploughing provided an ideal condition for sowing of crop. Before sowing, urea applied based on the soil test and mixed into the soil. The blanket recommendation of maize is 135 : 62.5 : 50 NPK Kg ha⁻¹. Urea should be applied in 3 splits, mainly at sowing, knee-high and tasseling stages. Entire dose of P & K₂O with 45 Kg urea should be applied at the time of sowing.

To prevent the spread of weeds, the Atrazine herbicide (500g /ha) was applied as preemergence at 3 days after sowing. The Coragen insecticide was applied at a rate of 900ml per hectare to control maize pests.

Irrigation

Irrigation scheduling is the direction of when and how much water to apply to the field and thus has a direct effect on water use efficiency. The quantity of water to be applied is estimated using a criterion to determine the irrigation requirement and strategy to prescribe how much to apply. Efficient application of irrigation water requires an understanding of the dynamic plant water use, which has a relationship with the weather, soil characteristics and plant physiology. Efficient irrigation scheduling applies irrigation water at the right time and in the right quantity to optimize production and offset adverse environmental impacts. On the other hand, poor irrigation scheduling results in under-watering or waterlogging which affects water use efficiency.

In this experiment, four types of irrigation methods are applied.

- IoT Based Drip Irrigation

- Drip Irrigation based on PE Ratio
- Surface Irrigation based on IW/CPE ratio
- Flood Irrigation

Sensor Based Irrigation

The irrigation timing in the smart farm was determined by soil moisture drainage from field capacity using a moisture sensor in the field. Two sensors have installed in the field to measure the soil moisture value. The optimal sensor depth of the maize crop is 20cm. The sensors were connected to the controller through wired for better accuracy. The flow of water to the field is controlled by the soil moisture value received from the treatments (T1 and T2). The valves have automatically opened, and closes based on prefixed soil moisture sensor observations for real-time operation. Accordingly, the plants were irrigated from planting to before corolla emergence, milking stage, moisture drainage and from seed milking to physiological maturity the plants based on 60% of field capacity moisture drainage (T1) and 80% of field capacity moisture drainage (T2).

The input parameter for minimum (60% of FC for T1 and 80% of FC for T2) and maximum (100% FC) threshold value of soil moisture needs to set for automatic irrigation operation for T1 and T2. User can set the value according to the crop-water requirement and management allowed a deficit for a specific crop. As the soil moisture reached or exceeded a pre-set threshold value, the motor driver module activates and open the solenoid valve. Similarly, when the soil moisture came upto 100% of field capacity, the motor driver module activated and close the solenoid volve.

Weather Based Monitoring

Weather-based monitoring involves real-time estimation of reference evapotranspiration ET using measured weather parameters and thus indicates the water lost by the plants and the soil environment. The quantity of water lost through evapotranspiration depends on humidity, wind speed, solar radiation and air temperature. The temporal dynamics of evapotranspiration on daily timescales is appropriate for determining crop water use in Treatment T3 and T4.

Drip irrigation water delivery system is used for treatment T1 to T5, that gives the ability to deliver water directly to the root zone, in accurate amounts based on the plants current needs. Drip irrigation is the only irrigation technique that has been able to avoid water stress without over-watering. In the sensor based smart (T1 and T2) , irrigation was based on

Intelligent sensor based control , Pan Evaporation value irrigation was applied in Drip irrigation (T3, T4 and T5) treatment. Irrigation was applied to the treatment (T6 and T7) using IW/CPE ratio. The irrigation for T3 to T7 was applied as per data of daily water sheet balance method. Flood irrigation was applied based on farmer practice every three days interval.

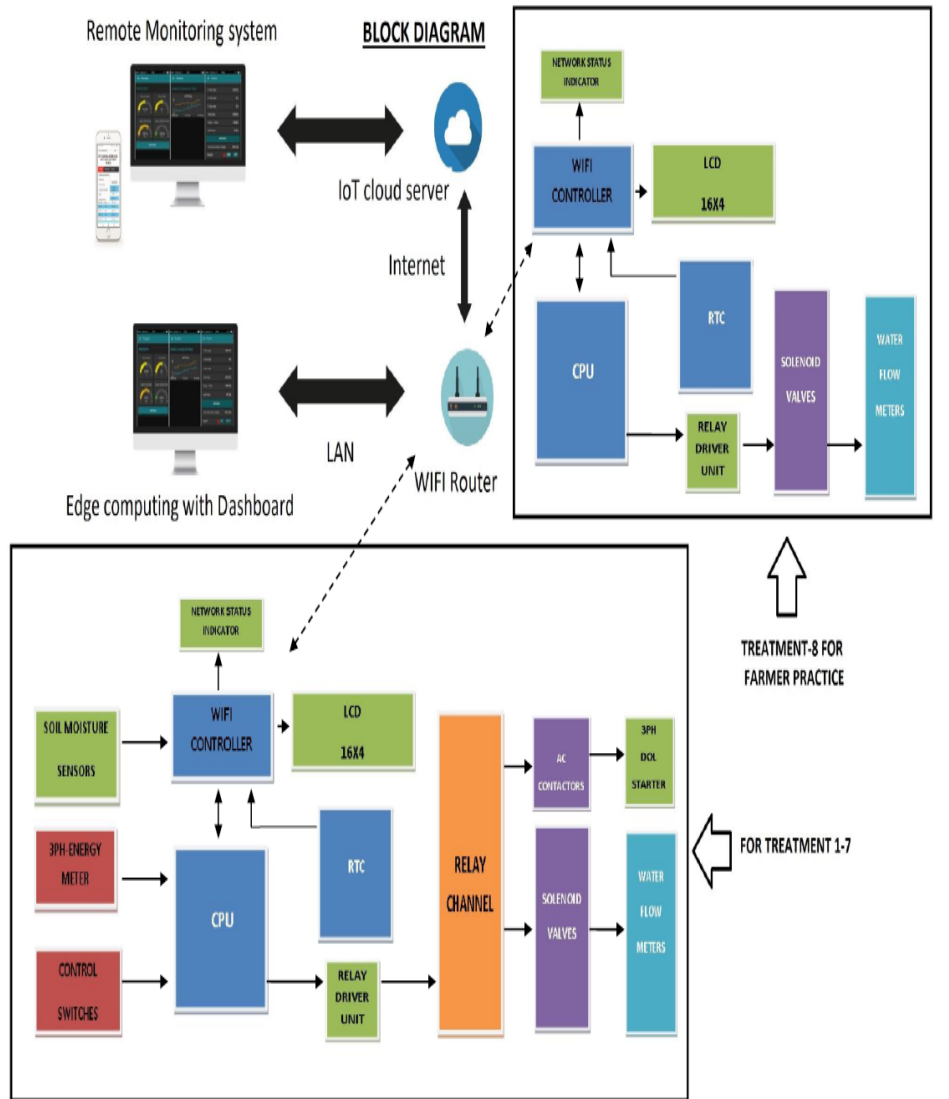
Components of automatic irrigation system

Hardware components

The design and Implementation of the IoT based smart intelligent system was divided into two parts such as design of the central controller and selection of the network operators and sensor. Implementation of this project in the field involved using the soil moisture sensor (Irrometer 200SS Watermark), Solenoid valves are used for actuating the relay module and pump for automatic irrigation and water flow sensor is used to measure the amount of water. An operator was also used to interrupt and connect the water flow. The Block diagram of the IoT based Smart Water Management system is mentioned in Fig. 1.

The controller unit consists of voltage converter, motor drive module, Arduino nano microcontroller, power and GSM Module.

The control box has three option buttons, one for power off and on , second for operation mode (Manual , Automatic and Reset), third one for status of water flow and sensor value display in LCD Panel. The whole system was powered with 230V 3 phase connection. The system was programmed to open and close the solenoid volve based on the sensor value (60% and 80% depletion value) for T1 and T2 , PAN Evaporation value for T3 and T4 and IW/CPE ratio for treatment T6 and T7. Manual Operation for T5 and T8.



IoT Based Smart Water Management System to Enhance the Water and Crop Productivity

Fig. 1 : IoT based Smart Water Management System

Software Component

The software used in the study for automation IoT-Agro unit were customized according to our research need, which consists of web and mobile-based interface so that the users can access it from anywhere.

In the experiment field, soil moisture sensors were tested and installed. Sensors were placed in sensitive and representative location of the crop's root zone. Soil moisture varies in three dimensions, such as variability in soil wetting from irrigation/rainfall, drying of soil from evaporation and root-zone water extraction for plant transpiration. Interaction of these dimensions were imperative for soil moisture sensor installation. The soil moisture has placed

at the top of the active root system, relative to drippers and the bottom of the root system. The suitable position of sensor position is 11cm between the drip line and 20cm beneath of surface of the soil.

Results and Discussion

Growth analysis elucidated the impact of sensor-based irrigation levels on all growth attributing parameters. Plant height is a direct index to measure the growth and vigor of the plant. The data pertaining to the plant height of maize as influenced by irrigation methods and irrigation schedules. Perusal of data indicates that the plant height of maize has progressively increased with the advancement of crop age up to harvest, irrespective of the treatments. The plant height of maize was significantly influenced by irrigation methods and irrigation levels.

Irrigation plays an imperative role in deciding the potential ability of maize to produce an economic yield. Characters like cob length, number of kernels per pod and 100 kernel weight are dramatically affected by moisture stress.

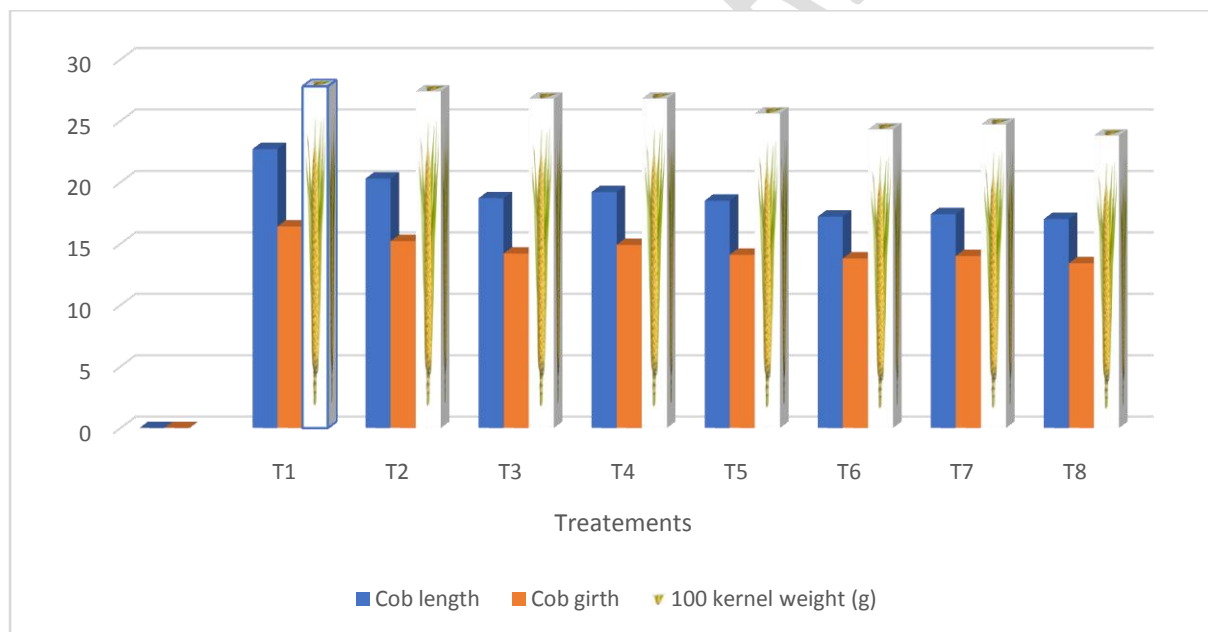


Fig 2 :Influence of irrigation methods and Yield attribute of hybrid maize

In the present study, IoT sensor based Drip Irrigation at 60% depletion level recorded lengthy cob (22.7cm) with higher girth (16.4 cm) and 110 kernel weight (27.8 g) compared to flood irrigation method which produced shorter cob with lower cob (17.0cm) , cob girth(13.4 cm) and 110 kernel weight (23.8 g). The cob length , cob girth and 100 kernel weight is represented in Figure 3. grain yield and straw yield data are summarized in Figure 3.,

In the present study, among the Irrigation method, IoT sensor based Drip Irrigation at 60% depletion level (T1) recorded the maximum grain yield (7050 kg ha^{-1}) and straw yield (11069 kg ha^{-1}) and the minimum grain yield (5069 kg ha^{-1}) and straw yield (7604 kg ha^{-1}) were recorded under surface irrigation method (T8). Treatment T1 was followed by IoT based Drip Irrigation at 80% depletion level (T2) and Drip Irrigation at 80% PE (T4).

The increase in the yield parameter was due to the availability of sufficient moisture in the soil, which also favored photosynthetic production and translocation of photosynthates to the sink and improved 100-seed weight. Significantly, the lower grain yield in surface irrigation was associated with the non-availability of required moisture at critical times, creating stress near the crop effective root zone.

Higher water use efficiency with sensor irrigation system was due to reduced water loss and efficient water use by the plants, resulting in a higher yield. The favorable effect of sensor irrigation and drip irrigation helped in maintaining constant soil moisture potential. The lower water use efficiency of surface irrigation was attributed to more evaporation loss of soil moisture due to a more exposed wetting surface upon irrigation.

The highest water saving recorded in IoT based Drip Irrigation at 60% depletion level (46.88%) followed by IoT based Drip Irrigation at 80% depletion level (40.63%).

Conclusion

IoT based Drip irrigation at 60% depletion level can be recommended for hybrid maize to augment higher grain and straw yield, water use efficiency apart from saving on irrigation water (46.88). Farmers can use these internets of thinking to schedule irrigation and monitor their fields from different locations. The application of artificial intelligence in agriculture will bring a new revolution in efficient irrigation and save used water. Smart irrigation technologies are changing the face of irrigation by increasing irrigation efficiency and increasing yields. Irrigation water used in agriculture is cut to a higher level so that excess water can be used in the field to grow other additional crops. Sensors help improve resource utilization.

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