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Alternate wet drying method in paddy cultivation in India by using soil moisture sensors: A review

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Abstract

The agricultural sector faces severe challenges because of climate change, particularly increase of global water scarcity, which threatens irrigated rice production. By 2025, 15-20 million ha of irrigated rice is estimated to suffer from some degree of scarcity (Kishore mote and Praveen rao valchala 2021) [2]. In India most of the rice producing farmers has tube well water availability for irrigation, so they have water availability throughout the season. This practice led to the massive extraction of groundwater, locally manifested by declining groundwater tables. This requires lot of energy consumption. Alternate Wetting and Drying (AWD) is a technology developed by the International Rice Research Institute (IRRI) (Robin J. Lovell 2019). The technology is based on the knowledge that rice tolerates up to 30-40% reduced water supply during the main growing period compared to conventional irrigation (Kishore mote and Praveen rao valchala 2021).

Alternative wetting and drying is an increasingly popular water saving practice in rice production (Robin J. Lovell 2019). Practical implementation of AWD was facilitated using a simple tool called a 'field water tube'. AWD technique can save water requirement up to 20-50% and improve water use efficiency besides reducing greenhouse gas emissions (GHG) by 30-50%. IOT (Internet of Things) based on soil moisture sensors by using artificial intelligence instead of human monitoring will be more precise and conserves more water and energy also gives more productivity with quality. Precision farming is one of the agricultural approaches involved on the adoption of technologies for better managing the variability within the field. With the help of this technology, there is a reduction in the human processing task, thus reducing the time and effort in accomplishing a certain job.

Keywords: Rice, alternate wet drying, precision agriculture, IOT, Soil moisture sensor

Introduction

Rice is the dominant staple food crop in India and it is the world's 2nd largest producer of rice, and the largest rice exporter in the world (Md Rahedul islam and wataru takeuchi 2019) [3]. The Production increased from 53.6 million tons in the year 1980 to 120 million tons in the year 2020-21. In India an average rice yield per hectare in flood irrigation is 2.5-3.1 tonnes. Since more irrigated land is devoted to rice than to any crops on world, wastage of water resource in the rice field should be minimised. On an average 3000-4000 litres of water is required to produce one kg of paddy (Kishore mote 2021) [2]. Due to heavy water consumption of rice crop by 2025, 20-25 million hectares of irrigated rice field India may suffer from water scarcity. 54% of India faces high to extremely highwater stress. 54% India's ground water in wells are decreasing (Kishore mote and Praveen rao velchala 2021) [2]. Flooded rice production system comprising irrigated lands, rainfed direct seeded converted to wet, deep water rice emits significant amounts of methane (CH4), a potent Greenhouse gas that contributes to global warming (Md Rahedul islam and wataru takeuchi 2019) [3]. Conventionally rice crop is raised by stagnant water in the field to a depth of 5- 10 cm. AWD is an irrigation technique in which water is applied to the field a number of days after the disappearance of stagnant water(Md Rahedul islam and wataru takeuchi 2019) [3]. This is in opposite to the conventional irrigation practice of continuous flooding where farmers never let ponded water disappear. AWD allows irregular drying during certain stages of rice growth because roots of the rice plant are still adequately supplied with water due to the initial flooding. Applying AWD could conserve fresh water resources and either extend the growing cycle during the dry season or expand rice production areas. In AWD irrigation since no continuous standing water is maintained in the field during crop growing season the number of irrigation events is reduced. This results in a net water saving of 35% when compared to continuously flooded rice crop. AWD can save upto 660-700 litres of water per kilogram of rice production. It is also considered as climate smart irrigation practice and helps farmers to cope with declining water level in wells and unforeseen water scarcity situations. AWD was developed through the research efforts of the International Rice Research Institute (IRRI), one of the major research centres under the Consultative Group for International Agricultural Research (CGIAR), a global agricultural research organization (Robin J. Lovell 2019) [7]. To solve the crucial problem, IRRI recommended field water tube for monitoring water depth in AWD irrigation management practices

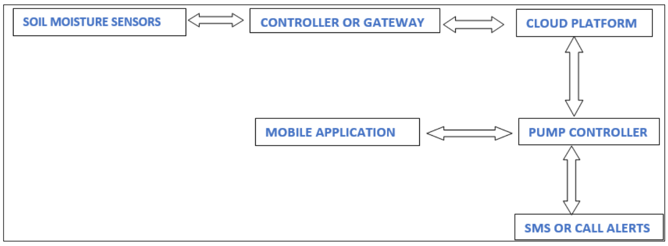
In modern agriculture, knowledge of the soil's water condition has become an economic factor of significant importance for the water supply to crops. Due to this knowledge of moisture content and salinity is essential to the development of new irrigation systems. Consequently, a new measuring technology has been developed to modernize future agricultural installations. This capacitive measuring principle is selected to measure moisture level in the soil, by soil moisture sensors. In this type of sensors, the main advantage is that it response in time of less than a minute, allowing the soil's hydric condition to be monitored in close to real-time. Internet of Things (IoT)-based automation of agricultural events can change the agriculture sector from being static and manual to dynamic and smart, leading to increase production with reduced human efforts. Precision Agriculture along with Wireless Sensor Network (WSN) are the main drivers of automation in the agriculture domain. Precision Agriculture uses specific sensors and software to ensure that the crops receive exactly what they need to optimize productivity and sustainability (G A Gines,JG Bea and T D paloag 2019) [4]. In water-level sensor system, several subsystems which measure the water-level are placed in the rice field and measure the water level. The data is accumulated on a field server at constant hourly intervals automatically. This data alerts farmers by sending SMS or inter voice calls by IVRS system. And also, android mobile applications also available to farmers which is helpful to monitor their fields and can know the field conditions like moisture content in soil, irrigation timings, how many litres of water applied through dashboard.

The IOT based smart farming monitoring system for paddy field is a smart system that can monitor the condition of paddy field and automatically controls the water level of the field. The system has sensors to measure the water level of the field. Then it will show the collected data to an LCD monitor. By the value of the collected data, it will turn ON/OFF the relay model to control the water pump. When the field need water, the motor will turn on automatically (GA Gines, JG Bea and T D paloag 2019) [4]. If the field has enough water, then the pump will be turned off automatically. The automation will be done on the basis of water level in the field which the data collected by the soil moisture sensors.

Smart irrigation system helps in protecting plants against pests/diseases with a 70% reduction in pest incidence. This system for paddy has been deployed to increase paddy yield by 52% which also reduces methane emission by 73%. Cost of production is decreased by 24% and farmers have gained 59% increase in their net income. By this AWD method productivity increased by 13%. Quality has been improved by 12%. Each hectare of paddy field requires 24,700,00 litres of water. By this smart irrigation we can save 35-40% of water per hectare, which means we can save upto approximately 1 crore litres of water per hectare.

Materials and Methods

The Principal driver of precision agriculture is Wireless Sensor Network (WSN), which is a network of multiple wireless nodes connected together to monitor the physical parameters of environment. Crops have diverse requirements depending on different crops on the same land and the same plant on different lands with different weather conditions. Sensors monitor the varying behaviour of these crop parameters (Priyamitra munoth and Rohit goyal and kuldeep tiwari 2016) [10]. Due to rapid advancement in WSN technologies, the size and the cost of sensors have reduced, which make it feasible to implement them in many sectors of life including agriculture. In general, a WSN consists of one or more wireless nodes that are further connected with sensors. These nodes are tiny devices that are responsible for collecting data. Nodes are divided into two types, a source node that collects the data, and the other is sink or gateway node, which receives data from the source nodes. A sink node has more computational power compared to a source node. However, there are energy, memory, power, size, data rate and price constraints when choosing wireless nodes (Priyamitra munoth and Rohit goyal and kuldeep tiwari 2016) [10].



IOT components

1. Soil Moisture Sensor

Working principle: A small charge is placed on the electrode and electrical resistance through the sensor is measured. As water is used by plants or as the soil moisture decreases, water is drawn from the sensor and resistance increases conversely as soil moisture increases resistance decreases. The sensor is capable of measuring soil moisture content and water depth and it send signal to the gateway.

Fig 1: Soil moisture sensor

2. Controller or gateway

An IOT gateway bridges the communication gap between devices, sensors, systems and the cloud. A device that connects sensors to the cloud or vice-versa. The gateway collects the information about soil moisture which is measured by the sensor and send it to cloud as well as from cloud to sensors.

Fig 2: IOT gateway or controller

3. Cloud platform

The information comes from the gateway analysed by the cloud. It is mainly work for data backup and controls whole IOT system. The analysis results are converted to the homepage format automatically. Therefore, it has become a mechanism that allowing the latest results to be checked at all times from any location.

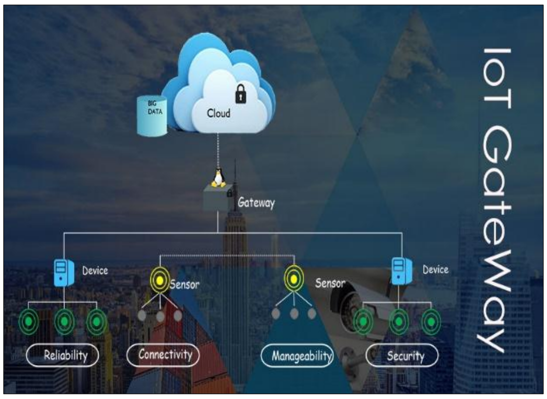


Fig 3: Cloud platform

4. Pump Controller: Based on the signals received from the cloud the pump controller controls the pump by switching ON/OFF.

Fig 4: Pump controller

5. **Mobile application:** Mobile application related to the system contains a dashboard which consists of all the information regarding the process and helps the farmers to check the data time to time from any place. He can operate the pump through the mobile application based on the signal given by the cloud.

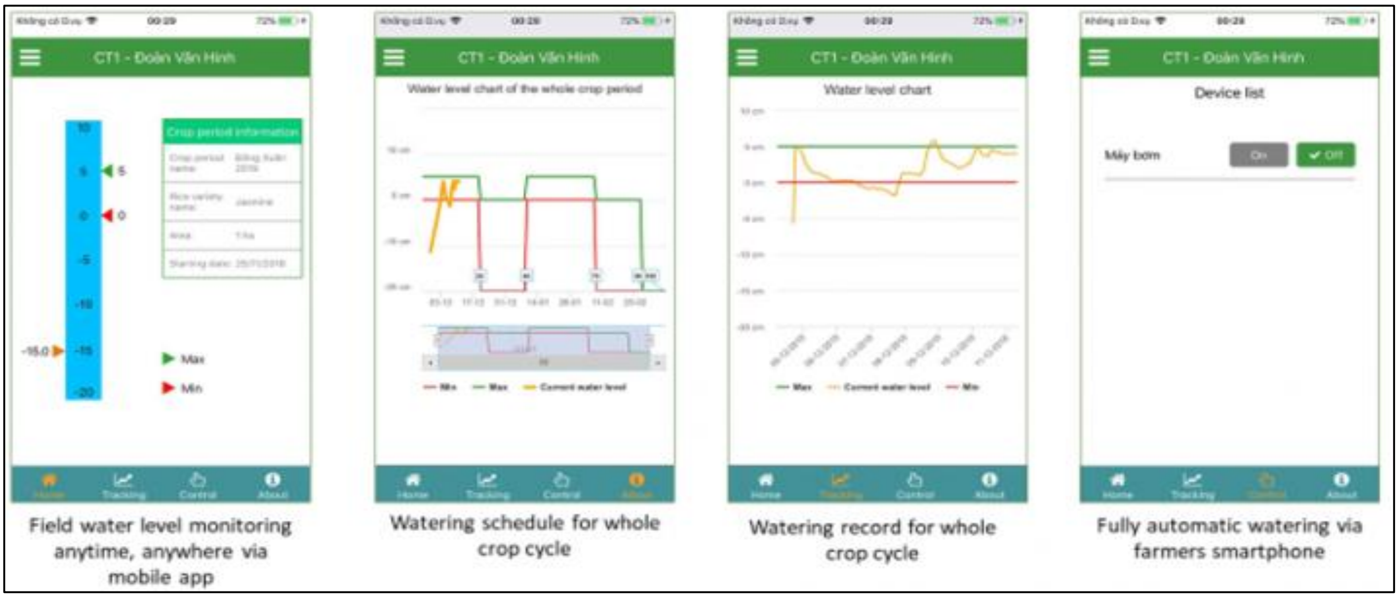


Fig 5: Mobile app dashboard

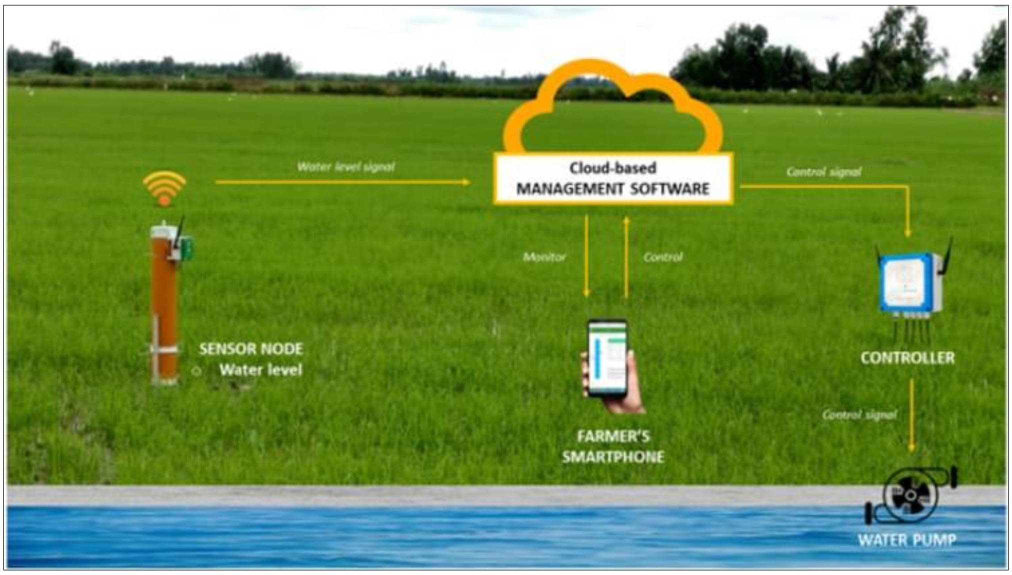


Fig 6: Technical architecture of the system

Graphical Representation of AWD and Conventional irrigation

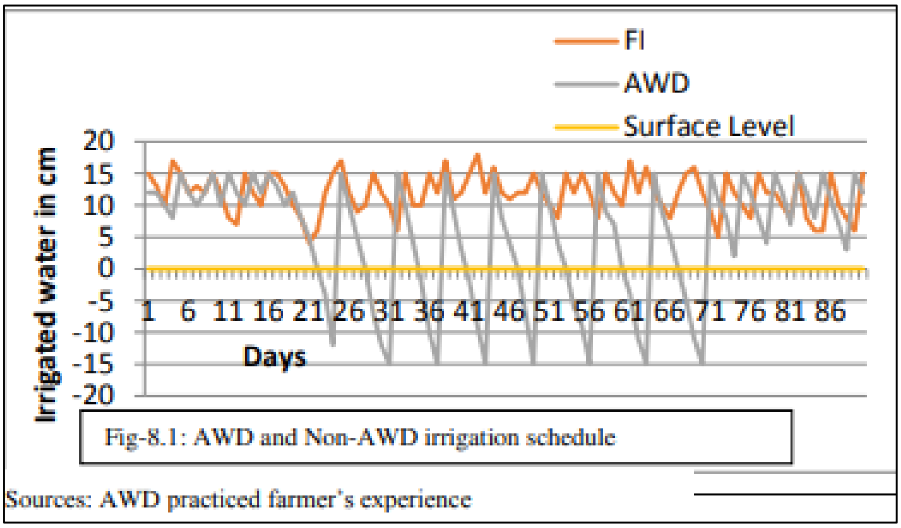


Fig 7: AWD and Non AWD irrigation schedule

As we observe in the fig. 7 (Md Rahedul islam and wataru takeuchi 2018) [3] in conventional irrigation system there is continuous water supply to the rice field throughout the crop and the depth maintained is from 10-15 cm. But in AWD irrigation system if we observe the water level is maintained from 15cm to -15cm. The spell between each irrigation may last from 4-5 days. Such that there will be no continuous irrigation and we can save lot of water.

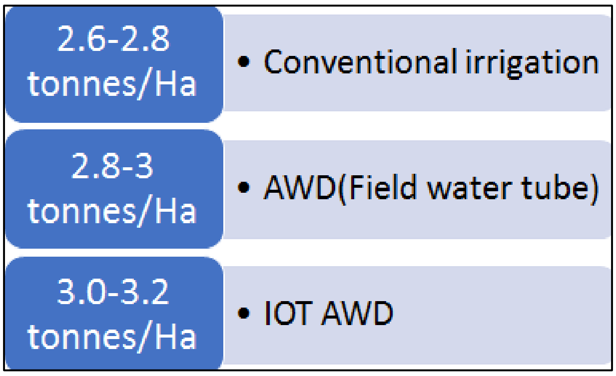
Result

In India most of the farmers grow rice crop, and it consumes lot of water if it grows in flood irrigation method. So, to conserve water there is a requirement of alternate irrigation methods for Rice crop. On the basis of this concept conventional irrigation method replaced by AWD field water tube method but this method is manually operated. Modern agriculture imposes the need for better knowledge of the soil moisture content to rationalize the amount of water needed to irrigate farmlands. In contest of this there is another alternate method called IOT AWD irrigation system in which everything is software operated. This method conserves 40-45% of water and produce more yield 16% than conventional irrigation method. In the following tables we can observe the water requirement and yield in each irrigation system. The water requirement gradually decreased and yield increased from system to system.

- **Water requirement for one kg of rice production**

3000-4000 LITRES/KG RICE	• Conventional irrigation
2500-3500 LITRES/KG RICE	• AWD(Field water tube)
1800-2400 LITRES/KG RICE	• IOT AWD

- **Rice yield when we applied different irrigation methods**



Graphical representation of conventional vs IOT

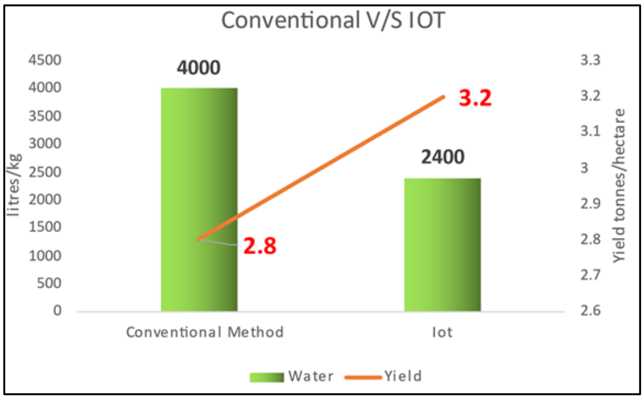


Fig 8: Conventional vs IOT

In the above graph we can observe how yield and water requirement vary from conventional to newly invented IOT irrigation system. From conventional method to IOT system, water requirement decreased around 40-45% and yield increased around 14-16%.

Conclusion

In the semi-arid areas of India like Andhra Pradesh, marginal farmers and small farmers who mainly depends on borewells and tube well irrigation for their crops. To avoid water, reduce GHG emission and to improve yield, right irrigation at right time in right amounts is necessary. These sensor technologies found to be suitable for collecting real time data for different parameters like crop and soil helps in developing solutions for majority of the agricultural processes related to irrigation. The development of wireless sensor applications in agriculture makes it possible to increase efficiency, productivity and profitability of farming operations.

Precision agriculture is a modern practice used to enhance crops' productivity using latest technologies, i.e., WSN, IoT, cloud computing, Artificial Intelligence and Machine Learning. Most of the research done so far indicates that Precision agriculture -based practices have a great influence on sustainability and productivity. The objective of Precision agriculture is to provide decision support systems based on water level of the soil. However, several challenges are involved in the development of these systems. In conclusion, there are many challenges that face this method, but with proper management, this new change detection approach could save time, money, and efforts wasted in promoting water-saving practices in the wrong places.

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