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An IoT Based Soil Analysis System for Variable Rate Application

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***Abstract*: Variable Rate Application is a method by which the farming inputs are dynamically calibrated to match the optimum soil conditions. This method has the potential to increase agricultural productivity, reduce input costs and make agriculture more sustainable. In this paper, a study has been presented in which variable rate application method has been compared to common rate application method in terms of yields and inputs utilized. The study used an IoT based soil analysis system that was used to obtain real time measurements of soil moisture, temperature and nutrient content to enable data based modifications of input rates and implementation of variable rate application method.**

***Keywords*: Precision agriculture, internet of things, variable rate application.**

1. Introduction

Around 49% India's workforce is engaged in agriculture for sustaining their livelihoods and India is one of the biggest food producers in the world; however the productivity of Indian agriculture is quite low, one of the reasons being that agriculture is still being carried out in a traditional manner and there hasn't been an adequate uptake of modern technology in the agricultural processes. [1] One way of increasing the productivity of Indian agriculture is by using Precision Agriculture. According to the International Society of Precision Agriculture: 'Precision agriculture is a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.'[2]. An important aspect of Precision Agriculture is Variable Application Rate (VRA) [3]. Evolution of technology has allowed greater accuracy in application of agricultural inputs by dynamically regulating the application rate according to the site-specific requirement. This method is called the variable-rate application (VRA) [4]. VRA is different from Constant Rate Application (CRA) in which the application rate of agricultural inputs is kept uniform over the field.

Crop yield and quality of the produce is dependent upon soil conditions in which the crops are grown [5]. The effectiveness of the inputs used is also dependent on the prevailing soil conditions. The Variable Rate Application (VRA) method thus has the potential to enhance the outcomes while reducing the cost of inputs for the farmer [6]. VRA can be implemented by using an Internet of Things (IoT) based system of sensors that record various properties of the soil. The Internet of Things (IoT) is a new paradigm that allows internet enabled "smart" electronic devices to communicate with each other [7]. IoT can help in significantly raising agricultural productivity [8].

In this paper, the effectiveness of Variable Rate Application (VRA) is compared to Common Rate Application (CRA) in terms of final yield and efficiency of agricultural inputs, and for this purpose an IoT based system is developed where sensors are used to record soil conditions, namely the soil temperature, moisture and soil nutrient content (i.e. the nitrogen, phosphorus and potassium content) in real time. This data is then utilized in determining the application rate in VRA. The site for the study was an Indian Gooseberry (Phyllanthus emblica) farm located in village Kawai, Bharatpur district, India where the study was conducted over a cohort of 50 Indian Gooseberry trees (cultivar N7) under VRA mode. The time period of the study was from 1st January 2020 to 1st November 2020, which forms one cultivation of N7 cultivar of Indian Gooseberry. The yields and input efficiency of this cohort were then compared to those another group of 50 Indian Gooseberry trees of the same age and cultivar under constant rate application (CRA) to determine the efficiency of VRA over CRA.

Utilization of technology for data collection in agriculture is an ongoing process where several advances have been made in recent years. Ahmad et al [9] successfully demonstrated an IoT based system for monitoring the for soil pH, temperature, and moisture. Shekhar et al., [10] developed an automated robotic system for irrigation using moisture content and temperature data collected via sensors. Jianhan Lin, Maohua Wang, Miao Zhang, Yane Zhang, and Li Chen [11] have provided an overview of how electrochemical sensors can be used to measure the soil nutrient levels which can then be used for calibrated use of fertilizers. Bob Longhurst, [12] measured the NPK values of the soil by measuring the change in electrode conductivity when electrodes of the same material were put inside the soil samples. N,P and K values have also been detected in aqueous soil samples by using fibre optic sensors operating on the basis of colorimetric principle. [13]. Vellidis, Tucker, Perry, Kvien, and Bednarz [14] developed a sensor

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based system for the measurement of soil moisture and temperature for creating an automated irrigation system. Mirell and Hummel [15] also created an Ion Selective Field Effect Transistor (ISFET) for calculating the soil pH and nitrate levels.

2. Design of the Soil Analysis System

The study used an Internet-of-Things (IoT) based Soil Analysis System using a network of sensors integrated with a cloud platform. The system enables the user to measure soil moisture, temperature, and nutrient content which includes Nitrogen, Phosphorous & Potassium levels on a real time basis. This data can then be used to vary the application rates of inputs. The system consisted of a sensor node and a Gateway. The sensor node comprised an Arduino Nano board, sensors and a NRF24L01 Wireless transceiver module. The nRF24L01 is a single chip 2.4GHz transceiver used for wireless applications.

The sensors measured physical properties that included soil moisture, which was measured by a Soil Moisture Sensor (Gikfun EK1940), the soil temperature, which was measured using the DS18B20 Temperature Sensor and the soil nutrient content (N,P,K values) which was measured by a JXCT Soil NPK Sensor. The gateway was built by using an ESP32 Wifi module and NRF24L01 Wireless Transceiver Module. The data from the sensor node was sent to the gateway using a Wireless transceiver Module. The data from the receiver was sent to a cloud based platform using a Wifi network where it was processed and presented to the user through a graphical user interface (GUI) for easy reading and operational decision making. The system architecture is shown in fig1.

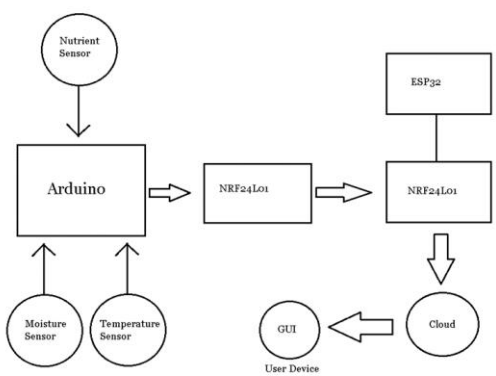

Fig. 1. System architecture

The cohort studied under the VRA mode was operationally managed using the data obtained from the soil analysis system. The entire cohort area was managed as a single management used as the area displayed low variation in terms of the parameters studied, except for soil moisture. For soil moisture, the cohort area was divided into three hydrological management zones with similar moisture levels based on mapping by the moisture sensors. Under the VRA mode, the data from the system was used to determine the amounts of irrigation and fertilizer to be used as an input for maintaining the optimal growth conditions. The irrigation was carried out using a manually operated drip irrigation system and fertilizers were dispensed manually based on the data. The cohort studied under the Common Rate Application (CRA) was operationally managed as a single management zone. The rate of irrigation and fertilizer used in the area under CRA was based upon standard farm practices that are utilized every season. The method of application of inputs under CRA was the same as that under VRA, i.e. irrigation was carried out through a manually operated drip irrigation system and manual dispersion of fertilizers. The fertilizers used under both VRA and CRA were kept the same and there was negligible difference in the water quality used for irrigation under both modes as the source of the water for the irrigation was the same, i.e. a water tank on the farm.

Table 1
Yield and Input Data

Mode of Application	**Average Yield (kg)**	**Average Water usage (Ltr)**	**Average N Fertilizer usage (gm)**	**Average P Fertilizer Usage (gm)**	**Average K Fertlizer Usage (gm)**
CRA	175	220	1000	500	1000
VRA	184	145	680	376	728

3. Results and Discussions

A summary of the data collected from the cohorts under VRA and CRA modes during the study period (1st January 2020 to 1st November 2020) is presented in table1 and in Fig2. The figures provided are average (quantity/tree) arrived at by dividing the total quantity by the cohort size, i.e. 50. The data reflects that farming operations conduction under the Variable Rate Application (VRA) mode led to an increase in the average yield per tree by 5.14 %, a reduction in the water usage per tree by 34 %, a reduction in the N Fertilizer usage per tree by 32% , P Fertilizer usage per tree by 24.8 % and K Fertilizer usage per tree by 27.2% as compared to the operation carried out under the Common Rate Application (CRA) mode

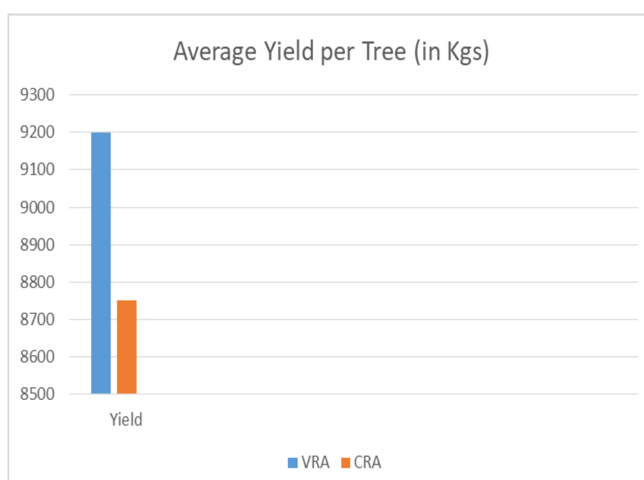

Fig. 2. Comparison of Average Yield per tree under VRA and CRA

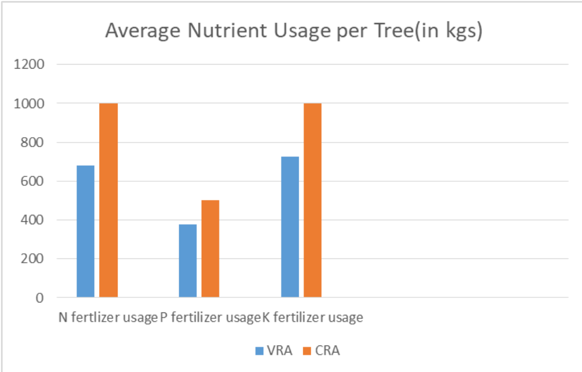

Fig. 3. Comparison of Average Nutrient Usage per Tree under VRA and CRA

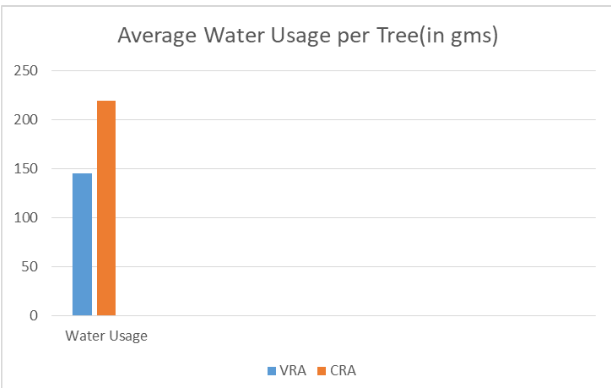

Fig. 3. Comparison of Average Water Usage per Tree under VRA and CRA

4. Conclusion and Further Discussions

As a means to implement Precision Agriculture, a soil analysis system was developed using an IoT based network of sensors integrated with a cloud based platform. The system provided real time data of soil moisture, soil temperature and soil nutrients which include Nitrogen, phosphorus and potassium. The use of the Soil Analysis system provided insights into the optimal rate of inputs using real time data. This allowed for the use of Variable Rate Application (VRA) where the dynamic calibration of the inputs according to the soil conditions lead to better yield outcomes and reduced usage of inputs. This demonstrates that the scaling up of this technology has the potential to make farming more economical, profitable, climate friendly and more sustainable. An automated fertilizer dispensing system along with an automated irrigation scheduler that works on data based feedback from a sensor equipped IoT system can further reduce operational costs and time in farming by making irrigation and fertilization processes fully automated and more accurate are compared to manual interventions. Further areas where technology can be applied for improving farming outcomes including usage of Light Detection and Ranging (LIDAR)/ Normalized difference vegetation index (NDVI) equipped Drones and Robotics for plant health assessment, pest/disease detection and yield estimation [16] and usage of Artificial Intelligence for data driven farming and process re-engineering.

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