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Techno-commercial feasibility of soil moisture scanner for efficient irrigation scheduling

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Abstract: This study proposes a new device to aid irrigation scheduling system using sensing and automation for precision irrigation. Despite agriculture being a predominant factor in the economic growth of a country, it has been facing several challenges like low productivity levels, volatility in return, difficulties in the supply of inputs and poor market regulation. In addition, water availability for timely watering of crops is critical that affects agricultural yield. Criticality of water as a resource is expected to increase with growing population and regional imbalances. In this context, there is a need to focus on optimal use of water through efficient irrigation techniques. This study has designed, developed and tested a unique device which outperforms the currently available devices on the market regarding functionality and cost effectiveness.

Keywords: GNSS reflectometry, Precision Irrigation, Irrigation scheduling, Crop Insurance and Crop marketing.

1. INTRODUCTION

Agriculture plays a pivotal role in the development of emerging economies, specifically with respect to growth and sustainability. Though agriculture is one of the core sectors in most emerging economies in Asia, there are several challenges such as reduced productivity, volatility in returns, constraints in the supply of inputs and poor market regulations. There have been sustained efforts by many entities such as government, research fraternity, and non-profit organizations to address the challenges in agriculture from varied angles. Government subsidizes the expenses, fixes the base price for agro products and provides inputs by training farmers on scientific methods of farming for better cultivation and output. A non-profit organization (NGO) on the other hand educates the farmers on the best farming practices and provides grants for innovative agriculture projects. In addition some NGOs also provide information to the farmers on weather conditions etc. through call centres. In contrast, academic researchers have addressed this issue by pooling resources for farming and recommending adoption of practices such as cooperative farming, contract farming and corporate farming (Barth etal, 2006, Pranaya et al, 2012). The group farming method provides a gateway for farmers to adopt innovative technologies such as wireless sensors network, robotics, remote sensing and use of drones for production monitoring. Despite technological advancement for better farming, the applicability is limited due issues in commercial feasibility (Neelam Srivastava, 2010, Valente J., et al., 2011). This study is an attempt to address the commercial feasibility issue to enhance the applicability of one such technology that can be used for irrigation scheduling, namely GNSS (Global Navigation Satellite System) reflectometry. Adopting the reflectometry technology will efficiently schedule irrigation leading to enhanced productivity. The uniqueness of the developed reflectometry technology will be appreciated if the current problems in irrigation scheduling are clearly understood. In the subsequent section the current problems with existing irrigation scheduling systems are discussed.

2. ISSUES IN IRRIGATION SCHEDULING

According to Sarah (2010), irrigation scheduling means "to determine the appropriate time and quantity of water to be supplied to a crop". The study also summarized the requirement of an efficient irrigation scheduling (described in Fig. 1.) for better returns. According to Sarah (2010) there are four inputs (soil texture, field capacity, soil moisture and quantity of water needed at each stages of a crop.) to be monitored for effective irrigation and better yields. Among the four it is observed that three are time invariant, and only soil moisture content is a time varying or a temporal input, which needs regular and accurate monitoring. If all the four inputs are managed to a value close to optimum value, the resultant yield will be near optimum crop yield, decrease water loss and optimize the pumping cost. Another important attribute to be considered along with the temporal variation of soil moisture is spatial variation. Studies have indicated that selective space sampling of soil moisture does not represent the whole area and may not be useful for irrigation planning. Brocca et al., (2007), states that "the plain site presents a random soil moisture spatial pattern, following the

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standard probability distribution, without a significant correlation length". This essentially indicates that there has to be appropriate number of samples at frequent intervals to achieve a desired level of confidence. An effective system can be designed if and only if large data is collected at regular intervals, random collection of data could lead to biased estimates.

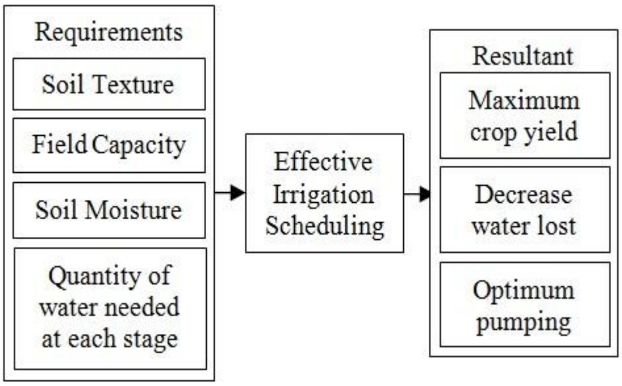

Fig. 1. Effective irrigation scheduling system.

Brocca et al. (2007) also suggested that if values are collected at a depth of 0.8 cm from the surface can be used to map up to a depth of 23 cm from the surface. Given these attributes it is almost impossible in a large farm setting to manage these parameters manually for an effective irrigation system. Though the current practices of automation in irrigation scheduling has lesser human presence (Jones, 2004) the accuracy level driven by automation is unanswered. Any level of irrigation automation has to address the following issues: (a) level of precision that can be achieved given the smaller number of sample points to test soil moisture, (b) the trade-off between cost, accuracy and maintenance of the device, (c) interruption in regular farming activity due to the contact with soil of the monitoring device. (d) cost involved in operation of control room and operation of individual valve in cases of far field monitoring such as using drones, remote sense, or in near field plant based monitoring mechanism, and (e) maintaining appropriate supply of water based on the need. In the subsequent section the ability of existing technology in addressing the concerns raised will be discussed followed by a description on the product developed to addresses the factors.

3. TECHNICAL FEASIBILITY REVIEW

The driving force for irrigation scheduling according to Jones (1990a) are namely (a) soil water measurement, (b) soil water balance calculations and (c) plant-based. Jones (2004) reported that both far field and near field plant-based methods though might communicate the need for irrigation will not be able to indicate the quantum to be supplied. Soil water balance calculation is the process of calculating the moisture content over a period by estimating the difference between supplied water to the water lost by runoff, drainage, and evapo-transpiration. Allen et al. (1999) reported that soil water balance calculation is found to be sufficient but subjected to serious issues of cumulative errors over time. Given the lack of effectiveness of these systems researchers have attempted adopted the use of camera based imaging sensing system with little effectiveness to analyze plant parameters. Due to the shortcoming of the soil water balance calculation and plant based method Allen et al. (1999) indicated that the best suited method would be soil based measurement for effective irrigation. Soil water measurement is the process of measuring moisture in the ground directly to plan for irrigation. The soil based measurement system can be used with the help of sensing technologies like wireless sensor networking (WSN), radar, radiometer, reflectometry technology, etc. Jones (2004) states that soil contact based systems as well as Unmanned Aerial Vehicle (UAV) based has drawback for irrigation scheduling, due to technology and functional limitations of the system. An alternative method to measure soil moisture is remote sensing. However, integrating the remote sensing device with ground-based real-time irrigation scheduling process is not viable due to time lag as well as cost. Further from Soil Moisture Active Passive (SMAP) satellite study, it can be observed that a far end use of radar and radiometer may not be highly effective in irrigation scheduling. Therefore, a solution for the near field moisture estimation with a non-soil contact sensing device reflectometry would be the ideal and effective method. Section 3.1, discusses the reflectometry based near field soil moisture measurement system.

3.1 Reflectometry-Based Measurement

The process of estimating the soil parameter including moisture based on the energy reflected from the earth surface is called reflectometry (Larson et al., 2010). It can be concluded from literature that there is no dedicated hardware device for that is used for measuring soil moisture in cropland-centric applications. This gap forms the core for developing a new device namely Soil Moisture Scanner (SMS). The expected functional capabilities of the proposed device are, (a) reduced computation platform, (b) capturing required data, (c) device clustering, (d) theft alarm, (e) inbuilt electric valve control unit and (f) at reduced cost. Section 3.2 discusses the test result of the developed SMS prototype with above functional capabilities for precision irrigation.

3.2 SMS Prototype

The prototype of the proposed solution, Soil Moisture Scanner (SMS), was tested in a farm located in a village called Salavathy, in rural Tamil Nadu (Fig. 2). The device is based on the principle of reflectometry, to estimate soil moisture. Based on the height of reflection the data can be segregated to identify the measurement from the soil or other elevated vegetative surface. For each quadrant covered by the device, data was recorded, continuously for 22 days. For the first eleven days, the soil moisture on the farmland was physically maintained in a pattern as illustrated in Table 1. From Fig. 3, which indicates the volumetric soil moisture values it can be observed that it is in accordance with the moisture content as indicated in the Table 1 essentially proving that the SMS device is able to assess the level of soil moisture in better way than the existing technologies. The subsequent section discusses the commercial feasibility of the instrument developed.