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A Digital Approach for Monitoring Soil and Crop Using Wireless Sensor Network

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Abstract: The various advancements made in numerous domains using new technologies are seen in many real time applications. Yet, the application of these technologies involves in the field of agriculture still remains a challenging task. The main aim of this paper is to propose a wireless sensor network technology in agronomy, which can show the path to the rural farming community to replace some of the traditional techniques. This paper proposes a software named'AGRO-TECH' that will be used to record, store and update the activities of various sensors which is accessible by farmers to keep track of his field details in terms of soil and crop monitoring. The activities such as leaf wetness, soil moisture, level of electrochemical, soil temperature, humidity, solar radiation, ultra violet radiation, temperature and atmospheric pressure are monitored and observed by different types of sensors that are included in the proposed system. These sensors collectively combine the information that mainly concentrates to increase the yield of pulse production. Hence the soil, crop and other environmental factors are observed and recorded. One such kind of observations i.e. based on the value of soil moisture sensor, the sensor node triggers the irrigation sprinkler to mitigate the impact of water scarcity. In case of any emergency, the farmer is intimated by SMS through his mobile. Hence, this sort of vital data will be sent to the farmers through our proposed digital approach.

Key words: Wireless Sensor Network · Soil and Crop monitoring · Sensor node · AGRO-TECH · Short Message Service (SMS)

INTRODUCTION

In today's environment, people are surrounded with networked sensors embedded in objects that will respond to their requirements. People are expecting an intelligent, embedded and digital environment that can so sensitive and responsive to the presence of people.

The Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors that can monitor physical mediums such as temperature, sound and pressure. Also, sensors cooperatively pass their data through the network to a main location. It has become a powerful tool for modern precision agriculture monitoring. Sensors are the key that connects available computational power with physical applications. Sensors have been designed for detection of ph range in soil, soil moisture, ultra violet radiation, temperature, soil temperature, leaf wetness, atmospheric pressure, humidity sensing and to support monitoring of crops.

These sensors are typically quite small and thus can be integrated into almost any application related to agriculture. In the field of agriculture, WSN extends its support for distributing data, collecting and monitoring the harsh environment information. Also, the WSN monitors the precise irrigation and fertilizer supply for increasing crop yield while diminishing cost and assisting farmers in real time data gathering.

Issues Faced in Agriculture: In India, Agriculture is the backbone of economy which contributes to the overall economic growth of the country and also supporting more than 50% of human life. There are some challenges in this field especially water scarcity, labor management, marketing the products and consuming the items (e.g. fertilizer) related to the agriculture. Of course, one of the big challenges in this field is water management. Most of the cases, the utilization of the water is not reached up to 100% and sometimes specific quantity of water is wasted

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due to the poor water management and alertness. Also, the other major factor in this area, certainly we say global warming which can tune 26% of water scarcity. Soil nutrients are also creating a big issue in the agricultural field even in the developing countries. Hence, a technology based application is needed to monitor agricultural system which decides itself intelligently and performing the actions.

Issues Focused in Production Yield: The issue focused in this paper, the yield of pulse production. Pulses are seeds of annual legumes that include plants such as dry beans, horse beans, dry chickpeas, cow peas, dry lentils, lupines, dry peas, pigeon peas, tur, masur, urad, moong, peas and vetches that are used for feeding humans as well as cattle. It plays an important and varying role in farming practices and in the diets of poor people worldwide. Pulses occupy a unique place in India's nutritional food as they are major sources of proteins for vegetarians. Pulses contain 22%-24% protein, almost twice the amount of protein content in wheat and thrice that of rice. But, India is facing a greater demand in pulses. Currently, the pulse production has stabilized at 18.5 million tones, our consumption is hovering at 22 million tones, which necessitates yearly pulse imports of around 3.5-4 million tones. India is losing precious force nearly $2.3 billion while importing pulses from producers such as Canada and Australia. Pulses grow in the regions of Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka and Rajasthan.

It grows under dry conditions. Pudukottai, Vizhupuram and Cuddalore districts are the driest regions in Tamil Nadu.The foremost crops under tank fed and open well irrigation system in this region in Tamil Nadu are millets, black gram, paddy and groundnut. Pulses like green gram, black gram and red gram are generally grown as a rain fed crops especially during summer. But the harvested pulses do not fetch a good profit because of low yields due to pest, disease attacks and poor processing facilities for value addition. The causes of demand may be Global inflation, less production of pulses, hoarding, increased cost of transportation and increased cost of production. According to Indian Institute for Pulse Research, by 2030 and 2050 the demand for pulses would be around 32 MT and 50 MT to meet country's increasing population, development and income of middle class. To meet this demand not only additional 3.0 to.5.0 m ha area would need to be brought under pulses cultivation but also fertility per hectare will have to rise to 1361 kg and 1500 kg respectively.

Table 1: Domestic production and demand of pulses survey [ref 17]

Year	Production Pulse Grains	Production Pulses	Demand Pulses	Demand Producion Gap(million tonnes)
	BASELINE SCENARIO			
2010	16.17	14.55	18.02	-3.47
2020	20.65	18.59	21.87	-3.28
2030	26.38	23.74	26.58	-2.84
	BASELINE SCENARIO +50% TFP GROWTH ACCELERATION BY THE YEAR 2030			
2010	16.17	14.55	18.02	-3.47
2020	20.7	18.63	21.87	-3.24
2030	26.57	23.91	26.58	-2.67
	BASELINE SCENARIO +50% TFP GROWTH DECELERATION BY THE YEAR 2030			
2010	16.16	14.55	18.02	-3.47
2020	20.59	18.53	21.87	-3.34
2030	26.14	23.53	26.58	-3.05

Related Works: Yuan yuan *et al*. have introduced the system, which is used for calculating the total size of crop leaves with light intensity readings captured by the sensors. It is used for long term monitoring with minimum cost [1]. But, his paper have limitations like it can only monitor crops and it is done by means of light intensity. In our work, we overcome his issues by monitoring soil, crop and other environmental factors on a large scale. Sonal verma et al. have introduced the system which can detect fire hazard by using EEPROM to store sensor data during power fail [2]. The system is more concerned about the fire hazard which is a rare case and in our proposed system we use solar radiation sensors for power. Nianmei *et al*. [3] have introduced the system for monitoring soil substance in xinjiang regions using wsn to improve the precision agriculture. His paper is more focused on monitoring the soil substance only. To resolve this issue, we have included a periodical soil and crop observation through our proposed software.

Proposed Work: This paper proposes a helping hand to the farmer through an embedded hardware kit and an interactive software. The system is based on the preliminary design on the development of various sensors embedded in a kit to detect the soil and crop growth which in turn is connected by means of WSN to a software named AGRO-TECH to update the activities of several sensors. Based on the value of soil moisture sensor, the irrigation sprinklers are actuated during the period of water scarcity. In case of any emergency, a mobile based SMS system is used and a weekly based yield report is also generated (Fig. 2).

Sensor Fusion Algorithm:

Step 1: To clearly understand fusion process of sensors, let us consider 2 areas(a(i) and a(ii)) in a field.

- Each area has 11 sensors that has been embedded into a kit.
- So according to our consideration, there will be 22 sensors accordingly.

Step 2: Here we assign:
FOR AREA(a(i))

- Sa1=Leaf Wetness Sensor(LWS) .
- Sb1=Soil Temperature Sensor(STS) .
- Sc1=Temperature Sensor Sensor(TSS) .
- Sd1m1= Soil Moisture Sensor(SMS) for watermark (m1).
- Sd1m2= Soil Moisture Sensor(SMS) for watermark (m2).
- Sd1m3=Soil Moisture Sensor(SMS) for watermark (m3).
- Se1= Humidity Sensor(HS).
- Sf1= Electrochemical Sensor(ES).
- Sg1= Ultraviolet Sensor(UVS).
- Sh1=Solar Radiation Sensor(SRS).
- Si1= Atmospheric Pressure Sensor(APS).

FOR AREA(a(ii))

- Sa2= Leaf Wetness Sensor(LWS) .
- Sb2= Soil Temperature Sensor(STS) .
- Sc2= Temperature Sensor Sensor(TSS).
- Sd2m1= Soil Moisture Sensor(SMS) for watermark (m1).
- Sd2m2=Soil Moisture Sensor(SMS) for watermark (m2).
- Sd2m3=Soil Moisture Sensor(SMS) for watermark (m3).
- Se2=Humidity Sensor(HS).
- Sf2= Electrochemical Sensor(ES).
- Sg2=Ultraviolet Sensor(UVS).
- Sh2=Solar Radiation Sensor(SRS).
- Si2=Atmospheric Pressure Sensor(APS).

Step 3: At first the sensors are being turned on by a power supply.

Step 4: Assign the input value for each sensor in float (initially as zero).

#Using Central Limit Theorem(CLT) for sensor data fusion.

- Let us consider one case (say) Leaf Wetness Sensor(LWS) where the wetness needs to be measure in a(i) and a(ii).
- We will be taking n number of readings or samples for Sa1 and Sa2 independently.
- Where n value(random approximation is n>=30) depends upon the estimation of bell shaped(Gaussian) curve.
- Our output sensor fusion value independently will be at the center of the standard normal distribution Gaussian curve.
- General equation for the mean of n observations:

$$z = \frac{(\bar{x} - \mu)}{\sigma / \sqrt{n}}$$

where,

$\bar{x}$ = Random variable for n samples
μ = Mean
σ = Variance
ans n = No. of Sample

- Thus for Leaf Wetness Sensor the fusion can be done using Sa1 and Sa2 values with noise variances

σ_1^2 and σ_2^2 respectively

- Hence,

$$\text{Y3}=\sigma_3^2(\sigma_1^{-2} Sa1 + \sigma_2^{-2} Sa2)$$

- where Y3= sensor fusion output for LSW and

$$\sigma_3^2 = (\sigma_1^2 + \sigma_2^2)$$

Similarly fusion values can be determined for the other 20 sensors in a(i) and a(ii), it can be seen that only in case of the soil moisture sensor(SMS) each 3 basic watermark depth fusion values are to be calculated separately.

Thus according to CLT definition the sample mean will be normally distributed for large sample sizes(n), regardless of what distribution from which we are sampling is valid for statistic inference.

Step 5: Record the value using READ function.

Step 6: Transmit the recorded value to the software through Router.

Step 7: Values will be categorized as high, medium and low by the software.

Step 8: Periodical changes in values will be managed by cloud storage.

The Image based remote sensing algorithm can be used for precision crop management. The remote sensing surface energy balance algorithm can be used as land monitoring in software. The precision agriculture drone algorithm is used to sample the performance by 30-35%. The static routing algorithm for sensing application, so these are the types of algorithms which could be used.

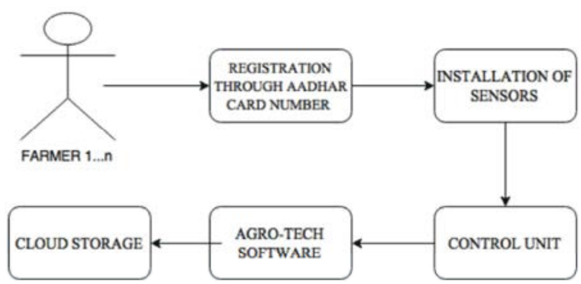

Fig. 1: Sequence flow of the proposed system

Farmer Registration: Basically, the farmers are provided with a software, a irrigation sprinkler and a hardware. The first step involves the registration of the farmers in the provided software. The n number of farmers can be registered through aadhar card number as a unique identification number. The registered farmers are then verified at the nearby taluk office for land assurance. So that the authorities could verify the land details and start the installation process.

Installation of Sensors: After the registration, the sensors are being attached according to the range of sensors embedded in a hardware kit and the field area, the authorities takes up the necessary steps for installation process. Then, a control unit will be provided to the farmer to activate the irrigation sprinkler, which acts as a water conserver in the period of water scarcity.

Table 2: Sensor activities

LEAF WETNESS	These sensors are used to detect the presence of surface moisture and can also be used to monitor the conditions which result in fungal development and growth of plants.
SOIL TEMPERATURE	These sensors detect the temperature of the soil . The soil required for pulses is Loamy and the required rainfall is 50 to 75 cm of rainfall per year for the growth of pulses.
TEMPERATURE	The temperature sensors detect the temperature of the environment. The required temperature is 20 to 30 degree Celsius for the growth of pulses.
SOIL MOISTURE	It is used to measure the volumetric water content in soil. Since the direct gravimetric measurement of free soil moisture requires removing, drying and weighing of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content.
HUMIDITY	Along with receiving the correct amount of water and light, moisture in the air in the form of water vapor greatly affects plant health. Water vapor is the gaseous, invisible state of water in the air known as Humidity. So, this sensor is used to detect the humidity.
ELECTROCHEMICAL	The primary nutrients are nitrogen, phosphorus and potassium. The other nutrients are calcium, magnesium, sulphur, boron, chlorine, copper, iron, molbidiyum and zinc. This sensor is used to give a optimal ph range based on the nutrients required for the plant growth.
ULTRA VIOLET	This sensor is used to detect UV-B, an important component of sunlight. It is a necessary component for the essential plant growth and in the production of chlorophyll.
SOLAR RADIATION	This sensor is used as mode of power to all other sensors using sunlight as a major source. In this way, power is been conserved by proper utilization of natural resource.
ATMOSPHERIC PRESSURE	Atmospheric pressure would depend on a number of independent factors, most especially the structure of the plant itself, and how high of a pressure you want to inflict. An important thing to consider is that a majority of plants are composed of a high percentage of water. Water is an extremely stable compound, and is considered a fluid that cannot be compressed. Therefore, in high pressure environments, the overall strength of a plant's tissue and its percent composition of water will decide its survival.

Control Unit: The control unit is the irrigation sprinkler which is used to sprinkle the water in the field sufficiently. Based on the calibration of the Soil moisture sensor, the irrigation sprinkler is been actuated and provides the necessary water needed for crops thus conserving water. After sprinkling, it is automatically been switched off. The number of irrigation sprinklers in a particular field is connected to a motor, which is a means of a water supply. The sprinkler can also be a overhead sprinkler.

AGRO-TECH Software: Through the WSN technology, the sensors activities in the embedded hardware kit is interpreted to the software being developed. Basically the software will be developed, making it more user friendly to be interactive with the farmers and their future generations to involve with technology easily and make efficient use of it for our country's profit in agriculture field. The data will be sent to the various sensors which update their activities in a embedded hardware kit which in turn is accessed by this software. The software can be build using platforms like visual basic, net beans and in future the App can be developed for all users as well. The various labels in the software are: Registration, Land monitoring, Data visualization, Emergency, Connectivity, Settings, Help and Report generation.

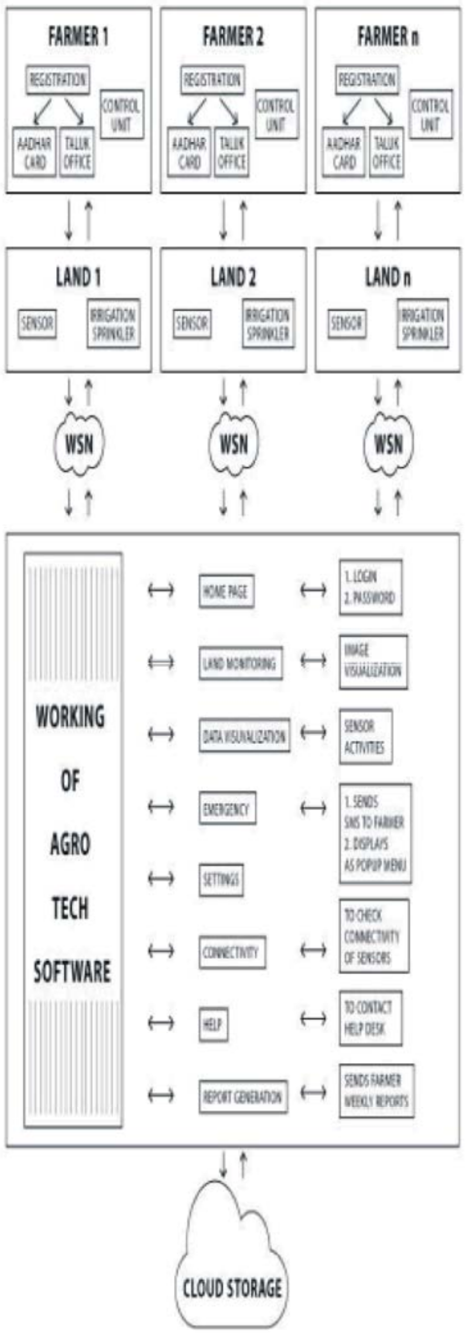

Fig. 2: Architecture of proposed system

The working of the Software involves registration of the farmers and after the farmers been registered they can be logged in. Then a land monitoring system using GIS (Geographic Information System) technology shows a visual view of the field as a image visualization. Then the data visualization is used to show the detailed activities of the various sensors for soil and crop as a means of monitoring. Incase of any emergency, the farmer has been intimated through SMS in mobile and also displays as a pop-up menu in the software. To check the connectivity of each sensor, the connectivity option is enabled. To contact, a help desk is been provided. Then the report generation is been provided by SMS to farmer on weekly basis.

CONCLUSION

The larger part of the difficulties in monitoring a field crop towards its growth and harvesting can be solved by using wireless sensor technology. Power management can also be done by using solar Radiation sensors. A water sprinkler to be effectively used in the period of water scarcity, thus water being conserved. Communication cost between the sensor nodes and the central server of software is also reduced by using efficient wireless technology. Agriculture provides the principle means of livelihood for the major Indian population. There is need to produce more food and conserve the water resources for the burgeoning population expected to reach 1.5 billion by 2025. The land is shrinking and the pressure on the natural resources is increasing technology can help farmers to augment their knowledge of which crops to produce for the best return, find the most effective farming practices and make plans. It could increase their output and earn more from what they already have through the use of innovative technology and conserve their valuable natural resources for sustainable agriculture in the truest sense.

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