USING WIRELESS SENSOR NETWORK FOR MONITORING GROWING ENVIRONMENT OF TEA IN NORTH-EAST INDIA

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ABSTRACT

This paper proposes a tea plantation monitoring system for monitoring information concerning tea production environment utilizing Wireless Sensor Network (WSN) technology. The proposed system collects environmental and soil information of the field through WSN-based environmental soil sensors and collects leaf image information through IR camera. This collected information is converted into a database and provided to planters. It could be expected that the use of such a system could contribute to increasing crop yields and improving quality in the agricultural field by supporting the decision making of planters through analysis of the collected information.

Key Words: Tea, Wireless Sensor Networks (WSN), Agriculture, Yield, Planters

INTRODUCTION

Wireless Sensor Networks (WSN) is an emerging technology and it has revolutionized data collection in real time. In agricultural research data collection from large landscapes supporting crops is a tedious task. Coupled with time taking laboratory procedures, farm decision making process is often delayed, many a times leading to loss of crops. Tea production system is no exception, where regular monitoring and quick decision making at garden level can lead to improved crop yields. Tea is grown on acid soils (optimal pH 4.5-5.5), which undergoes changes on prolonged cropping and/or due to many other factors. However, there are no frequent pH measurements at the garden level. Impacts of the amendments added to correct pH1 changes are also not regularly monitored. Soil moisture is another crucial factor in tea production, where too much and too little levels impact crop yields adversely. Much of monitoring of soil moisture at tea garden level is only visual often using plant wilting as the indicator of deficit and surface coverage by a thin film to ponding as too much water or waterlogging. While there is no monitoring of subsurface water, irrigation scheduling at many places is ill spaced and under/overdone. Soil moisture measurements even in field research is also done maximum once a day that too by using sophisticated instruments like neutron probe. Such systems are not practicable at the garden level and require special skilled workers. Soil temperature monitoring is often ignored in many crops, but it largely controls microbial activities, nutrient dynamics and chemical kinetics in soils. Relative humidity is one external environment factor2,3 which is very important for tea growth as well as the ambient temperature. The recent advance in wireless communications and microelectronics has enabled the development of small, low-cost sensors. Sensor networks are developed to organize and control these sensor nodes, which have sensing, data processing, communication and control capabilities. Information collected from the sensors or nodes is routed to a sink node via different types of wireless communication approaches. The combination of small size, low cost and wireless networking

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functionality makes sensor network technology exceptionally scalable. In a farm level far decision making process, minimum datasets are necessary which range from soil properties, external environmental conditions (often micro-climate) and input availability. Quick availability of real time data leads to quality and timely decisions. Wireless sensors specific to a parameter placed in the area of activity (typically a tea plantation field) can capture the parameters required for decision making quickly and transmit the data across to a monitoring station. These data after its capture can be integrated into a decision making process after making necessary iterations, and if required, to the usable format. Depending on the volume of data, necessary analytical platform (usually high end computing system or server aided network) can be used. Further, such data can be integrated to a farm/garden map using a GIS platform, which can provide immediate visibility to a decision making process at the garden level.

Warm and humid conditions, which support best tea growth are conducive to the growth of various pests and diseases in the form of mites, nematodes, algae and fungi that can infect the tea plantations. Existing systems take preventive actions against these impacts only after they have infected the plantation. WSN presents the onus of allowing the modelling of growth cycles for the pests by studying the conducive weather conditions aggravating their growth. Thereafter, the occurrence of similar weather conditions will be active input to a pest management decision support system which can forewarn a possible pest outbreak. Moreover, manual analysis of the causes of diseases in large crop fields is impossible; hence we need a generic and rapid method for the analysis of the causes and timely prevention of the stresses.

Wireless Sensors Network (WSN) is a promising data mining approach for precision agriculture where quality decisions are required in real time. The rapid increase in WSN deployment in industrial, agricultural and environmental monitoring applications is as a result of being a low power and low data rate hence energy efficient technology. It also offers mobility and flexibility in connectivity which promote network expansion when needed.

Recently, there have been numerous publications on the application of WSNs to Precision Agriculture. Keshtgary and Deljoo discussed the simulation of WSN for agriculture using OPNET simulation tools in which random and grid topologies were compared. They evaluated the performance of the networks by monitoring delay, throughput and load. Zhou et. al. presented a WSN deployment for irrigation system using ZigBee protocol. A design method of WSN node and gateway node for monitoring environmental status in a tea plantation was introduced by Sun et al. Results showed that the system can collect the temperature and humidity of the tea plantation and transmit remotely to the base station using the established WSN. The nodes were deployed in both random deterministic plans. Temperature is one of the primary variables effecting the growth of the plants. Another stand-alone wireless embedded network system was developed for continuous monitoring of soil water contents at multiple depths and the results indicated that the wireless underground network system to continuously monitor soil water contents at different locations and soil depths performed well. In another WSN design wireless sensors network for tea plantations information acquisition was quite satisfactory, whereas in a contemporary development, a sensor node was designed to collect special tea information such as temperature, humidity, soil moisture, sunshine etc. from the tea gardens which were collected using sensors and then transferred to the monitoring centre.

For drought monitoring in tea plantations, a Wireless Sensor Network (WSN) was used which can collect the temperature, humidity and soil water content, and transmit data remotely to the base station, which provided the characteristics of working stability and reliability in the system. Since tea grows well on high land well drained soils having a good
depth, acidic pH in the range 4.5 to 5.5 and more than 1% organic matter with a good hydro-thermal regime. Hence, monitoring soil is important for the growth of tea.

In tea plantation, field placement of high resolution cameras can capture the canopy surface activity that include any insect and disease incidence/activity/physical damage to canopy/discoalouration/leaf puncture-spots by insects etc., and can help in immediate decisions making. Tea estate monitoring system with ground based camera system (sensor network) and meteorological stations as well as satellite imagery data on a Geophysical Information System (GIS) was proposed by Arai and the study concluded that the most appropriate time for harvesting new tealeaves could be determined as well as it was possible to estimate mass and quality of new tealeaves based on monitored camera imagery data and satellite imagery data derived total nitrogen and fiber contents in the new tealeaves. Estimation method for total nitrogen and fibres which are contained in tea leaves has been proposed together with a method for tea estate monitoring with network cameras, because of the fact that Near Infrared (NIR) camera data shows a good correlation to total nitrogen. Also it is possible to estimate mass and quality of new tea leaves based on monitored camera imagery data and satellite imagery data derived total nitrogen and fibre contents in the new tea plantation. It is also found that monitoring of a grow index of tea leaves with BRDF measured with networks cameras is valid. Thus it can be concluded that monitoring of tea estates with network cameras of visible and NIR is appropriate.

AIMS AND OBJECTIVES

This paper proposes a tea plantation growing environment monitoring system to monitor information on the field by utilizing WSN (Wireless Sensor Network) technology. The broad objectives of the study are a) to monitor some important soil, meteorological and canopy surface activities and b) to develop and embed a decision support toolkit in the monitoring system.

MATERIAL AND METHODS

Experimental site

The WSN set up was deployed in the experimental area of Tocklai Experimental Station at Jorhat, Assam, India, having tea plantation with a mixed population of tea clones. The sensors were deployed to capture soil, meteorological and other canopy surface parameters to form a part of the DSS framework.

In case of WSN data acquisition, at first different sensors measuring different parameters (physical, chemical etc.) were procured. Those sensors were then integrated into a sensor board. In this board all the signal processing such as amplifying, noise removing etc. has been done. The sensor board is getting supply voltage from wireless node and giving power to the sensors. The output of the sensors are then amplified and made in a suitable form for the input to node. Thus, the node gets the sensor value. Two WSN nodes were placed 10 m from each other in the tea plantation field. A specially designed weather shield box protected the WSN and the electronic sensor module. The WSN node supplied a 12 V, 20 mA (max) current to the sensors. Then wireless nodes collect those sensor data and transmit to the gateway. The wireless gateway connected to the PC, located in the server room, through an Ethernet cable. The gateway was kept inside the laboratory approximately 50 m from the farthest sensor node. Signal conditioning circuit were developed for the sensors. The voltage signals captured by the sensor nodes transmitted to the Ethernet gateway every 15 minutes. The system stored the measured value in a MySQL database. The whole setup from the sensors to the monitoring station including the communication path is shown in Fig. 1. The setup in the field had ambient temperature, soil moisture, soil pH, soil temperature and Solar radiation sensors linked from the WSN node to the monitoring station located in the climate research facility of the Tocklai experimental station, Jorhat, Assam, India.
The PTZ (pan, tilt, zoom) infrared camera with 360 degree scanning was set up for live image capture in the field. All the electronic modules have been mounted in IP 65 standard enclosure to withstand environmental harshness in the field.

![Sensors placed in the field](image1)
![PTZ Infrared camera placed in the field](image2)
![Node 1](image3)
![Node 2](image4)
![Ethernet hub and wireless gateway](image5)

**Fig. 1**: Experimental setup of the sensors to the monitoring station

**RESULTS AND DISCUSSION**

Continuous flow of data to the monitoring station was achieved which provided large datasets for analysis and developing decision making tools. Each day a continuous graph was prepared for 24 hrs, which is kept in archives to be integrated the next day with subsequent data. Few of the continuous graphs with the sensors generated data for some of the parameters at an interval of half an hour are shown in **Fig 2(a)** to **Fig. 2(f)**.

![Graph for ambient temp(°C) at an interval of 30 minutes](image6)

**Fig. 2(a)**: Graph for ambient temp(°C) at an interval of 30 minutes
Soil moisture

Fig. 2(b) : Graph for soil moisture at an interval of 30 minutes

Relative Humidity (%)

Fig. 2(c) : Graph for RH(%) at an interval of 30 minutes

Soil temperature (°C)

Fig. 2(d) : Graph for soil temp(°C) at an interval of 30 minutes

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A perusal of Fig. 3 to Fig. 6 revealed that the data obtained by the sensors and the laboratory analyzed manual data has a close match. However, it may be kept in mind that laboratory measurements do not have a fine resolution (interval between two measurements is large) as compared to the sensors data (which give continuous data). Therefore, such coarse resolution data when compared masks some of the abrasive readings given by the sensors. This has been overcome by fine tuning the software as well as applying stringent control on field sensors maintenance (reconditioning and standardization). Studies are sparse in literature where pH has been measured so frequently and closely to figure out changes occurring on hourly basis or even lesser time interval with a non destructive method.
It is difficult to measure at close time intervals (e.g. hourly basis in a non-destructive manner) as to how soil amendments or fertilizers/chemicals impact pH immediately after application in tea soils. However, some of the applied chemicals/amendments degrade within 24 hrs after application and impact pH. With WSN, it is possible to measure the changes with small time intervals even within seconds and minutes and can be repetitive. These continuous precise measurements, besides, its immense use for tea industry in making quick and quality decisions have lot of implications in understanding the behaviour of soils, which is not possible with conventional means. Based on the data acquired through the sensors, an intelligent DSS was inbuilt into the system to get important decisions, such as scheduling agronomic operations (giving water, fertilizer, and pesticides). If the soil moisture moves below field capacity, the system shows moisture deficit and may go for irrigation. Appropriate soil moisture content help determine the best application time. The system manages decisions based on the data coming from the different sensors. An application can be built and attached so that when the soil requires irrigation, the PC generates a signal to switch on a water pump to feed water from the storage tank. The DSS can also control the pumps to provide the liquid fertilizer, respectively, when fertilizer is required.

In agriculture systems, the plants are the best indicators of various stresses and external influence. Field camera installed for the purpose gave large set of images but among those some informative captures of pest attack has been detected. Few of those images are shown in Fig. 7 and Fig. 8.

![Graph of Soil Moisture Percentage](image1)

**Fig. 3**: Comparison of sensors generated and manually analysed data for soil moisture

![Graph of Soil pH](image2)

**Fig. 4**: Comparison of sensors generated and manually analysed data for soil pH
Fig. 5: Comparison of sensors generated and manually analysed data for ambient temperature

Fig. 6: Comparison of sensors generated and manually analysed data for soil temperature

Fig. 7: Insect activities captured at the canopy surface at night time
These insect activities captured by the camera is first of its kind and some of these can be a precursor of a larger insect/pest attack as the conditions for a particular insect become conducive.

CONCLUSION

The WSN system can monitor the tea growing environment giving real time values for some soil and meteorological parameters. The outputs obtained by the WSN network will be quite helpful in making quality decision and will find immense use in tea industry applications particularly while deciding the agronomic inputs. Further field cameras can monitor the canopy surface and can help in developing early warning systems.

REFERENCES


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**We have modified our environment so radically that we must now modify ourselves to exist in this new environment.**

Norbert Wiener