Soil salinity and moisture measurement system for grapes field by wireless sensor network

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Abstract: Soil moisture and salinity measurement are the essential factors for crop irrigation as well as to increase the yield. Grapes eminence depends on the water volume contents in soil and soil nutrients. Based on these conditions, we determined water demand for best quality of grapes by wireless sensor network (WSN). Using lot of chemical fertilizers increases soil salinity but reduces soil fertility, soil salinity defines electrical conductivity or salty soil. Precise agriculture systems are integrated with multiple sensors to monitor and control the incident. Integrated WSN is designed and developed to measure soil moisture and salinity. ATmega328 microcontroller, XBee and Soil sensors are integrated across the system. This system is more competent, it can be helpful to automatic irrigation system and soil salinity monitoring.

1. Introduction
Soil content measurement is the major part in agriculture research. In rainy season, all nutrients of soil are carried away because of water flow and soil erosion in summer season, it is harmful for the growth of crop. Soil moisture and salinity-related crops yield (Katerji, Van Hoornb, Hamdyc, & Mastrorillid, 2003),
water management as well as soil nutrients are essential for growth and quality of grapes. Grapes are grown in the different area across India, but each area has different soil conditions and quality as well. Some important factors are affecting the quality of grapes and those are also based on the soil.

To know, some important principles for the study of grapes are most essential i.e. symptoms on the vine of water anxiety and physiological stages i.e. size and quality of the grapes, depth, and size of the root, because of lack of water; all these factors depend on water storage capacity of the soil (Coggan, 2002). Mostly, water management depends on types of soil such as alluvial sandy soil with different layers of sand and silt. If clay content having less than 5% and water retention capacity is less than 50 mm³/mm³, then it has to irrigate every 7 days. If well-drained red soil of high physical potential, but with low pH and clay is equal to 15–20%, then it has to irrigate every 20 days. The quality of grapes depends on the type of water supply; water supply can be from different resources such as gravitational water, free drainage, rainfall, and available water (Holzman, Rivas, & Piccolo, 2014).

2. Literature

2.1. Physiological stages
After harvesting of grapes, building of reserves for next season period of active root growth maintain adequate moisture levels, but do not encourage any active growth that can utilize reserves (very dangerous for freeze damage), leaves should stay active only, manage the ripening of the shoots for protection against winter chilling.

2.2. Practical methods for evaluating soil moisture
Various systems can be used to evaluate the soil moisture, important facts that to know the rooting depth (make profile pit) by Tensiometers, Neutron Probe, and Resistance Blocks.

There are many automatic irrigation systems such as full surface wetting flood systems; it covers total soil area, overhead sprinkler systems, and micro jets are concentrated wetting such as drip system. Water penetration time depends on the type of irrigation system as well as rate of water penetration depends on soil type and volume of water applied. Water is irrigated which depends upon the physiological stages of soil type (water holding capacity), climate (temperature, relative humidity, wind), type of irrigation (flood, sprinkler, drip), and water quality. Most important thing is availability of water (how much? and when available?). Extraction of water is 40% from the top and 25% of rooting zone for planting (Coggan, 2002).

2.3. Practical methods to decide timing and size of irrigation
There are certain methods in estimation of soil water holding capacity, plant factors, depletion level of soil water, effectiveness of irrigation system, and water volume.

2.3.1. Water quality
Grape vines have moderate to good resistance with salinity. Water for irrigation containing saline salts or elements has direct and indirect effects on the plant. In field, direct effect is uptake nutrients and indirect effect is the physical effect on the soil.

2.3.2. Soil sensors
Soil sensors that measure necessary soil properties. These sensors can be used to control conflicting rate application equipment in real-time soil parameter measurement. There are many types of sensors like electromagnetic, optical, mechanical, electrochemical, airflow, and acoustic for different applications such as industrial, defense, agriculture, medical, etc.

2.3.3. Measuring soil properties
In ideal precision agriculture system, sensor is connected directly with a “black box” which can read the data, processes it and controls output changes immediately. The system contains real-time signal detected by the sensor.
(1) Some sensors and controllers systems require a certain time for measurement, integration, and amendment, which decreases the operation speed.

(2) Design of treatment algorithms.

3. Sensor data-based systems

Today, various systems that are vehicle-based soil sensors are available; only electromagnetic sensors are commercially available and commonly used. Ideally, developer would like to operate sensors that provide inputs for existing treatment algorithms. Instead, commercially available sensors provide measurements such as electrical conductivity that cannot be used directly since the absolute value depends on a number of physical and chemical soil properties such as texture, organic matter, salinity, moisture content. On the other hand, electromagnetic sensors provide precious information about soil differences and similarities, which makes it possible to divide the field into smaller and relatively reliable areas referred to as management zones (De Benedetto, Castrignanò, Quarto, 2013).

As new active soil sensors available, different real-time and map-based system treatments may be economically applied for much smaller field areas, reducing the effect of soil contradiction within each management zone.

3.1. Wireless sensor network (WSN)

Wireless sensor network (WSN) have many applications such as industrial automation, automated and smart homes video surveillance, traffic monitoring, medical device monitoring, monitoring of weather conditions, air traffic control, robot control, personal body area network (Majone et al., 2013).

Different types of communication topologies are available for WSN i.e. mesh, star, etc. But in distributed sensor network, data sharing is not centralized because such WSN networks consist if central node is collapsed then entire network will be collapsed. It will help to better collection of data, to provide nodes with backup in case the failure of the central node.

Characteristics of WSN (Shruthi, Shaila, Venugopal, & Patnaik, 2015):

(1) Power consumption constrains for node using battery.
(2) Mobility of nodes.
(3) Scalability to large scale of exploitation.
(4) Capability to stand with inclement environment conditions.
(5) Ease to use.
(6) Cross-layer design.

We have developed such wireless sensor node for soil moisture monitoring of crops. This system is energy efficient, low cost, portable, and small size. From soil, sensor read real-time moisture level is displayed in analog and digital form. Same sensor is also used for measurement of soil conductivity (salinity).

4. WSN architecture

It is wireless automatic distributed sensor network. It has multiple sense stations called sensor nodes. It is operated on IEEE 802.15.4 protocol and 2.4 GHz frequency. We can also use 6LoWPAN which stands for IP^6 protocol for Internet of things (IoT). Sensed data send wirelessly to router and then to coordinator. Every sensor node is equipped with sensor, microcontroller, XBee, and power supply.
For grapes quality monitoring, we have developed Soil moisture or conductivity sensing WSN system. Figure 1 shows that architecture of WSN for grapes quality monitoring. Also end device (WSN node or mote), routers (mediator), and coordinator (gateway) are shown in Figure 1 with wireless communication mode.

4.1. WSN node structure

4.1.1. Soil moisture sensor with interface module

A simple water sensor can be used to detect soil moisture. When the soil moisture module detects low moisture, outputs will be high level. The sensing level is adjustable using a small potentiometer. It has both analog and digital outputs using a LM393 comparator chip. It requires the operating voltage 3.3–5 V and some extra features power indicator (red) and digital output indicator (green). The module is basically testing resistance between the input terminals. It can be used for sensing soil moisture, or can be a “raindrop” detector if you make many close-together wires on an insulator. Long-term stability as soil sensor will be better with two stainless steel probes such as cooking skewers, etc.

4.1.2. ATmega 328 microcontroller

It is 8-bit high-performance low power microcontroller. It is advanced RISC architecture, high endurance non-volatile memory segments; it has many peripheral features and operating voltage 1.8–5 V. It has three power consumption modes i.e. active mode, power mode, and power save mode. Operating temperature range is −40°C to 85°C. It has 32 KB flash, 1 KB EEPROM, and 2 KB RAM.

4.1.3. XBee

XBee is the brand name of Digi International for a family of the form factor compatible radio module. Such communication is wireless IEEE 802.15.4 based protocol. All XBee’s are available in 20 pin packages and two form factors surface mount (SMT) and through the hole. Typical antenna modules have certain antenna options.

XBee operates still in a transparent data mode or in a packet-based application programming interface (API) mode. In the transparent mode, data coming into the Data IN (DIN) pin are directly transmitted over-the-air to the intended receiving radios without any modification. Incoming packets can either be directly addressed to one target (point-to-point) or broadcast to multiple targets (star). This mode is primarily used in instances where an existing protocol cannot tolerate changes to the data format. AT commands are used to control the radio’s settings. In API mode, the data are wrapped in a packet structure that allows for addressing, parameter setting, and packet delivery feedback, including remote sensing and control of digital I/O and analog input pins. XBee programming uses software tool XTU. It is a special tool for programming of ZigBee different modes.
5. Simulation survey of WSN

WSN simulation is a significant role for WSN development. Protocols, schemes, even new ideas can be evaluated in a very large range in simulation study. WSN simulators permit users to isolate different factors by tuning configurable parameters. This section illustrates using several simulation tools like NS-2, NS-3, TOSSIM, EmStar, OMNeT++, J-Sim, ATEMU, and Avrora; and can analyze the advantage and disadvantage of each simulation tool (Yu, 2011; Yu, Wu, Han, & Zhang, 2013). Today’s most of WSN simulation is done in NS-3. It is network simulator series 3 which is discrete event computer network simulator and WSN simulator.

6. Development of WSN system

Soil moisture sensor reads the analog data and provides to the on-chip ADC of ATmega 328. Those data are converted and it transmits serially through XBee. The entire system contains WSN node as shown Figure 1, it shows the architecture of WSN. Figure 2 indicates wireless node architecture. Figure 3 shows WSN node circuit diagram. Those data are sensed by sensor node and collecting at the coordinator.
The circuit schematic is shown in Figure 3, it shows that supply section that contains the regulator 7805 is 5 V for microcontroller and TPS7A4533 is 3.3 V voltage regulator for Zig-Bee. Soil moisture sensor is an interface to ATmega 328 pin 23. The circuit schematic and circuit layout is designed in eagle PCB designing software to routing tracks automatically within given area. We have also interfaced Zig-Bee to the microcontroller for wireless communication. This circuit diagram shows many sections that are integrated on a single board mean we reduced the size. Microcontroller ATmega 328 is low cost, low power, and having many features on a single chip. Figures 4 and 5 show water and humidity sensor nodes. Figure 6 indicate, the coordinator window which displayed real time soil moisture analog data of WSN nodes.

Figure 4. Sensor node 1.

Figure 5. Sensor node 2.
7. Results
Analog data are displayed on the coordinator window read by the system and this received data could be shared with mobile and the internet. As per given conditions, programmed WSN system read data i.e. if analog value is greater than 900, then it is said to be dry soil, if a value greater than

| Sensor node 1 | Sensor node 2 |
|---------------|---------------|
| 425 (Water)   | 836 (Humid soil) |
| 429           | 878           |
| 424           | 871           |
| 428           | 864           |
| 430           | 857           |
| 422           | 860           |
| 431           | 861           |
| 430           | 866           |
| 426           | 864           |
| 425           | 862           |
| 423           | 863           |
| 424           | 861           |
500 and less than 900, then it is humid soil and if a value greater than 250 and less than 500, then it could be water. As per these conditions, both sensor nodes data from the coordinator window is shown in Table 1.

8. Conclusion
The proposed system is low cost and energy efficient to measure the soil salinity and moisture for grapes quality monitoring wirelessly. System performance is exceedingly superior for multiple sensor nodes across single coordinator and multiple routers. Such system we can use for several crop monitoring and their environment study as well as precision agriculture systems. The said system can build up within Indian currency Rs 2,500/node.

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