Crop Monitoring System To Maintain Proper Soil pH & Soil Water Content For Citrus Tree :A Review

Kushal M. Ghadge , Ram B. Alapure

***Abstract* —The goal of this paper is to review the crop monitoring system to maintain proper soil pH level and soil water content for citrus tree as citrus is grown in more than 140 countries. This paper aims to create crop monitoring system with soil moisture sensor and soil pH sensor based on Wireless Sensor Network (WSN) for precise irrigation and fertilizer supply to produce profuse Citrus crop production while diminishing cost and assisting farmers in real time data gathering. WSN in agriculture helps in distributed data collection and monitoring in harsh environments. There is a great need to modernize the conventional agricultural practices for the better productivity. Due to unplanned use of water, the ground water level is decreasing day by day and solubility of the fertilizers in irrigation water contains various chemical constituents some of which may interact with dissolved fertilizers with undesired effects which may leads to inferior quality of Citrus fruit production. Citrus which is largest grown fruit in world and third largest fruit crop grown in India, originates from the wet tropics in Southeast Asia. The large-scale commercial production is found in the subtropics under irrigation The most commonly cultivated citrus species in India are Citrus reticulata (mandarin), Citrus sinensis (sweet orange), Citrus aurantifolia (acid lime), Citrus aurantium (sour or Seville orange), Citrus grandis (pummelo, shaddock), Citrus limon (lemon), Citrus medica (citron), and Citrus paradisi (grapefruit).**

Index Terms—Soil pH, Soil Moisture, Citrus, ZigBee, Fertigation, Wireless Sensor Network (WSN), Graphical user interface (GUI),RISC(Reduced instruction set computing).

I. Introduction

Water quality is an important concern when injecting fertilizers though irrigation system to citrus trees. Water with high pH, magnesium and calcium levels may cause precipitation of phosphorus from the fertilizer. Water high in salts may not be suitable for injecting fertilizers through irrigation system since some nitrogen source such as ammonium nitrate or potassium chloride increase total dissolved solids in the irrigation water and may cause damage to trees. Citrus trees, particularly those on trifoliate or trifoliate-hybrid rootstocks, are salt sensitive. Hence it is necessary to maintain adequate soil pH and water content in soil [3].Citrus can grow well in wide range of soils. Soil Properties like soil reaction, soil fertility, drainage, free lime and salt concentrations, etc. are some important factors that determine the success of citrus plantation [4]. Citrus fruits flourish well on light soils with a good drainage. Deep soils with pH range of 5.5 to 7.5 are considered good. However, they can grow in pH range of 4 to 9. Presence of calcium carbonate concentration within feeding zone may adversely affect the growth. Light loam or heavier but well drained sub-soils appears to be ideal for citrus [4].

Citrus is grown in more than 26 states in India. The important states producing major citrus fruits in the country are given in Table 1[4].

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Kushal M. Ghadge, Department of Electronics and Telecommunication Engineering, Government College of Engineering, Aurangabad, Maharashtra,India.

Ram B. Alapure, Department of Electronics and Telecommunication Engineering, Government College of Engineering, Aurangabad, Maharashtra,India.

Table 1: States producing major citrus fruits in India

Type of Citrus Fruit	States	Varieties
Sweet orange	Punjab, Rajasthan, Uttar Pradesh	Pineapple, Jaffa, Hamlin, Valencia, Late Campbell Valencia
Mandarin	Maharashtra	Nagpur mandarin
	Madhya Pradesh, A.P., North Eastern region, Punjab, Rajasthan, U.P., West Bengal and Sikkim	Nagpur mandarin Khasi mandarin Kinnow, Nagpur mandarin and local Darjeeling mandarin
	Karnataka and Tamilnadu	Coorg mandarin
Acid lime	Andhra Pradesh, Rajasthan, Karnataka, Uttar Pradesh,Gujarat, Madhya Pradesh, Maharashtra	Kagzi lime, Indore seedling Baramasi, Kagzi lime
Lemon	Gujarat, Andhra Pradesh, U.P. Assam	Eureka Hill, Galgal Assam lemon
	Karnataka	Baramasi, Nepali oblong, Italian lemon, Lisbon lemon, Eureka lemon, Seville
Pummelo	Andhra Pradesh, Assam, NEH	Red fleshed, White fleshed

Source: National Horticulture Board, Horticulture Information Service-2010-2011.

II. REQUIREMENTS OF CITRUS CULTIVATION

a. Irrigation:

Citrus requires critical stage watering in the initial year. It further reduces fruit drop and increases the fruit size. Diseases like root rot and collar rot occur in flooded conditions. Light irrigation with high frequency is beneficial. Irrigation water containing more than 1000 ppm salts is injurious. Quantity of water and frequency of irrigation depends on the soil texture and growth stage. A micro irrigation system not only saves water and nutrients but also ensure good retention of fruits during crucial stages of crop growth in March – April even in situations where water is not a limitation [4].

b. Fertilizer injection (fertigation) methods:

Application of fertilizers through irrigation system is referred to a 'fertigation'. Fertigation through micro irrigation system provides a technique of application of water and nutrients to an area of the soil where most of the roots are present to coincide with the timing of nutrient requirement by the trees. Therefore, fertigation is expected to increase the nutrient uptake efficiency [5].Fertigation is the application of soluble fertilizers through micro-irrigation systems which has been used in citrus production since the 1960s.Currently fertigation is being used in many citrus growing regions including Israel, the Mediterranean region, South Africa, and the United States. Nevertheless, many regions in our country still use dry fertilizers due to tradition, lack of fertigation equipment, technique, uneven topography or poor quality irrigation water. The objective of this paper is to discuss fertigation, advantages and disadvantages of fertigation, methods of fertigation, fertigation in citrus production based on research and observations from citrus growing regions in India [3].

Advantages of citrus fertigation-

There are several advantages of using fertigation over conventional dry application of fertilizers. Nutrients are already in soluble form when applied and are thus potentially more available for uptake by the tree than dry materials. Moreover, the soil concentration of nutrients can be maintained within specific ranges throughout the year. Fertigation systems are easily automated and provide an effective delivery system for water and fertilizer [3].

Minimizing leaching losses compared with the application of fertilizer in dry granular form broadcast over a large soil area at less frequent intervals. In addition to the tree response, fruit yield and quality, the changes in groundwater nitrate concentrations impacted by the different fertilizer deliverymethods [5].

Disadvantages of citrus fertigation-

Irrigation water contains various chemical constituents some of which may interact with dissolved fertilizersWith undesired effects. The degree of acidity of the fertilizer solution has to be considered.

c. Significance of soil pH :

Soil pH determines the nutrient availability to plants. Some nutrients become 'tied up' in the soil at certain pH levels. For example, acid soils can lead to deficiencies of phosphorus, calcium, magnesium and molybdenum, as well as toxic levels of manganese and aluminum. Alkaline soils may lead to deficiencies in iron, manganese, boron, copper and zinc [6].

Therefore to keep the soil pH around 5.5 to 7.5 to avoid certain nutrient deficiencies, which will weaken the plants and make them more vulnerable to pest and disease attacks. A common pH-related condition in the metropolitan area is 'Lime-induced chlorosis' which is an iron deficiency caused by high pH levels. It manifests as yellow-white leaves on plants growing in limestone-based coastal sands. This condition is rectified by applying iron sulphate, which will also drop the soil pH [6].

d. Significance of Watering :

Water is the basic component of plant cell tissue. It is water, above all, which controls the growth and development of citrus trees. Most of the water absorbed by the plant comes from the soil. Nutrients present in the soil are dissolved in water, taken up by the tree, and supplied to all parts of plant through translocation. Water is needed by the plant for transpiration. An adequate water supply during the growth stage has a significant influence on plant development, fruit quality and yield. In most citrus-growing areas, rainfall is unevenly distributed at different parts of the year, with marked dry and wet seasons. To stabilize fruit production and quality, it is necessary to supply adequate irrigation in the dry season, and proper drainage during the wet season. It is important to provide the right amount of water and fertilizers at different growth stages not only enhances the growth of citrus trees, but also improves yield and fruit quality [2].

Strong and healthy plants which get sufficient water, nutrition and sunlight, will build up a natural resistance against pests and diseases .Like soil pH, soil moisture content is too important for better yield, irrigation water at the right time and in the right amount for consistently high yields. Excessive water application reduces yields by carrying nitrates below depths of root penetration, and by displacing soil air for too long, causing a lack of oxygen to the roots. Water shortage also reduces yields. So it is important to check soil moisture to determine when to irrigate and how much water to apply [6].

e. Significance of Proper Soil Type :

Citrus plants are grown in a wide range of soils ranging from sandy loam or alluvial soils of north India to clay loam or deep clay loam or lateritic/acidic soils in the Deccan plateau and north-eastern hills. Citrus orchards flourish well in light soils with good drainage properties. Deep soils with pH range of 5.5 to 7.5 are considered ideal. However, they can also be grown in a pH range of 4.0 to 9.0. High calcium carbonate concentration in feeder root zone may adversely affect the growth [4].

Soil has physico-chemical as well as electrical properties. Spatial and temporal variability of soilphysical and chemical properties within a field are unavoidable. Color, texture, bulk density, nutrientsand pH can be defined as its physico-chemical properties while dielectric constant, electricalconductivity and permeability are electrical properties [7].

III. SYSTEM DEVELOPMENT

This system is based on soil identification which consists of Zigbee module for communications purpose. In order to produce more crops per drip, drip irrigation is used. Soil moisture sensor sense the moisture of soil and soil pH sensor will sense soil pH value. The output of the sensors is recorded by microcontroller and output is generated by microcontroller here in this project we are using MSP430 microcontroller. If the moisture content of soil is high then valve unit remains closed and if it is dry, then valve unit remained open as shown in figure 2. Other valve will control the tank of water soluble fertilizer for citrus. pH value of 5.5-7 is appropriate for better yield of citrus so if pH value for citrus is not appropriate then it will start fertigation tank which contain water soluble fertilizer. Also it will send both sensory data to remote terminal where GUI will be installed with full of control over entire system. GUI will show various sensory outputs. Microcontroller controls the operation of motor. Microcontroller sends this data to computer through ZIGBEE.As shown in figure 1.

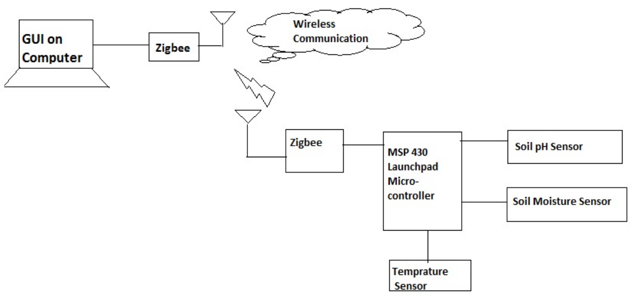

Figure 1: Block diagram of system

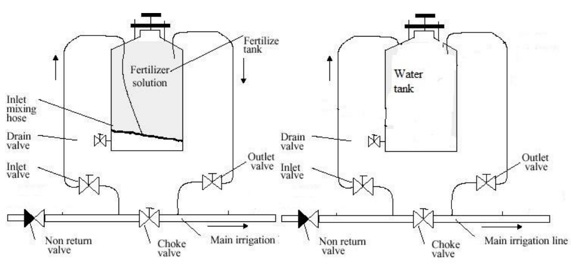

Figure 2: Fertigation Tanks

a. ZigBee Module For Wireless Communication:

Zigbee is a low cost, low power, wireless mesh network standard .Low power uses, allows longer life. Zigbee chip vendors typically cell integrated radios and microcontrollers with between 60 kb and 256 kb flash memory.

Zigbee technique is one of the new techniques in drip irrigation. It is real time feedback control system which monitors the moisture content of soil. This is a modernize technique which is used over a large agriculture land. Zigbee is one new technology that is used in agriculture sector as shown in figure 3.

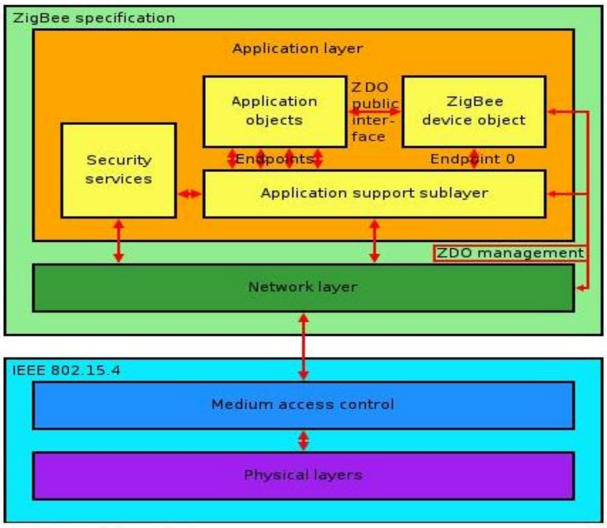

Figure 3: Architecture of ZIGBEE module

b. Using MSP430 as Microcontroller:

- MSP430 Modular Architecture

A 16-bit RISC CPU, peripherals and flexible clock system are combined by using a von-Neumann common memory address bus (MAB) and memory data bus (MDB). Partnering an optimized CPU with modular memory-mapped analog and digital peripherals, the MSP430 device offers solutions for today's and tomorrow's mixed-signal applications.

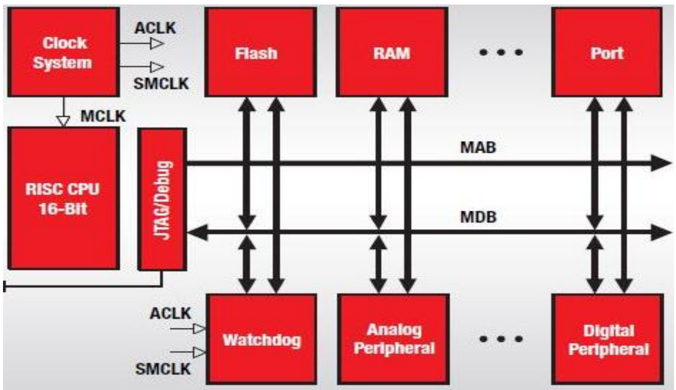

Figure 4: MSP430 von-Neumann architecture

- 16-Bit RISC CPU

The MSP430 MCU's orthogonal architecture provides the flexibility of 16 fully addressable, single-cycle 16-bit CPU registers and the power of a RISC. The modern design of the CPU offers versatility using only 27 easy-to-understand instructions and seven consistent addressing modes. This results in a 16-bit low-power CPU that has more effective processing, is smaller-sized, and more code-efficient than other 8-/16-bit microcontrollers. This will allow you to develop new ultra-low-power, high-performance applications at a fraction of the code size

- Ultra-Low-Power Performance

The MSP430 is designed specifically for ultra-low-power applications. A flexible clocking system, multiple operating modes and zero-power always on brown-out reset (BOR) are implemented to reduce power consumption and dramatically extend battery life. The MSP430 BOR function is always active in all low-power modes to ensure the most reliable performance possible. The MSP430 CPU architecture with 16 registers and 16-bit data and address buses minimize power consuming fetches to memory and a fast vectored-interrupt structure reduces the need for wasteful CPU software flag polling. Intelligent hardware peripheral features were also designed to allow tasks to be completed more efficiently independent of the CPU. Many MSP430 customers have developed battery-based products that will last for over 10-years from the original battery!

c. Soil Moisture Sensor

The sensor measures the dielectric constant of the soil in order to find its volumetric water content (VWC). It obtains volumetric water content by measuring the dielectric constant of the media through the utilization of frequency domain technology. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of volumetric water content.

The sensor shown in figure 5 has a low power requirement and very high resolution. This gives the ability to make many measurements (i.e. hourly) over a long period of time with minimal battery usage. In addition, the sensors incorporate a high frequency oscillation, which allows the sensor to accurately measure soil moisture in any soil with minimal salinity and textural effects.

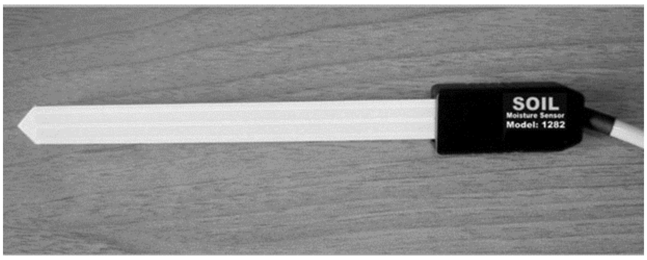

Figure 5: Soil Moisture Sensor

Specification of Soil Moisture Sensor:-

- Working Voltage: +5V
- Reading outputs every 100ms, very fast response time
  - Output Format: Serial Data at 9600 baud rate (8 bits data, No parity, 1 stop bits). Outputs four ASCII bytes per reading.
  - Dimensions: 18mm width x 160mm length of total sensor, sensing probe is 110mm long, wire length is 2 meters

d. Soil pH Sensor:

Soil pH measurement is useful because it is a predictor of various chemical activities within the soil andhence can be used as a rough indicator of nutrients in the soil [7].

Technical Specification:

- pH Range : 0.0 to 14.0 pH
- Temperature : 5 - 60 degree C
- Material : Epoxy, Gel Filled
- Connector : BNC

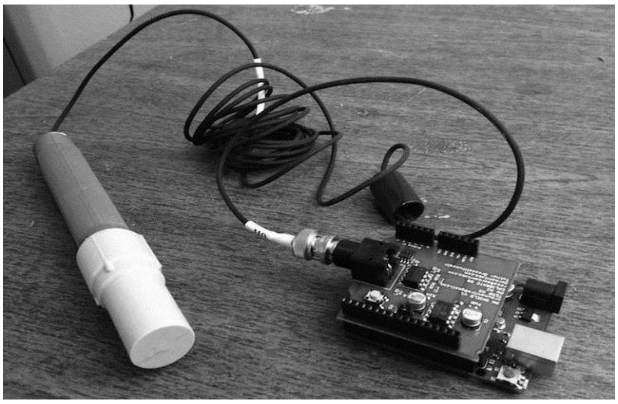

Figure 6: pH sensor probe with pH sensor shield.

– *Shield for interfacing pH probe with Microcontroller:*

Shield as shown in figure 6 that allows measuring PH with microcontroller. It has two point calibration and high accuracy. It uses pins A3 for temp, A2 for PH, Pin 8 for a button. The measurements it takes are available ambient temp compensated and without. In addition the user can read ambient temp from the onboard temp sensor.. Pin 8 can be freed for another use by removing the jumper pin.

IV. NUMBER OF SOIL MOISTURE SENSOR NEED PER FIELD.

Since every field has variations, at least 2 sets of sensors will need to be placed in a field. A set consists of 2 or 3 sensors placed near each other and buried at different depths within the field. The following is a general guide to help to decide how many sensors might be needed:

- Large field / single crop / flat field—two sets
- More than one crop—at least one set for each crop
- Soil type variation—a set for each soil type.
- Hills—one set each for hill-top, hill-side, and hill-bottom

The sensors must be buried at two or three different depths in order to provide data that represents soil moisture data within the changing crop root zone. Crop type and management style will determine installation depths for the sensors.

Soil moisture sensors should be placed at the driest location relative to the average of the soil moisture sensor controlled zone(s). These driest locations may include

- Areas with significant sun exposure
- Lot-specific high elevation points

Depth in the ground – Citrus tree has shallow root system. Sensor probes should be placed within the root zone, in contact with relatively undisturbed soil that is representative of the irrigated landscape area. Contact with disturbed soil with a higher (or lower) amount of void space will likely result in unrepresentative soil moisture content readings. However, if the soil in the entire landscape is disturbed (i.e., fill material is used to elevate and level a new construction site), a disturbed area would be representative.

The goal with choosing a depth for each sensor is to represent the soil where the majority of the plant's active roots are. Most of the active plant roots are nearer the surface where there is also evaporation water loss. Therefore, the soil nearest the surface will experience the most wetting and drying cycles. Sensors located in this area will help indicate when to irrigate. Deeper sensors will indicate the degree of soil water depletion and/or the depth of irrigation water penetration, or help give feedback on how much to irrigate.

V. MATHEMATICAL ANALYSIS FOR SOIL MOISTURE SENSOR PROBE

The soil moisture sensor measures the dielectric constant of soil in order to find its volumetric water content through the utilization of frequency domain technology.

Dielectric constant:

Dielectric constant is the ability to store charge. The dielectric constant of a material is, in general, complex and proportional to the electrical permittivity of the material and the permittivity of free space such that [8],

$$K=\frac{\varepsilon}{\varepsilon_0} \qquad (1)$$

$$\text{And } K=\varepsilon_r + i\varepsilon_i \qquad (2)$$

Where K is the dimensionless complex dielectric constant, ε is the electrical permittivity, ε_0 is the permittivity in free space, ε_r is the real component of the complex dielectric constant and ε_i is the imaginary component of the complex dielectric constant [8].Probe measures both ε_r and ε_i .

Effects of frequency dependent dielectric polarization and frequency independent electrical conductivity measurements are related following expression,

$$\varepsilon_i = \frac{\sigma}{\omega\varepsilon_0} \qquad (3)$$

Where σ is the electrical conductivity, ω is the angular frequency, another critical element is the loss tangent 'tan δ' is proportional to the energy dissipation experienced by the input voltage and defined as [8],

$$\tan\delta = \frac{\varepsilon_i}{\varepsilon_r} \qquad (4)$$

VI. CONCLUSION

This paper aims for developing automatic crop monitoring system for citrus plant using soil pH sensor and soil moisture sensor. Soil pH sensor determines soil's nutrients uptake efficiency, which measures indirectly soil fertility for citrus. Soil moisture sensor determines water content of soil which is more important factor to conserve water. In this paper automatic fertigation system using wireless sensor network using ZigBee technology is proposed. Both sensors will help to judge fertility and moisture content of soil respectively. This application of sensor-based fertigation system can be used for different crops but it is more important to analyze requirement of proper soil pH and soil moisture (water content) of that specific crop.

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Kushal M. Ghadge, ME Final Year Student in Department of Electronics and Telecommunication Engineering, Government College of Engineering ,Aurangabad, Maharashtra, India

Ram B. Alapure, ME Final Year Student in Department of Electronics and Telecommunication Engineering, Government College of Engineering, Aurangabad, and Maharashtra, India.