iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** IX **Month of publication:** September 2023

DOI: https://doi.org/10.22214/ijraset.2023.55819

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IX Sep 2023- Available at www.ijraset.com

Agriculture Based Mobile Applications by Using Automated Irrigation Sensor

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Abstract: Wireless sensor networks (WSNs) are one of the most rapidly developing information technologies and promise to have a variety of applications in Next Generation Networks (NGNs). The major goal of this technical paper is to give recent advances and state-of art results covering both fundamental principles and use cases of WSNs in NGNs. This technical paper presents design techniques and guidelines, overview of existing and emerging standards for the subject area, modeling principles for WSNs. The mobile App wakes-up the smartphone, activating the device with user-defined parameters. Then, the built-in camera takes a picture of the soil through an anti-reflective glass window and an RGB to gray process is achieved to estimate the ratio between wet and dry area of the image. After the Wi-Fi connection is enabled, the ratio is transmitted via a router node to a gateway for control an irrigation water pump. At the farm level, irrigation is generally scheduled based on the grower's experience or on the determination of soil water balance (weather-based method). An alternative approach entails the measurement of soil water status.

Keywords: Wireless sensor network (WSN), Global system for mobile communication (GSM), Short message service (SMS), Liquid crystal display (LCD), Dielectric soil moisture sensors.

I. INTRODUCTION

From the point of view of practical application, WSNs offer unique opportunities for monitoring and data collecting from a number of spatially distributed sensor nodes. In addition to providing distributed sensing of one or a few parameters of a big object like a building or open space, WSNs also allow to control the processes in the object. For example, WSN may be installed in a building for automatic control of load-bearing constructions' conditions. For this reason engineers determine the places on the building most appropriate for data measuring. In these places autonomous sensor nodes with necessary sensing elements are installed. After installation they start to interact and exchange data. Receiving these data from the sensor nodes and comparing measurement data from each of the sensor node with its position, building structure specialists can in real time mode supervise, control and predict emergency situations. Consequently, improving irrigation water use efficiency (i.e., the ratio between applied water and crop yield) is decisive to satisfy the increased world demand for food and other agricultural products. This objective may be accomplished by cultivating more water-efficient crops (as developed by means of conventional or recombinant DNA-based breeding) and/or through the application of efficient irrigation technology. Despite the efforts made in recent years, irrigation efficiency (i.e., the amount of water stored in the crop root zone compared to the amount of applied water) is still unsatisfactory (less than 40%) and its improvement is a key goal for the future. Irrigation efficiency depends on the type of irrigation used (for instance, surface irrigation wastes much more water than pressurized overhead or drip irrigation) and on irrigation scheduling, which is the method used to determine the amount of water to be applied to a crop and the timing for application. Since it determines the crop's water use and influences its yield, irrigation scheduling has a remarkable effect on water use efficiency. Irrigation scheduling is crucial in intensive agriculture, since under-irrigation generally results in reduced crop yield and quality. On the other hand, over-irrigation increases the nutrient requirements of the crop and its vulnerability to diseases, the energy costs for water pumping, water loss and environmental pollution due to the leaching of nutrients applied to the crop with conventional fertilization or fustigation (the technique of supplying fertilizers dissolved in the irrigation water. The goal of an efficient irrigation program is to supply the crop with enough water while minimizing water waste due to deep percolation and runoff. Different approaches to irrigation scheduling have been developed, each having both advantages and disadvantages. Innovative methods based on the direct monitoring of plant water relations have been also proposed for irrigation scheduling.

Although some companies have designed irrigation control devices exploiting micro-measurements of stem diameter, leaf thickness or stem sap flow, plant-based irrigation management is still in the research or development state and is scarcely employed commercial operations.

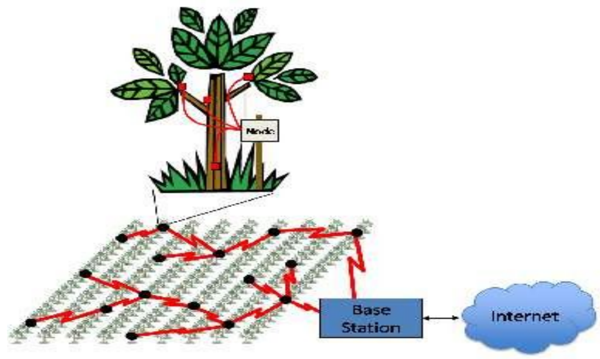

Fig-1 Base station connection with internet

The most widespread irrigation scheduling method is based on the determination of soil-water balance, which implies the estimation of crop evapotranspiration (ETC). The latter need regular updating by the farmer for each crop type and growing stage. One rather new approach is to obtain crop coefficients with satellite based radiation images, rather than by using Access to the satellite data has become much easier and faster due to recent development with web-based access and due to improvements of sensor spatial resolution and accuracy. The other approach to irrigation scheduling entails the use of root zone sensor (RZS) to obtain soil moisture status and to replenish the water in growing medium to a preset level. In principle, this method by-passes the need to calculate ETC and works for any crop, as long as the set-points for the irrigation controller are correctly chosen. So far, applications of RZS for irrigation management have been less common than those of the water balance method, but novel types of RZS, which are based on the measurement of soil dielectric properties, have opened new possibilities for irrigation scheduling and nowadays, after the doubts originated from the first attempts with gypsum blocks, the irrigation industry worldwide has recognized that RZS' are valuable tools for modern smart water application technology in intensive agriculture. In this review, the main features of RZS' (for both soil moisture and salinity) designed to be connected to irrigation controller for commercial cultivations are identified and discussed.

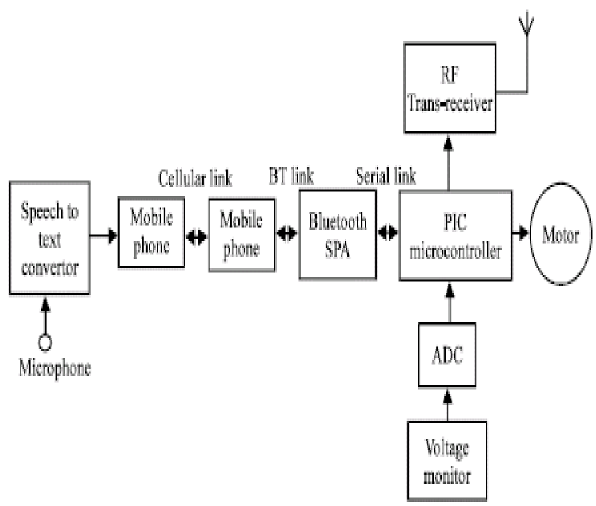

Fig-2 Flow Diagram

The paper is based on classical and more recent literature on soil moisture sensing technology and its application to irrigation scheduling. The findings, also unpublished, of our recent experimental works conducted in the framework of national or international projects (see Acknowledgements) have been considered. These works concern mostly the outdoor cultivation of pot ornamentals, which is an important horticultural sector in Italy. The main area for this kind of cultivation is located in Tuscany, around the town of Pistoia, definitely the most important centre in Europe for landscaping ornamentals [7]. In this area, nearly 1,400 ha, of approx. 4,500 ha of nurseries, are used for growing pot ornamentals, with an estimated yearly consumption of irrigation water (mostly, low salinity groundwater) of more than 10,000,000 m3 /year [8].

The low cost of water has not led to a more efficient approach to water management. On the other hand, current legislation on water resources and the competition for water among agriculture, urban population and industries will affect the future development of "green industry" in this area, stimulating the search for more efficient solutions. Therefore, the design of a sustainable irrigation management system is one of the goals of RTD activities conducted by both public and private territorial entities (regional extension office, growers associations etc.) The paper is agriculture-oriented and then it considers only those sensors that can be implemented in irrigation controllers, such as traditional water-filled tensiometers and the more recent dielectric sensors. Expensive and sophisticated RZS' currently used by soil and plant scientists, such as neutron probes, are not addressed. The paper also discusses how these sensors may be integrated into wireless networks for computer-controlled irrigation and employed for the application of innovative irrigation strategies, such as deficit or dual-water (alternate use of different water sources) irrigation.

II. SOIL HYDRAULIC CHARACTERISTICS

Apart from the direct measurement of water content by thermo-gravimetric methods, soil moisture m) of pore water or theψconditions can be assessed by the determination of the matric potential ( ), which is the volume of water in a certain volume of undisturbed soil.θvolumetric water content (Recently, some sensors have been developed also to measure the soil salinity (namely, electrical conductivity o EC), as discussed later. m describes the amount of energy which must be exerted to extract water from a porousψThe term m corresponds to the suction required for theψmedium such as soil or soilless substrate. Therefore, water uptake by the plant roots. Moisture tension represents the degree of such suction and, according to the terminology used in crop irrigation management, it is a positive number; the higher the number, (also called waterθm and ψthe higher is the tension and the drier is the soil. The relationship between retention curve) depends on the nature of growing media and in some cases this relationship is not unique being different in drying and wetting cycle, in particular in fine-textured soils. Conventionally, the water retention curve may allow computation of a few parameters that, along with porosity and bulk density, are used to describe the water relations of a given soil sample. Field FC) is the water content in soil after it has been saturated (all pores are filled with water) andθcapacity is theθallowed to drain freely till the downward movement of water is terminated; wilting point (at θWP is the bulk θFC and θminimal moisture the plant requires not to wilt.

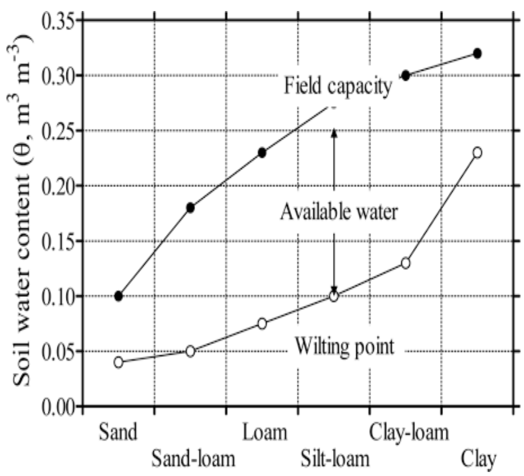

Fig-3 Soil Water Level Graph

The physical definition of m of -33 or -1,500 kPa, respectively. The limitation of these determinations is evident, sinceψ WP. Nevertheless, theseθFC and θmany factors, also related to the plant, affect the actual values of parameters serve as a practical measure of soil water holding capacity, also called available water.

III. SOIL MOISTURE SENSING TECHNOLOGY

A. Tensiometers

Tensiometer is a kind of artificial root that measures consists of a shaft filled with (distilled) degassed water with a porous ceramic cup at the end and a dial vacuum gauge or a pressure transducer at the top. The shaft is generally made of plastic due its low heat conduction and high resistance to corrosion.

The ceramic cup has small air entry potentials in order to prevent de-saturation when subjected to negative potentials. The transducer can be connected to a data-logger for long-term monitoring, to a hand-held meter for spot measurements or to an irrigation controller. The tensiometer is buried at the desired depth in the rooting zone with the ceramic tip in close contact with the soil particles. The water in the tensiometer reaches equilibrium with the surrounding soil through the ceramic tip. When water is pulled out through the ceramic tip by drying soil, a tension is originated in the tube; when the soil is re-watered, the decrease in water potential gradient causes a reverse flow of water. As the soil goes through drying and wetting cycles as a result of ETC and watering (by irrigation or rainfall), tension readings can be taken. The porosity of the ceramic tip influences the velocity of water flow from and into the instrument. When used in very dry conditions, the ceramic must be very fine and this slows down the tensiometer reaction to the changes m. Obviously, the responsiveness of tensiometers to soil moisture conditions determines theψin soil field of application. For instance, in container cultivation the irrigation lasts generally a few minutes instead of one or more hours as in soil culture; therefore, a quick response is required, especially when tensiometer is used to determine both the time and the duration of watering. Moreover, they must be protected from frost and need regular maintenance, for instance to refill the water in the tube and to avoid the contamination by algae. Suitable hand-held vacuum pumps are generally supplied by tensiometer manufacturers to recharge tensiometers in situ.

IV. CONCLUSION

A developed smartphone irrigation sensor complied with the conceived concept of an optically triggered automated irrigation using a soil imaging process. Due to rapid growth of smartphone appliances at affordable prices, this App represented a simple and practical implementation. The sensor installation in the field can be done simultaneously with the preparation of the cultivation beds and irrigation tubes, so there is no significant additional labor, nevertheless compared with traditional sensors, the installation in the field requires more effort and time.

The irrigation sensor has an inherent advantage over other kind of soil moisture sensors for irrigation purposes. The outcome of others depends of soil characteristics like: density, compaction, gravimetry or mixture of their components among others. The irrigation sensor is of non-contact type, requiring only an in situ calibration to acquire the dynamic range for any soil type. This is performed using a dry soil image and water saturated. This procedure may represent a disadvantage respect to other kind of sensors.

The irrigation sensor is a low power consumption standalone device that can be maintained operative with a small solar panel and rechargeable batteries in order to operate for the whole cultivation period, without the usage of cables or external wired connections.

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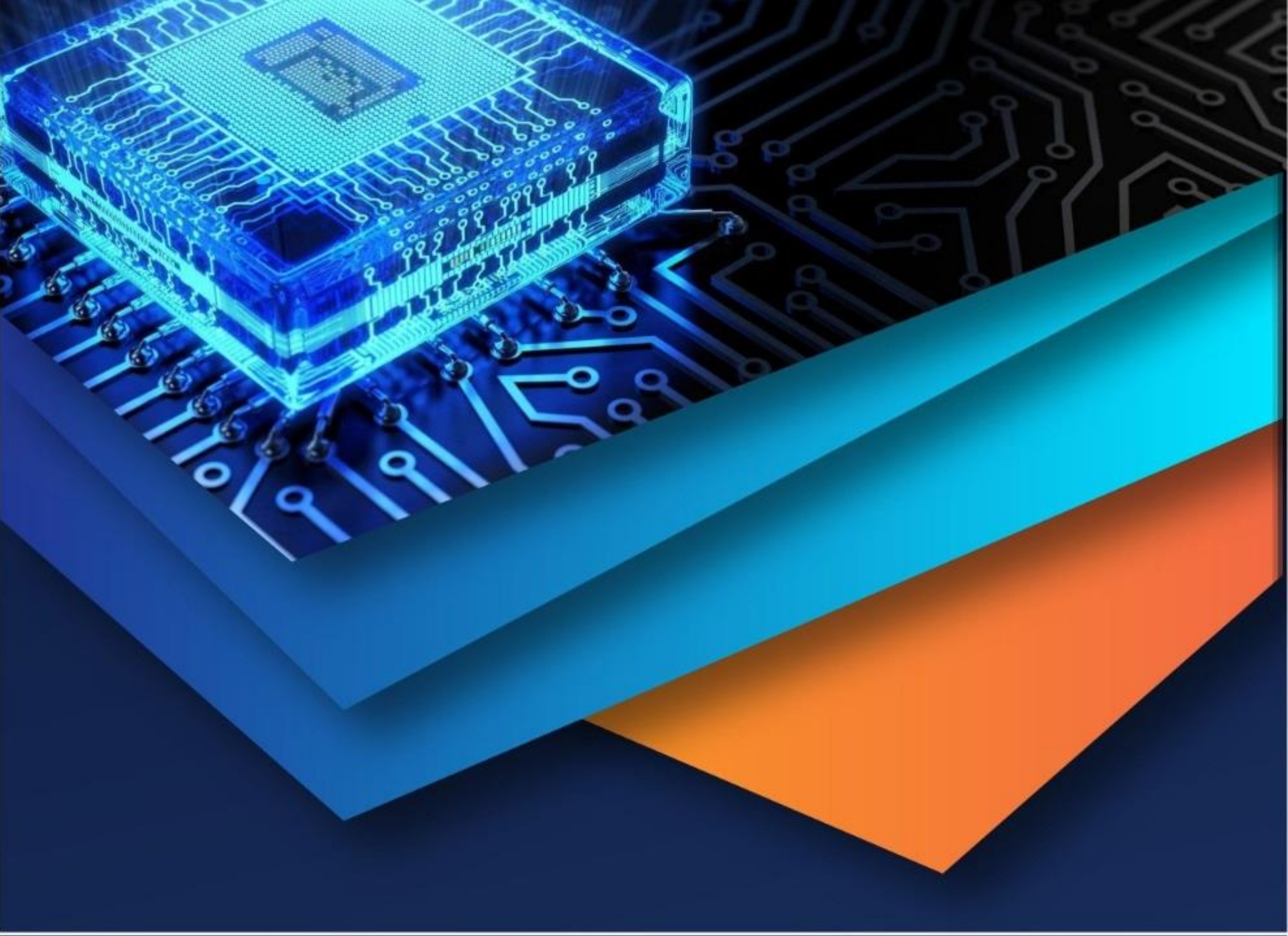

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