Application of Wireless Sensor Networks with GIS on the Soil Moisture Distribution Mapping

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Abstract

The development of microelectronics began in 1948 and continued with the miniaturisation of sensors during the last ten years. Today, microsystems which are used in silicon microtechnology are called microelectromechanical systems (MEMS). Microsensors are defined as very small sized devices that convert humidity, moisture, temperature, pressure, pollutants, light intensity, etc. into electrical signal. Integration of MEMS with the radio frequency wireless communication technique put forward low power consuming, cheap and communicating small devices called wireless sensor networks (WSN). WSN have spatially distributed transceivers with microsensors that give the possibility of monitoring and collecting data easily and quickly. Nowadays, these devices are used in many different application areas like home automation, forest fire monitoring, traffic control, noise and pollutant detection in the crowded areas.

Classical definition of Geographic Information Systems (GIS), which is known by everybody is a computer based system that collects, stores, edits, analyses and displays spatial data. GIS is a powerful tool to access, analyse and evaluate large amounts of spatial data. The total time to get the results is a strategic part of the study. GIS is very efficient for reaching the correct conclusion in a fraction of time. WSN provides huge amount of data. If it would be possible to integrate the power of WSN with GIS, the data can be obtained in a very short time and the evaluation time can be decreased.

In this study, integration of WSN with GIS is used for preparation of the soil moisture distribution map of the studied area. Wireless devices with moisture sensed sensors are located at predetermined locations. Geographic coordinates of these points are obtained with GPS. The sensed data is collected by using WSN and evaluated by using GIS. Finally, moisture distribution map of the soil is prepared. We claim that the irrigation of the soil can be done more efficiently by using this prepared map. Moreover, dry situation can be alarmed with this system and adaquate irrigation can be done just on time.

In the following section, we briefly introduce wireless sensor networks. In Section 3, and Section 4 we describe the application of WSN for agricultural studies and the integration of WSN and GIS for agricultural fields, respectively. Finally, in Section 5, we conclude the paper with our recommendations.

Keywords: wireless sensor networks, geographic information systems, soil moisture mapping

1 Introduction

During the last decades, growth of the earth population has created many environmental problems. Nowadays, the human beings are faced with many serious environmental problems. One of the crucial problems is the climate change. Climate change influences the human beings directly and indirectly. Global warming (which is a result of the climate change) affects the agricultural fields by causing a decrease in the water supplies. As a result of this water shortage, inadequate irrigation decreases the quality and quantity of the products.

The Water Poverty Index (WPI) was developed by a team of researchers, practitioners and stakeholders (led by CEH) to help determining priorities for action and monitoring progress towards targets. Turkey, which we live in, is “water poor” according to WPI. Lower scores indicate water scarcity and poor water provision. Turkey has 57 points over 100 as of the observations in 2002.

Technological developments in the electronic fields like the other application areas tend to apply these new technologies to prevent these natural disasters. Data collection, sending the data to the needed point and analyzing has been the most popular and classical studies for the last decades (especially for the earth scientists) to prevent a possible natural disaster. We note that data collection is the most time consuming and expensive part of these kind studies. Hence, wireless sensors and wireless sensor networks are the most popular and appropriate devices and methodology for these studies.

Decision making is becoming increasingly complex as dwindling natural resources and more demanding economical priorities diminish the chances of today’s decision being right tomorrow Despite many comprehensive studies, the global environment is still not well understood, because nature is very complex [1]. It needs to use new technologies and new methodologies. Wireless sensor networks are used for detection of soil moisture content of the soil. The data are transferred to the computer and soil moisture map of the area have prepared by using Geographical Information Systems (GIS) techniques. It is known that huge amount of spatial data can be evaluated by using the advantages of GIS. It’s seen from the prepared map, the soil moisture content can change even from very close distance.

In our study, wireless sensor networks are used for detection of soil moisture content of the soil. The data collected by the sensors is transferred to the computer (in a hop by hop fashion) and soil moisture map of the area is prepared by using GIS techniques. We could easily evaluate huge amount of spatial data can be by using the advantages of GIS. We observed from the prepared map that the soil moisture content changes even from very close distance.

It is understood and recommended that if the farmers can establish these kinds of systems their quality and quantity of their harvesting products would be increased.

2 Wireless Sensor Networks (WSN)

A **wireless sensor network** (WSN) is a wireless network consisting of spatially distributed devices integrated with sensors to cooperatively monitor physical or environmental conditions, such as temperature, pressure, humidity, vibration, motion or pollutants at different locations [8]. Each wireless device is also called a node that behaves individually. Each node has one or more sensors integrated on it. In addition to these sensors, a node is also equipped with a transmitter and a receiver. These transmitter and receiver are used for wireless communications with other nodes or directly with the gateway. The gateway is responsible for transmitting sensor data from the sensor patch to the remote base station that provides wireless ad-hoc network (WAN) connectivity and data logging through a local transit network. Finally, the data is available to scientists through a user interface [5]. The other parts of a sensor node are the microcontroller and the battery (as the energy source) (Fig.1).

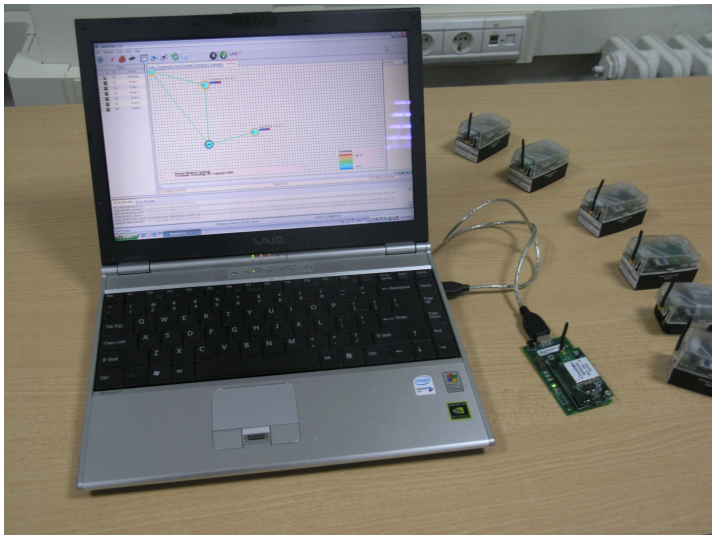

Fig. 1. Wireless sensor sensors (on the right), gateway and computer

The size of a node can vary from a cigarette package size to one Euro coin size. A sensor network normally constitutes a wireless ad-hoc network, meaning that each sensor supports a multi-hop routing algorithm (several nodes may forward data packets to the base station).

Wireless sensor networks can used in many different fields. When these small, tiny and low power consuming devices deployed in areas of interest, each individual node collects data about its immediate surroundings. Especially the increasing environmental problems during the last decades made it crucial to collect data from different areas and to analyze and evaluate them as quick as possible.

3 Application of WSN for Agricultural Studies

As it is mentioned in Section 1, due to atmospheric pollution, climate change and global warming, there is a serious shortage of unpolluted water for irrigation. It is known that, irrigation is directly proportional to the harvesting plant quality and quantity. Information on the temporal and spatial variability of environmental parameters, their impact on soil, crop, pests, diseases and other components of farming play a major role in formulating the farmer's strategy [6]. If the farmer knows the correct irrigation schedule for the plant, he can use less water and less energy while getting a high amount of harvesting which is the most desired scenario for a farmer in a farming season.

In this study, we used WSN technology for detection of soil moisture by monitoring a pilot area. The pilot area is selected as close as possible to the city of Eskişehir. Eskişehir is the sixth biggest city of Turkey and belongs to the Central Anatolia region (Fig.2).

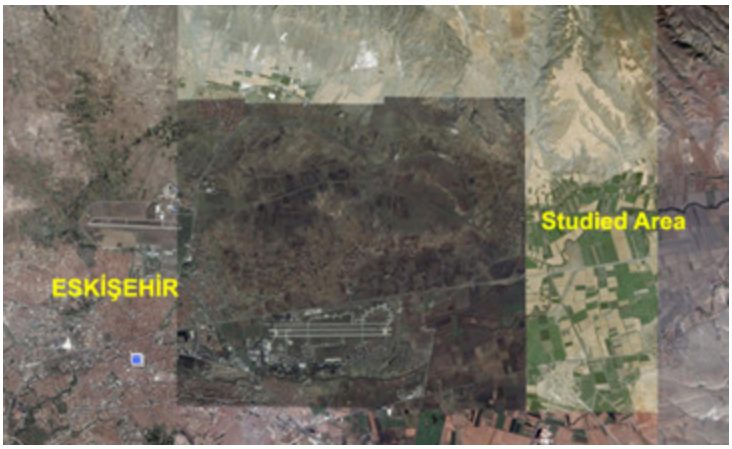

Fig.2. Location of the studied area (from Google Map).

The climate is cold in winter and hot in summer. Generally, wheat and sugar plant is harvested at and around the pilot area (Fig. 3).

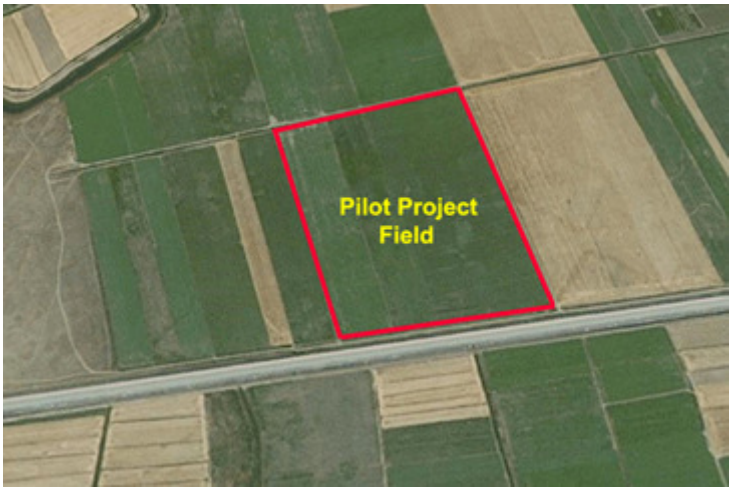

Fig. 3. Location of the pilot project harvesting field (from Google Map).

The main road is located on the south and one of the main water irrigation canals is located on the north side of the field. The soil profile of the field is generally clayey-silt. The more precise soil analyze should be done after the pilot project for the real application.

Crossbow's wireless sensor network system is used for this study [2]. MICAz type modules are used. These modules work on the global 2.4 GHz ISM band with support for IEEE802.15.4/ZigBee. All modules include a fully programmable microcontroller, a two-way ISM band radio transceiver, and a flash memory for over-the-air-programming and data logging of up to 100,000 measurements [2].

Capacitance type soil moisture probes area used in this study. Capacitance probes area a fast, safe and relatively inexpensive means of measuring the relative permittivity of soils, which can be used to estimate soil water content [7]. VGA-400 soil moisture sensor has been chosen since the probe measures the dielectric constant of the soil using transmission line techniques, it is insensitive to water salinity, and it does not corrode over time as does the conductivity based probes [9]. Probes are small, rugged, and consume under a milliamp of power.

4 Integration of WSN and GIS for Agricultural Fields

Classical definition of Geographic Information Systems (GIS), which is known by everybody, is an organized collection of hardware, software and geographic data designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information [3]. GIS as a powerful tool for access, analyze and evaluate large amount of spatial data. The GIS greatly increases the productivity of employees who collect, manage, analyze and distribute land data [4]. The total time of getting the result is a strategic part of the study. GIS is very efficient for reaching the correct conclusion in a fraction of time. WSN provides huge amount of data. If it would be possible to integrate the power of WSN with GIS, the data will be obtained in a very short time and the evaluation time will be decreased.

In our study, wireless sensor network is deployed to the selected sugar plant field. The soil moisture sensor probes are jointed to the wireless sensors. Then, the sensors are deployed to specific locations. The soil property of the field is taken into consideration during the deployment. It is known that, if the soil size changes from silt to sand the moisture content of the plant needed for irrigation also changes. Hence, the locations of the sensors are selected based on this information. The batteries are installed to each sensors and it is verified that each nodes are connected to the gateway.

The spatial location of each sensor must be known for the integration of data with the Geographic Information System. X and Y coordinates of each sensor is collected by using a GPS. These location data is used during GIS studies. After all the devices are set, we waited for about half an hour, and observed that GIS software analyzes the data collected by the sensors.

Analyze result indicates that the moisture percentage in the soil is between 28 % and 86 %. It is understood that the NE side of the field is oversaturated (red colored region) but the middle and the W side of the field is under saturated (blue colored region) according to water content (Fig. 4). This result was created by using GIS techniques. We note that the preparation of soil moisture map like this is very easy by using GIS functions. Evaluation can be done quickly and the irrigation of the dry part of the field can be done immediately. This increases the production quality of the plant and the production amount increases according to this new technique.

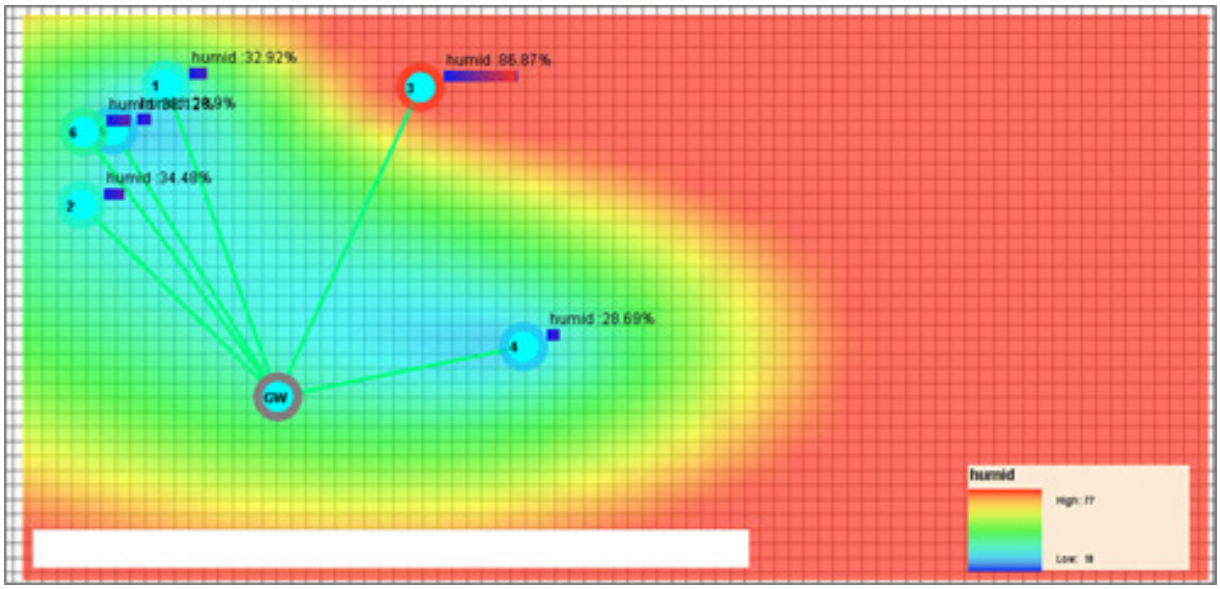

Fig.4. The moisture content distribution map of the selected field.

5 Results and Recommendations

At the end, it's understood that wireless sensor network technique is available for agricultural fields and these devices are powerful tool for data collection.

Integration of these sensors with the wireless communication technique put forward low power consuming, cheap and easy installed techniques for prepare an accurate schedule plan for irrigation.

Integration of wireless sensor network with geographic information system creates an easy and quick map by using huge amount of data.

Application of this technique for agricultural area would control the irrigation schedule and only this item would increase the production quality of the plant and the production amount.

It's recommended that, this pilot project must be extending for different plant types and different soil types in the same region. The same procedure must be applied to different climatic region and the results must be compared due to general application.

It's believed that, application of this new technology to agricultural area would decrease the amount of water used and increasing the quality and quantity of plant would positively affect the economy.

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