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Cloud based Smart Irrigation for Agricultural Area of Pakistan

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ABSTRACT

A beneficial product of Smart Irrigation for Agricultural Area of Pakistan has been presented in this paper. Pakistan stands in need of a participatory solution that is efficiently workable, sustainable, and profitable, to develop the way for the agricultural sector by improving crop productivity with minimum water loss. The goal of this project is to introduce Cloud support to the Smart Irrigation System for Agricultural Area of Pakistan. To achieve this objective Wireless Sensor Network (WSN) is used to determine how much water to apply and when to irrigate. The system is divided into four main modules, i.e. Sensor node, Coordinator node, Server Module and Web Application. On the basis of acquired parameters from the WSN, the software application is programmed to take intelligent decisions increase the efficiency of the agricultural system.

Keywords: Water resources management, Cloud, Smart Irrigation, Wireless Sensor Network, Web Application.

1. INTRODUCTION

Agriculture is one of major source of income for Pakistan. The country’s economy highly depends on it. Agriculture accounts to be a major source of development. There has been a lot of research in this area, which could greatly improve the crop productivity [1]. Keeping in front the agricultural problems faced by our country in which water deficiency is the most prominent one, decision have been taken to develop a smart irrigation system that can achieve water conservation up to 40%.

Nowadays, there are different approaches for solutions that are being used to improve crop production. For enhancing crop production we need to monitor the crops constantly using sensors. Wireless Sensor Network in agriculture is showing progress [2]-[5]. WSNs provide possibilities to gather sensors data and information, regarding the environmental and crop condition. One of the application areas of WSN is Smart irrigation. A smart irrigation method is where the amount of inputs (like seed, fertilizer, pesticides, water etc.) given to a specific farm field is important to control and monitor the condition of the farm. It helps to determine the amount of the crop output.

A system [6] is deployed using a ZigBee network. It consists of soil moisture and temperature sensors. A microcontroller based gateway is used for controlling the water quantity. It transmits data to the Web server. The researchers [7] also conduct a simulation work using various sensors. The sink node is responsible for aggregating and sending data through internet to the control center where the information is processed. A mathematical calculations based irrigation management system has been proposed [8]. The system is using wireless sensor technology for monitoring potato crops to improve their production. In a research paper [9] monitoring of agriculture is described which consists of several XBee sensors and a microcontroller. The data is first interfaced to the computer by using UART which is a serial protocol then analyzed and monitor by using a FPGA element. Certain unnecessary events may occur in irrigation process, to avoid this kind of events an automatic irrigation system has proposed [10]. It is using a timer that is triggered when a threshold is reached. The gathered data facilitates the farmer to schedule the process of irrigation. In a proposed system [11] sensors are placed in the field where it converts moisture content into equivalent voltage. The reference voltage can be set by the farmer. The difference between these two voltages is directly proportional to the amount of water needed for irrigation. The application [12] deals with combating with a fungal disease in potatoes. The data is gathered at a field gateway and then transferred to a PC for data logging through Wi-Fi. Smart irrigation [13] can also use the smartphone technology to manage urban and agricultural irrigation. SoilNet [14] focuses on real time monitoring and estimation of soil water content. It belongs to Underground ZigBee WSN. Coordinator, Router and End device are the main three devices in WSN. It has used hybrid topology to provide transmission on wider range. WaterBee [15] is a smart water management system. It consists of a web driven WSN that is centrally monitored through a server. A web service analyzes and models the data. A system has proposed [16]. The system consists of various agents to gather information. In that way this system provides flexibility allowing to dynamically adapting the agent behaviors. It enables the system to deal with dynamic problems ultimately ensures a better adaptability to its environment. A system [17] consists of a microcontroller, ZigBee WSN, a weather station and several wireless actuators. The wireless sensor node collects temperature and humidity data, transmits it to the controller wirelessly. The actuator nodes are used to control the electromagnetic valves and pumps. The coordinator assigns network addresses and collects the sensor data for processing on the basis of which intelligent decisions are taken. Reference [18] validates a setup of ZigBee WSN. The sensors are powered through solar panels. They also measure the water level in canals.

In this paper, the development and deployment of the first prototype of Cloud based Smart Irrigation is presented. It consists of WSN, ZigBee transceivers, Microcontroller, Raspberry Pi and GPRS packet transmission. The purpose of this project is to make this system so reliable, efficient, accurate, and user friendly for the farmers of Pakistan. The System aims to design and implement an irrigation system for fields in Pakistan that is more efficient in water usage. It also aims to educate clients about their specific irrigation needs and allow them to take advantage of the latest technological innovations available. Ultimately, this system helps the farmer to cultivate healthy crops without stress. In this way, it adds some flexibility to the farmer’s schedule strengthens the plants and helps to maintain good productivity. The development of Cloud based Smart Irrigation is conducted to use sensors information. A WSN has developed that employs different sensors to acquire various parameters such as water flow, soil moisture, temperature, pH, humidity etc. Server Node receives the data from WSN nodes through ZigBee technology and the processing module takes the decision if there is a need of watering the crops. The pumps are switched ON/OFF as and when necessary. The

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gathered information is uploaded into the smart web application through internet. The data is analyzed by the Application. The software application also has capability to send smart notifications to the farmer on his mobile phone. The user is also updated about the water level in farms and can manually control the irrigation system too.

2. ARCHITECTURAL ANALYSIS AND DESIGN METHOLOGY

2.1. HARDWARE ORGANIZATION

The Cloud based Irrigation System presented here, consists of four main modules. These modules include Wireless Sensor Units (WSUs), Wireless Coordinator Node (WCN), Wireless Server Module (WSM) and Remote Site (FIGURE. 1). The Wireless Sensor Network is linked by ZigBee transceivers. The transceivers make the nodes wireless so that they have the ability to transfer sensor's data and other status parameters wirelessly. The main server node has a LAN connection through which it sends the entire gathered information from the field to the Web Application through internet. The information is stored and analyzed at the software side. The application is providing graphical views and generating various reports. The intended user can also view the farms information online through internet access.

2.1.1. WIRELESS SENSOR NETWORK (WSN)

WSN introduces new capabilities for measurement and control applications. It consists of different wireless nodes. These nodes are spread in a particular environment to monitor certain parameters (i.e. collect and route data). The concept of WSN can be defined by the Equation (1):

$$\text{Sense} + \text{Process} + \text{RF} = \text{Thousands of Applications} \quad (1)$$

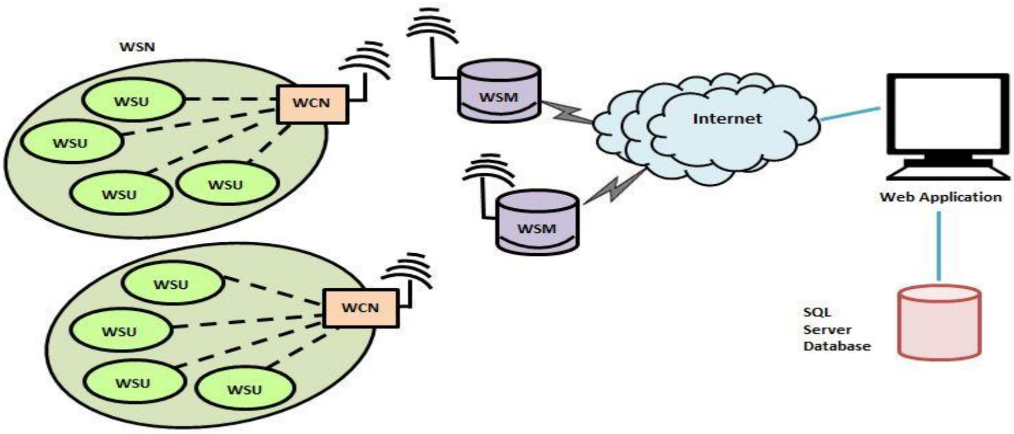

FIGURE.1 Architecture of Cloud based Smart Irrigation System

The WSN developed in the system used ZigBee technology. It is defined by IEEE 802.15.4 standard for personal area network. In WSN, various sensors are interfaced with each node. They required battery to sustain at a remote location. Therefore the key features required in WSN are low power and low cost. ZigBee technology supports these features as compare to other wireless technologies like Bluetooth (802.15.1 standard) and WiFi (801.11b standard). The transmission range of ZigBee is 1000-1500m. It can support 65,000 nodes in a network while other technologies can't support such a big number of nodes. In short, ZigBee is more scalable, flexible, reliable, and fewer complexes as other wireless protocols. The only limitation while using ZigBee is its low data rates (250 kbps). In WSN the data transmissions do not require high bandwidth. Therefore, ZigBee is the best suited technology to be used in this application.

2.1.1.1.WIRELESS SENSOR UNIT (WSU)

Wireless Sensor Unit is one of the most salient components of the deployed system. Each unit incorporates power source, microcontroller, sensors and RF transceiver. A variety of sensors have been used. They include water flow sensor, humidity sensor, Hygrometer (soil moisture sensor), external and internal temperature sensor. All these sensors are providing the data about the field. This information is used to take further agricultural intelligent decisions. All the sensors are interfaced with the high performance, low power Arduino UNO controller, ATmega168. The pins of the controller are interfaced with sensors and XBee, through the serial port. A separate board for providing the sensors power has been created. A 13V Lithium battery is used to provide the voltage. It is regulated by a 78H05K regulator to maintain the voltage at 5V for Arduino which then further lowers the voltage to 3.3V for XBee. Moisture sensors provide analog values to be read by Arduino. They range from 0 to 1023, from wet to dry. The microcontroller is programmed to receive data parameters from these sensors and organized the entire data in the form of a packet. The data is then transmitted serially through ZigBee transceiver. XBee series 1 has used in sensor node. Encryption and checksum/CRC techniques are also introduced in the ZigBee transceiver to make data secure and error free.

2.1.1.2. WIRELESS COORDINATOR NODE (WCN)

The WCN of a typical WSN works as a sink node. It is very similar to sensor node and operates as a master microcontroller. It has several crucial tasks to perform. The additional features in it are filtering data, alarm generation system and communication with wireless server module. The architecture of WCN consists of power source, sensors, alarm system, Processing Unit (AVR microcontroller) and wireless communication module (XBee Pro series 1). The sensors provide data from the field which goes to ADC block for data sampling and quantization further it is processed in processing unit and stores in memory for short term history logging. If there is any disturbance in hardware side it generates alarm. All the gathered data then send to the server module through wireless communication.

2.1.1.3.WIRELESS SERVER MODULE (WSM)

This module basically acts as a bridge between the WSN and the Remote site. This module consists of power source, XBee transceiver, Raspberry Pi, SD card and LAN connection. The UART pins of R pi are considered as a powerful feature to

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connect it with the external world. These pins are used to interface XBee Series 1 transceiver with R pi. Through this transceiver R pi is wirelessly receiving information from the WCN. The SD card provides storage for Operating System and files. It is used to maintain history logging of the fields' parameters. R pi have configured to enable LAN connection. Socket programming has been implemented using python on R pi to send the received packet to the software application. TCP communication protocol have used as a GPRS transmission plane. It enables two hosts to establish a connection and exchange streams of data. It guarantees delivery of data and in order transmission. Here, it is required that information from the field should not be lost because certain processing parameters on the Remote Site rely on the nature of collected data from the field.

2.2. SOFTWARE IMPLEMENTATION

The Software Application for visualizing, monitoring, calculating, and storing the field parameters is programmed in C# programming language. The platform used to develop the application is Microsoft Visual Studio 2010. The data values are stored in tables and these tables are managed by creating stored procedures. SQL Server 2008 Management Studio has used in this productive application for table management. The software is basically consists of three main layers (FIGURE. 2):

(a) A graphical user interface layer to read and visualize the sensor's information
(b) A business layer which is programmed to receive data from the internet and store it in the Database
(c) A storage layer to store all the information in the form of tables and stored procedures to access relational tables.

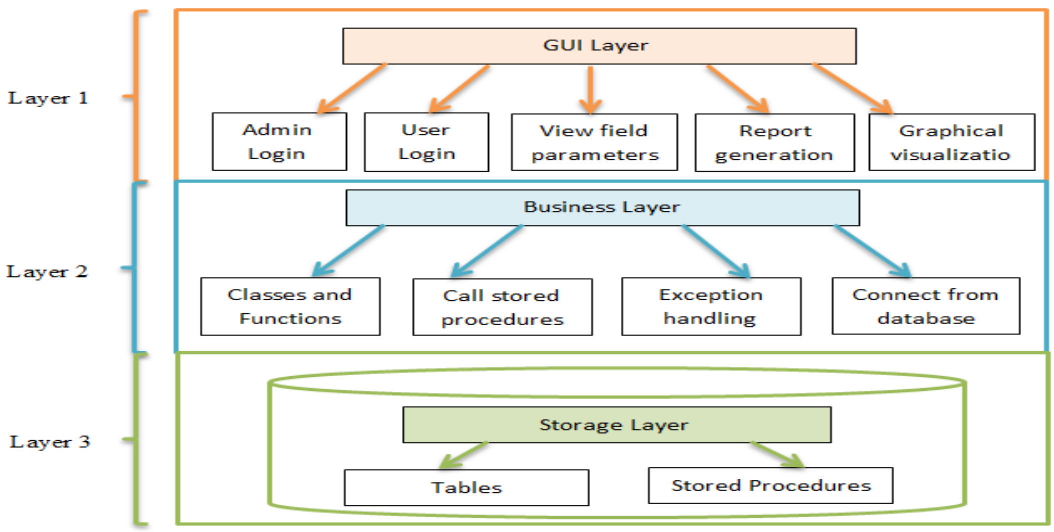

FIGURE. 2 Architectural Layout of Web Application

The Web Application is developed for visualizing and storing real time data from the field. Through this secure application the farmer can easily keep track of his field by checking certain realistic parameters. It actually permits an authorized user to access the data of his particular field. All the gathered information from the cloud is stored in the database. The Web application displays all the statistical parameters from the field i.e. Soil moisture, Temperature, Humidity, and Water flow. On the bases of the gathered data this application is calculating the water usage on hourly, weekly, daily and monthly bases. These kind of calculative results are generated in the form of reports. User can visualize these reports in the form of different graphs (FIGURE. 3-7) so that they can easily contemplate the trend in the data values. Some comparative analysis has also been done (FIGURE. 8-9) to visualize the changes in certain parameters as the other variable changes.

3. ANALYZED RESULTS

The visualized results of field parameters are presented below:

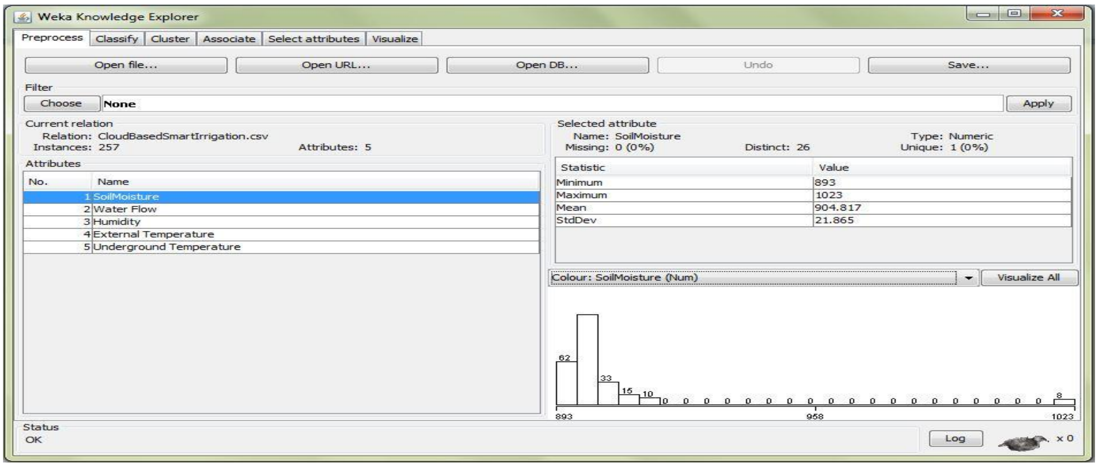

FIGURE. 3 The statistical measure of soil moisture of a particular acreage is presented. The results are also visualized in the form of a graph. Its value ranges from 0 to 1023 (wet to dry). When water pump is off the soil moisture level is 1023. As its status changes the value of soil moisture level is decreased to 893.

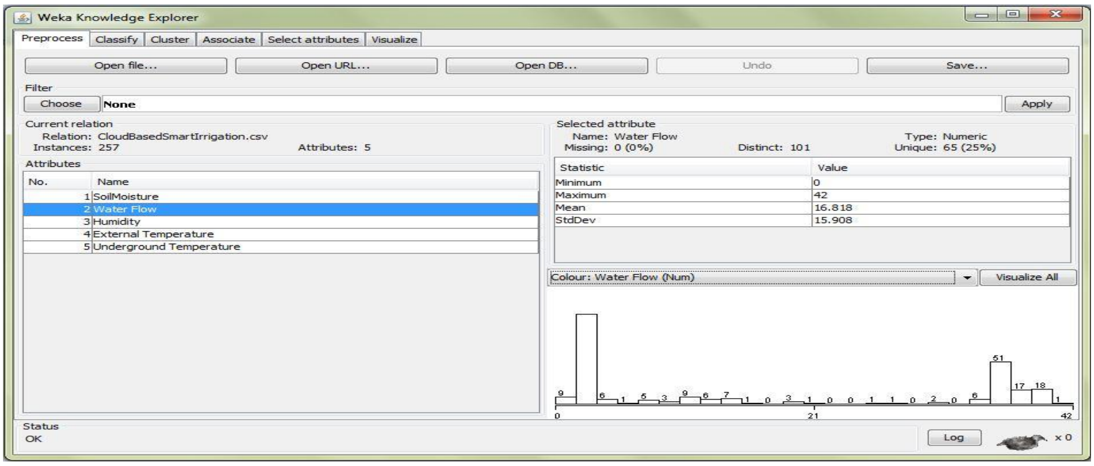

FIGURE. 4 The statistical measure of water flow level in l/hr. of a particular acreage is presented. Its value ranges from 0 to 40 (low to high rate). When water pump is off the rate is 0 l/hr. As the water flow started its value increases to 39.75 l/hr and maintained with certain variations till the pump is on.

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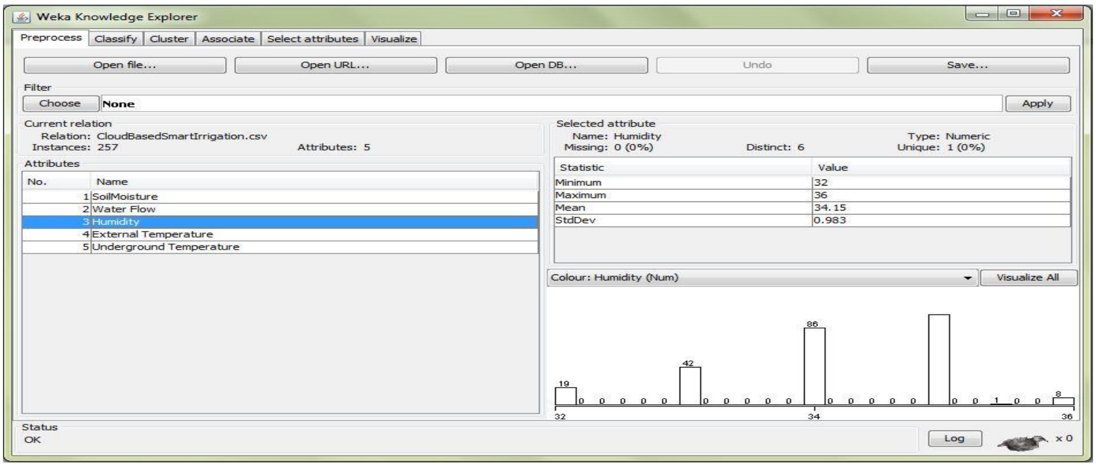

FIGURE. 5 The statistical measure of percentage of humidity of a particular acreage is presented. Its value ranges from 38 to 32 (low to high) percentage. When water pump is off the humidity is low i.e. 36%. As the water flow started its value decreases to 32% and maintained with certain variations till the pump is on.

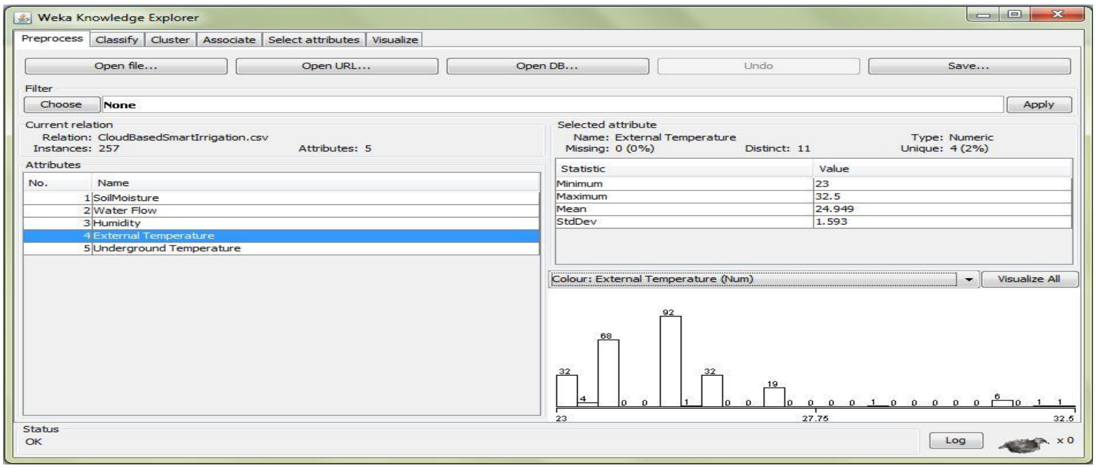

FIGURE. 6 The statistical measure of Environmental temperature in °C of a particular acreage is presented. The results are also visualized in the form of a graph. Its value ranges from 40°C to 20°C.

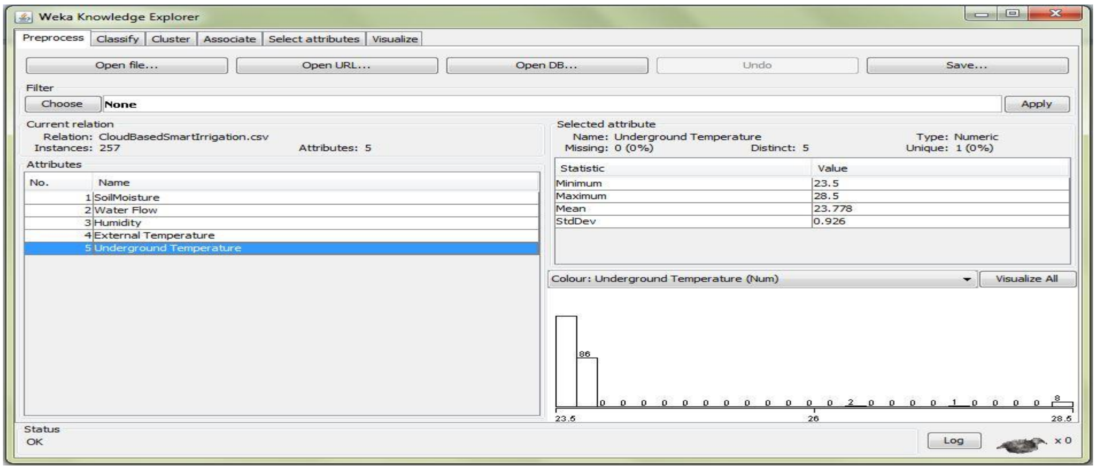

FIGURE. 7 The statistical measure of Underground temperature of a particular acreage is presented. Its value ranges from 30 to 22 °C (dry to wet). When water pump is off the Underground temp. is 28.5 °C. As its status changes the value of Underground temperature is decreased to 23.5 °C.

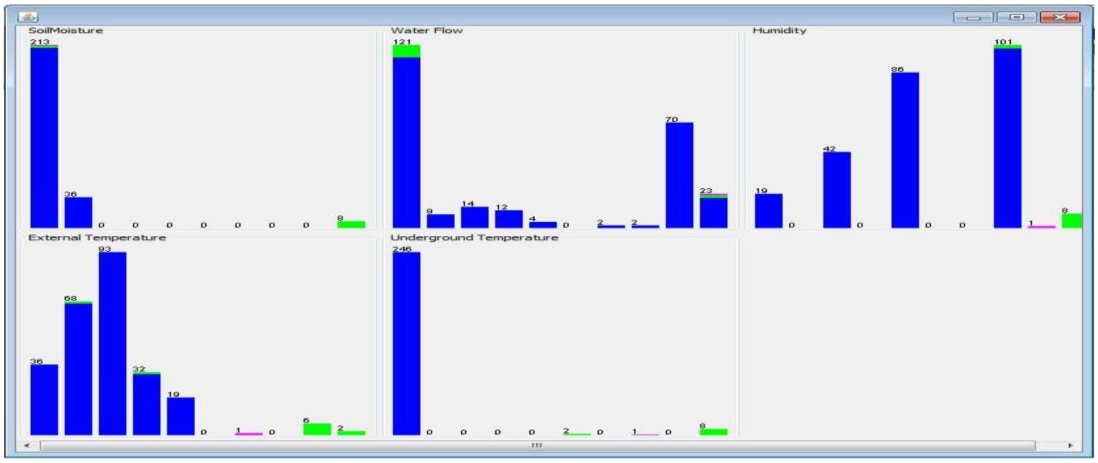

FIGURE. 8 The statistical measure of Soil Moisture, Water flow, Humidity, Internal and Underground temp. of a particular acreage is visualized by using unsupervised Discretize learning.

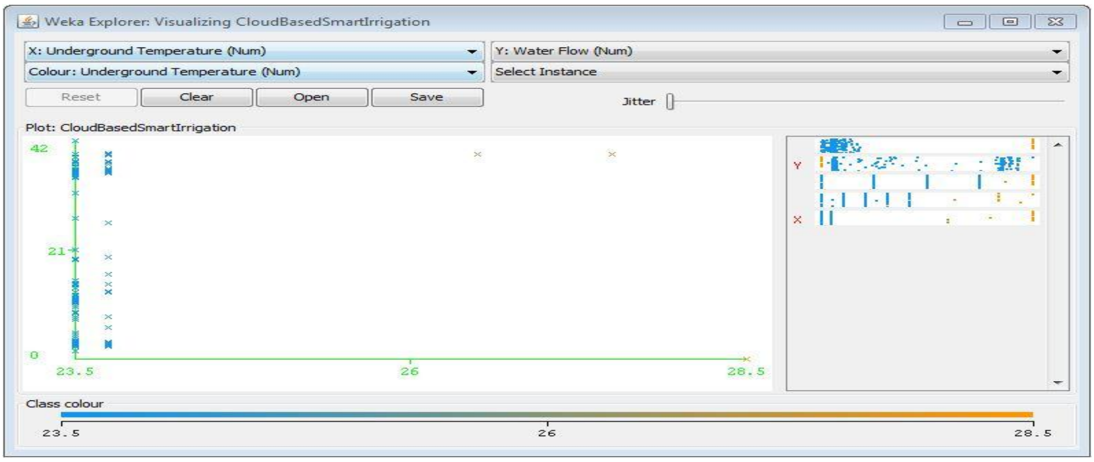

FIGURE. 9 The above graph shows the comparison between underground temperature (°C) and water flow (l/hr). When the water pump is off the underground temperature is 28.5 °C. As the pump is on the underground temperature starts decreases and stables at approximately 23.75 °C.

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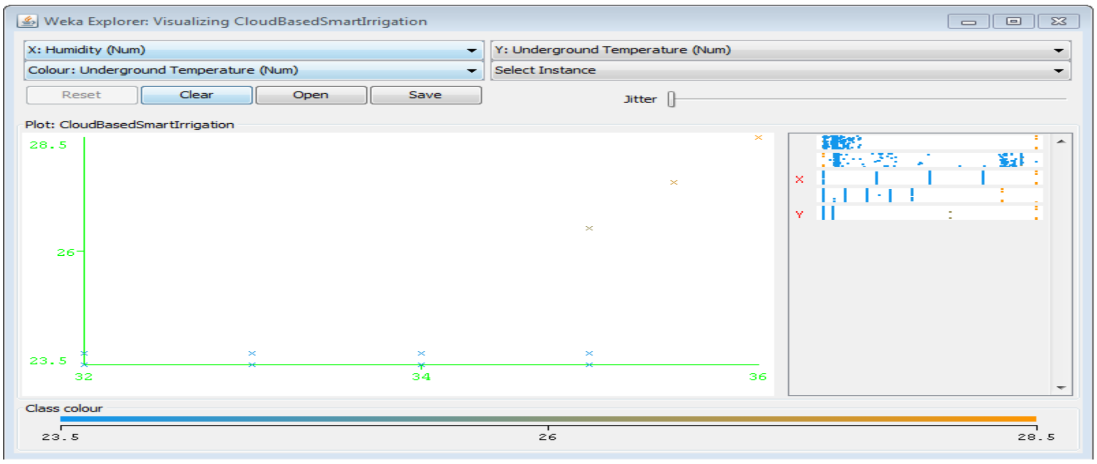

FIGURE. 10 The above graph shows the comparison between underground temperature (°C) and soil moisture. As the soil moisture is low (wet) the underground temperature is also decreased. When the water pump gets on the temperature is gradually decreased from 28.5 °C to 23 °C, and the moisture level is also gradually shifted from 1023 to 893

4. CONCLUSION AND FUTURE ENHANCEMENTS

Cloud based smart irrigation system for agriculture sector of Pakistan have been used to save water and increase crop productivity. This system is developed to facilitate the clients (farmers) on the basis of sensed parameters from the WSN. The first prototype of this smart system is deployed in CIS Garden of NED University of Engineering and technology. It has been monitoring the garden's water flow level, humidity, soil moisture, environment, and soil temperatures. The system decides when to water the plants according to the acquired parameters. In this way it has successfully saved a good quantity of water.

In future, the plan is to establish two-way communication, i.e. the Web Interface can generate commands to the WSN. The WSN can act accordingly as mentioned in the instructions. The Web Application will also be detecting outliers by using various intelligent algorithms. The other main next focus is on the design of a hardware development kit to make the product more compatible and user friendly.

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