AUTOMATIC FERTILIZED-IRRIGATION CONTROL AND MANAGEMENT SYSTEM

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Abstract: As serious food insecurity persists in many parts of the world, improving productivity in agriculture in a sustainable manner is today a realistic target. Farming plays an important role in food production and economic development in Nigeria and the world as a whole. Getting high yield from farm produce depend on land fertility, soil moisture and other climatic factors. This paper aims at developing an automatic fertilized-irrigation control and management system for the improvement of soil porosity and nutrient by timely application of fertilizer and water level required for the crops growth and development. This will metabolize the soil texture, give the nutrient to the crops, build plant tissue as well as increase the rate of crop productivity. The implementation of the system has been achieved by interfacing several components and intelligence unit such as ISE sensors, DHT11 sensor, Actuator, AT89C52 microcontroller and other components to automatically apply soluble agrochemical fertilizer and water based on plant needs. The designed system is tested with tomato crop planted on sandy, loamy and clay soil, respectively. The obtained result shows that the developed system applied higher water of about 391 mm^3 on the tomato crop planted on sandy soil compared with the other soil types which was 383 and 380 mm^3 on loam and clay soil, respectively at the moisture content of 16%.

Keywords: AT89C52microcontroller, DHT11 sensor, fertilized-irrigation, food production, land fertility

Introduction

Fertigation (fertilizer + irrigation) may be defined as the combination of irrigation and fertilizer application to the soil in order to improve crop production and plant growths. Irrigation systems assisted in the growing of agricultural crop, maintenance of landscapes and re-vegetation of disturbed soil in the dry area and during the periods of inadequate rainfall (Sowah *et al*., 2014). Agricultural land that relies on rainfall is referred to as rain-fed. Irrigation is often considered together with drainage, which is the natural or artificial removal of surface and sub-surface water from a specific area (Kumar *et al*., 2013). Of course, the channelling of water sprain over the farm lands plays an important role in the crop productions and plant nourishing. This includes protection of the plants against frost, suppression of the weed growing in grain fields and aiding in soil associated prevention (Sims, 2009).

In a survey carried out by the News Agency of Nigeria, the price of tomatoes increased by about 300% during the 2015/2016 dry season (NTA.ng-Breaking News, 2016). This was attributed to the diseases, decline of irrigation water and insufficient conventional methods of applying large amounts of water for tomato farming (NTA.ng-Breaking News, 2016). To resolve these challenges, micro-irrigation methods such as Drip irrigation and Sprinkler irrigation system are required (Hussain *et al.*, 2013).

Drip irrigation system: is an effective method of irrigation technique that can be primarily used to apply water and fertilizer into the plant. It enables water to drop little by little to the root of plants through tubing or valves pipes as shown in the Fig. 1.

Sprinkler irrigation system: This technique can be referred to as an artificial rain system The system dispenses water through a pressurized pipe network to the nozzle of sprinkler that sprays water into the air as shown in Fig. 2.

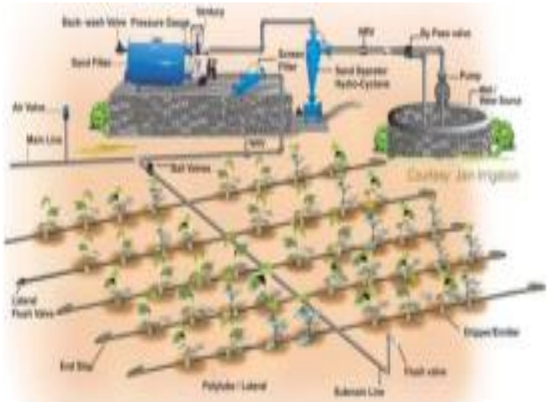


Fig. 1: Drip irrigation layout (Hussain *et al.*, 2013)

Fig. 2: Sprinkler irrigation layout (Hussain *et al*., 2013)

Research by Jyothipriye and Saravanabana (2013), proposed a microcontroller based drip irrigation mechanism with a real-time feedback for monitoring and control of the drip irrigation activities. The operation of the system only controls by the user at a desired time through the use of the ZigBee controller module without prior determination of temperature or humidity of the plant environment.

A related prototype microcontroller based intelligent irrigation system was developed by Kumar *et al.* (2013). The method of irrigation was divided into a zones, where watering is applied using moisture sensor, pesticide sprinkler and soil humidity sensor. The system seems completely automated. However, atmospheric temperature, which is one of the important parameter to determine plant growth, was not taken into the consideration.

Pranita and Dixit (2012), developed indigenous low cost microcontroller time based irrigation scheduler that performs user defined functions and give command to derive appropriate actuators using temperature sensor and timing bucket rain-gauge to measure both temperature and rainfall. After a pre-set quantity of precipitation falls, the level tips dumping the accumulated water and sending an electrical sign.

Guerbaoni *et al.* (2013) developed a PC-based automated drip irrigation system for a greenhouse management. The adoption of data acquisition card (PCL-812PG) controlled by PC was provided with a hydraulic circuit based on an electric pump for the irrigation function and monitoring irrigation process.

In the approach of Riza *et al*. (2011), a solar based intelligent water sprinkler system was designed. The system consists of an electrical-capacitance soil moisture sensor installed into the soil and interfaced with a Motorola 68HC11 handy board microcontroller. The operation of the system is based on a fuzzy logic controller; a new method of irrigation system, based on the closed loop scheme with a temperature monitoring unit presented by Neelam and Dilip (2012). A real time soil moisture valve and temperature sensor was used to determine the status of soil. The state of the actuator and irrigation valve was designed to be controlled based on moisture level desired by the user using ZigBee.

Rahali *et al*. (2011) designed a microcontroller based automatic irrigation system for providing adequate irrigation without user involvement. Also, Venkata (2013), design an irrigation system using microcontroller to activate the sprinkler whenever there is alteration in temperature or humidity parameter of the skirting. The system was designed to be powered by solar technology which can be affected by climatic condition.

Shiraz and Yogesha (2014), attempted to automate nursery irrigation that allows a farmer to apply the accurate amount of water at a specific period of time, regardless of the availability of labour to turn ON/OFF the system. The system appeared to be effective without human involvement; however, it is only powered by solar panel technology which can be affected by atmospheric condition.

Conventional way of sampling soil and laboratory analysis is expensive and time consuming. The development of proximal soil sensor is very important for crop yield. Numerous proximal soil sensors are available in the market, but no single proximal sensor has been identified for measuring soil nutrient in a real time directly (Lobsey *et al.*, 2016). A multi-ion sensitive Field-Effect Transistor (MISET) nitrate sensor based on Flow Injection Analysis (FIA) system was developed by Birrell and Hummel (2001). The system capability is limited to measuring soil nitrate in manually extracted soil solution (r^2>0. 9) for a duration of 1.25 second.

Viscarra *et al*. (2004) developed a system using the chamber for estimation of Lime Requirement (LR) for the measurement of soil PH. This was used for the collection of soil conductivity on the farm land. In a similar work by Kim and Hummel (2007), a universal extraction solution for multiple ion based on Ion Selective Electrodes (ISEs) analysis system was carried out. The result showed that Kelowna soil extract ant is compatible with specified ISEs for phosphorus, nitrate and potassium. However, the elucidation is a combination of a series of chemical that may have consequences in an environment.

In this study, an automatic fertilized-irrigation control and management system that can automate supply of water and soluble fertilizer to the crop in accordance with their needs has been developed. This system can determine the condition of the environment, soil temperature and humidity before the decision of irrigating taken place and complement sample regimen with chloride, nitrate and ammonia measurements.

Materials and Methods

The system implementation is divided into two major components which are hardware and the software. The hardware component consists of the AT89C52 40-pin microcontroller, which is used as an intelligent system for data processing, control and triggering of the system. It holds the instruction codes that responsible for the control of sensing, actuator, triggering and display of information on both the graphical user interface and LCD module. 16x2 liquid crystal display (LCD) module is used to display the sensing information about the temperature and humidity of the soil environment, the data line pins of LCD (D4-D7) is connected to port 0 pins (33-36) of microcontroller while the other pins of LCD module like RS (register select), RW (Read/Write), E (Enable) pin, VCC and VDD for power and ground is connected to the port1 pin (1-3) for the data display. The pin 2 of DHT 11 temperature and humidity sensors is connected to the port 2 pin 21 of the controller, pin 1 and 4 is connected to power and ground, respectively. Also, A1015 switch relay used for triggering the system by connecting negative pin to the stepper motor, and other pin to the port 3 pin 23 of microcontroller using PNP BC549 for a current amplifier to toggle relay.

The software used for the programming is Keil µVission4 and the graphic user interface was designed in the Java programming environment. The data through the serial port Max 232 connected to the microcontroller chip, and the hardware system divided into modules: the controller unit (AT89C52MCU), output unit (GUI and LCD), sensing input (DHT 11 sensor), switching unit (relay switch) and power supply unit which all are interfaced together to function as automatic fertilizing-irrigation control and management system as shown in the block diagram of Fig. 3.

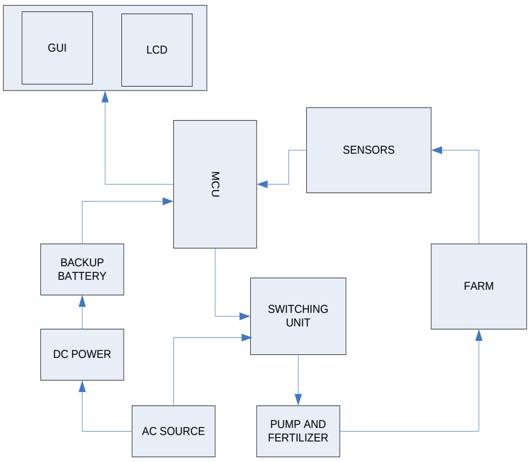


Fig. 3: The system block diagram

Power supply unit

This unit consists of a charger circuit, battery, step-down transformer, rectifier, capacitor and voltage regulator. The mains power is supplied to the transformer which step down the alternating voltage from 220/230V to 15VA.C and regulated to 12V and 5V using LM 7812 and 7805, respectively. The 15VAC is converted to D.C by the rectifier and filtered by the 1000 uf capacitor to give a pure D.C output, which is used to charge the battery, effectively through a monitoring circuit that consist of LM317, 12VZener diode and 220 Ohm resistor.

Switching unit

This unit consists of 12V relay, which derives its power from the power supply unit. This device is used to trigger ON the water system whenever the moisture content of the soil, getting low that is 30% (2V) and displayed the value on the LCD unit as well as GUI, respectively.

Since A1015 transistor is used as a current amplifier that produces ample current to toggle the relay, the mathematical model in (1) was used to model the base current.

$$Vcc = IcRc + Vce \quad (1)$$

Where: I_b represent base current, I_c represent collector current, V_{cc} represent Voltage collector-to-collector (DC supply voltage) and hfe represent transistor Gain.

At saturation,

Vce = 0 where,

$$Vcc = IcRc \quad (2)$$

But, Rc = resistance of relay = 100Ω

$$Ic = \frac{Vcc}{Rc} \quad (3)$$

$$Ic = \frac{5}{100} = 0.05A \quad (4)$$

$$hfe = \frac{Ic}{Ib} \quad (5)$$

assuminghfe = 12V,

Then,

$$Ib = \frac{0.05}{12} = 4.167mA \quad (6)$$

When microcontroller is high, it produces 4.0V. Therefore, Base resistance can be modelled as;

$$Rb = \frac{Vb}{Ib} \quad (7)$$

$$Rb = \frac{4.0}{4.167} = 959.92\Omega \quad (8)$$

Rb ~=1KΩ is suitable for the A1015 transistor to limit the base current flow through the transistor.

Sensor unit

This unit consists of two sensors, DHT11 is a digital temperature and humidity sensing device, that uses a capacitive humidity sensing element and a components called thermistor to measure air in the surrounding, and emit a digital signal on the output of data pin. It is perfect for measuring humidity of 20-80% with 5% accuracy, temperature at 0-50°C with±2°C accuracy, it takes sampling rate of 1 Hz per every second and the power rate is 3-5V. While the ISESoil moisture sensors used for measuring the volumetric content of water in the soil, using some property of the soil such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content.

Liquid crystal display unit

This is the unit where all the information obtained from the sensors is displayed. It provides support for the system user to know the status of his farm environment.

Evapotranpiration model

Evapotranspiration (Eto) net can be calculated using the Penman-Monteith combined equation, which has been accepted generally as a scientific ways require for the estimation and observation of fresh water consumed and sustainable crop production by agronomist, soil scientist and others. The sum of evaporation, ground surface and transpiration of plants by regulating the water and balancing energy required in the atmosphere for the agricultural productivities is called evapotranspiration. Combination function of minimum and maximum temperature, wind speed, radiation, and vapor pressure are expressed in this equation. After the update of the Penman method by FAO (Umair & Usman, 1990), it is now written as:

$$\text{Eto} = \frac{0.408\Delta(R_n - \text{G}) + \text{y}\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + y(1 + 0.34u2)} \quad (9)$$

$$\Delta = \frac{409eo(T)}{(T + 273.3)^2} \quad (10)$$

$$e^o(T) = 0.6108 \exp\left(\frac{17.27T}{T + 273.3}\right) \quad (11)$$

$$\gamma = \frac{CpP}{\epsilon\lambda} X\, 10^{-3} = 0.001628\, XP/\lambda \quad (12)$$

where:

Eto = Evapo-transpiration reference [mm day^{-1}]

G = Soil heat flux density [MJ m^{-2} day-1]

Rn = Net radiation at the crop surface [MJ m^{-2} day 1]

T = Mean daily air temperature at 2 m height [^{0}C]

e_a = Actual vapour presure [kPa]

e_s = Saturation vapour pressure [kPa]

e_s - e_a = e^o(T) = Saturation vapour pressure deficit [kPa]

λ = Latent heat of vaporization = 2.45 [MJ kg-1]

ε = ratio molecular weight of water vapour/dry air = 0.62

Software design of the system

The software utilized in this study was basically written in C Language. It is this source code used to program the microcontroller in order to achieve and actualize the work. The software source code was compiled using Keil, and AT89c51 microcontroller was used to control and coordinate the operation of the system. AT89c51 microcontroller was chosen because it's low power idle, power down modes and easy to program (Ahmed *et al*., 2016). The aim of this simulation is predicted and familiar with the behaviors of the proposed system. Fig. 4 depicted a simulated design of the proposed system, while Fig. 5 depicts the flowchart diagram of the system functions.

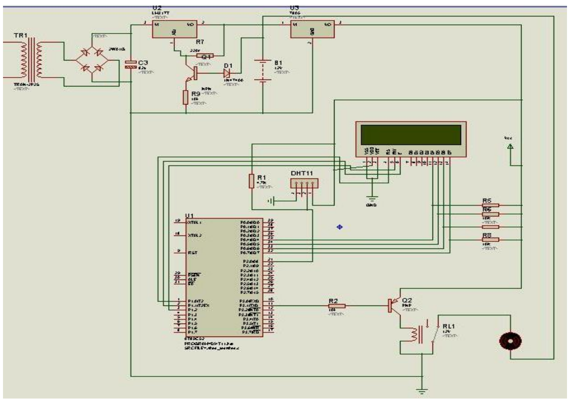


Fig. 4: Simulated work of the system

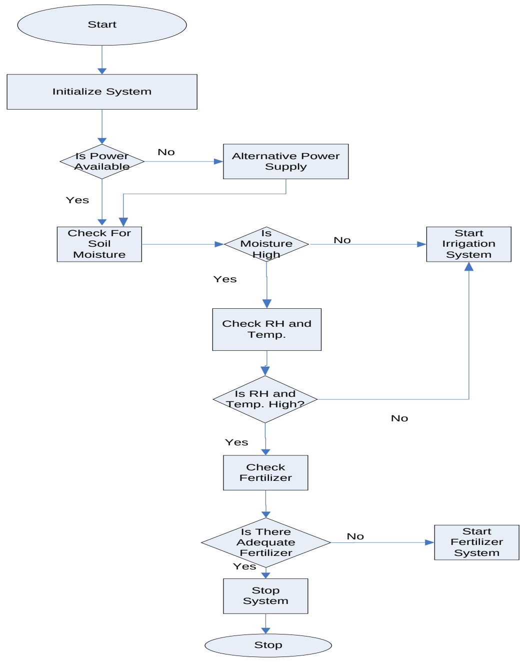


Fig. 5: System operation flowchart

Graphical user interface (GUI) unit

The microcontroller was interfaced to the graphical user interface (GUI) through the serial port using Max 232 to visualize equivalent value displaying on the LCD screen for user to know about the status of the soil content. Fig. 6 shown developed GUI of the system.

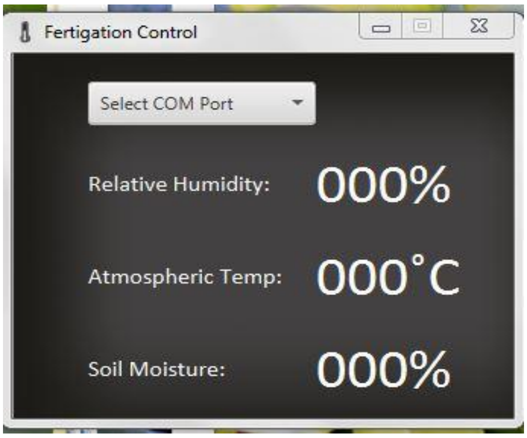


Fig. 6: GUI of the system

Result and Discussion

The developed model of automatic fertigation management and control system is depicted in the Fig. 7, and Table 1, 2 and 3 presents the parameter value of the soil moisture and applied water for the sandy, clayed and loamy soil respectively of a used farm area.

Table 1: Value of moisture and quantities of water applied to the sandy soil

Moisture (%)	Water Applied (mm^3)
8	450
16	391
24	318
32	253
40	175
48	110
56	45

Table 2: Value of moisture and quantities of water applied to the clay soil

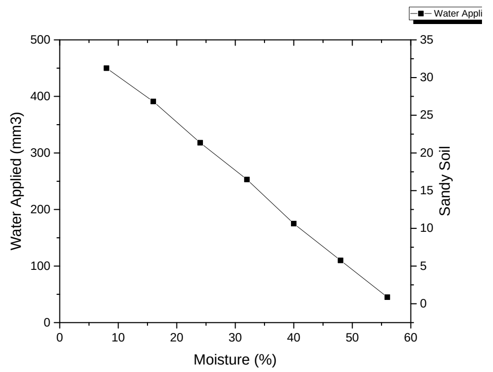
Moisture (%)	Water Applied (mm^3)
16	383
32	253
48	110

Fig. 7: Prototype of working system

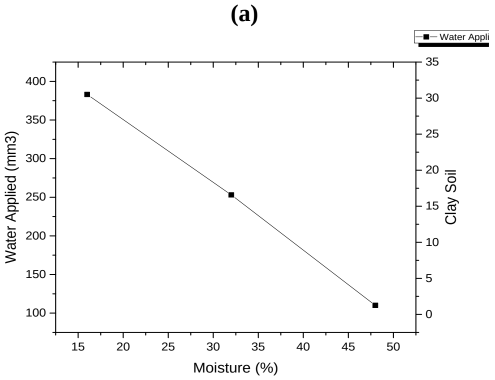
Table 3: Value of moisture and quantities of water applied to the loamy soil

Moisture (%)	Water Applied (mm^3)
3	474
6	448
9	422
15	396
18	370
21	344
24	318
27	292
30	260
33	240
36	214
39	188
42	162
45	136
48	110
51	84
54	58
57	32

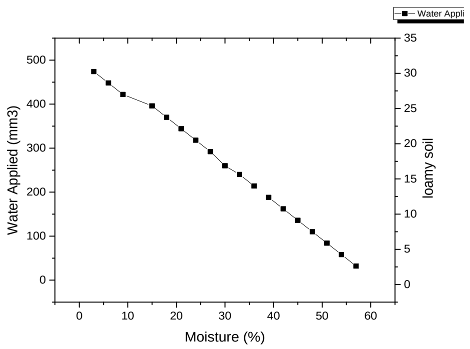
The system was developed by interfacing all the system units in a module together (such as control unit, display unit and the sensing unit), and work effectively. The solenoid valve of the water circuit opens when the voltage exceeds 3V (dry soil) corresponding to 3% of soil moisture level and closed when voltage reaches 1V below (moist soil) corresponding to about 60% of soil moisture level which is used to determine the system output as depicted in the graph for various soil types. The results show that the developed system applied higher water of about 391mm^3on the tomato crop on a sandy soil compared with the other soil types which was 383mm^3 and 380mm^3on loamy and clay soil, respectively at the moisture content of 16%. These imply that sandy soil required higher water than other soils. Fig. 8 shows the comparative chart of the moisture values against the quantities of water applied to the different soil types.



(a)



(b)



(c)

Fig 8: Comparative chart of the moisture values against quantities of water applied **(a)** Sandy soil; **(b)** Clay soil; **(c)** Loaming soil

Conclusion

In this study, a fatigation system that can manage and improve the yield of crop has been developed. The system is capable of measuring soil moisture parameters, display the information acquired and take appropriate action. This system can operate without the human intervention thus, reduce farmers strength and energy required for the cultivation of foliage crops most especially during the dry season. To improve the performance of this system, it is recommended that more robust system using different sensors for measuring soil fertility parameters such as Ions, Potassium (K), Phosphorous (P), Calcium (CaS), Sulfur (S) and other soil parameters for the intelligence system information computation and decision making can be designed.

References

Ahmed A, Buhari U, Olaniyi OM & Adegboye MA 2016. An ionization based smoke detection and control system. *J. Advancement in Engr. & Techn.*, 4(2): 1-5.

Birrell SJ & Hummel JW 2001. Real-time multi ISFET/FIA soil analysis system with automatic sample extraction. *Computers & Electronics in Agric.*, 32: 45-67.

Essiet D 2016. Tomatoes, a vegetable consumed in most households, is scarce and very costly. Many have attributted the shortage to the Mile 12, Ketu, Lagos crisis. Some blame diseases, the high cost of transportation and insecurity in the North. The Nation. Retrieved 30th August, 2016, from http://thenationonlineng.net.

Guerbaoni M, Ed-Dahhak A, Lachab A & Bouchikhi B 2013. PC-based automated drip irrigation system. *Int. J. Engr. Sci &Techn.*, 5.

Hussain R, Sahgal JL, Anshulgangwar R& Riyaj M 2013. Control of irrigation automatically by using wireless sensor network. *Int. J. Soft Computing & Eng. (IJSCE)*, 3(1): 324-328.

Jyothipriye AN & Saravanabana TP 2013. Design of embedded system for drip irrigation automation. *Int. J. Engr. Sci. Invention*, 2(4): 34-37.

Kim HJ, Hummel JWS, Motavalli PP 2007. Simultaneous analysis of soil macronutrients using ion-selective electrodes. *Soil Sci. Soc. Am. J.*, 71: 1867-1877.

Kumar ND, Pramod S & Sravani C 2013. Intelligent irrigation system. *Int. J. Agric. Sci. & Res. (IJASR)*, 3(3): 23-30.

Lobsey C, Viscarra Rossel RA & McBratney AB 2016. Proximal soil nutrient sensing using electrochemical sensors. *Australian Centre for Precision Agriculture, McMillan Building A05, The University of Sydney NSW 2006 Australia*. Retrieved from https://www.researchgate.net/publication/226233158

Neelam RP & Dilip KT 2012. Micrecontroller based closed loop automatic irrigation system. *Int. J. Innovative Techn. & Exploring Engr.*, 1(1): 4-6.

NTA.ng-Breaking News (Producer) 2016. Survey Indicate Increase In Tomato Price In Lagos. [News, Oct. 10, 2016] Retrieved from www.nta.ng.

Pranita AB & Dixit VV 2012. Water saving-irrigation automatic agriculture controller. *Int. J. Sciencentific & Techn. Res.*, 1(11): 118-123.

Rahali A, Guerbaui M, Elafou Y, Lachhab A & Bouchikhi B 2011. Development of a data acquisition and greenhouse control system based on GSM. *Int. J. Engr. Sci. & Techn.*, 3(8), 297-306.

Riza M, Winda A & Kasim NA 2011. Solar-based fuzzy intelligent water sprinkle system. *J. Mechanics, Electrical Power, & Vehicular Techn.*, 2(2), 65-72.

Shiraz P & Yogesha B 2014. Microcontroller based automated irrigation system. *Int. J. Engr. & Sci.*, 3(7): 6-9.

Sims BG, Hobbs P & Gupta R 2009. Policies and institutions to promote the development and commercial manufacture of conservation agriculture. Paper presented at the proceedings of the 4th world congress on conservation agriculture, February 4-7, 2009, New Delhi, India.

Sowah RA, Armoo SK, Koumadi KM, Agyeman R & Fiawoo SY 2014. Design and development of an efficient and cost-effective microcontroller-based irrigation control system to enhance food security. *World Acad. Sci. Engr. & Techn; Int. J. Electrical, Computer, Energetic, Electronic & Communi. Engr.*, 8(8), 1343-1350.

Umair SM & Usman R 2011. Automation of irrigation system using ANN based controller. *Int. J. Electrical & Computer Sci. IJECS-IJENS*, 10(02).

Venkata NRG 2013. Microcontroller based automatic plant irrigation system. *Int. J. Advancement in Res. & Techn.*, 2(4): 194-198.

Viscarra Rossel RA, Thylén L, McBratney AB & Gilbertsson M 2004. Development of an on-the-go soil sensing system for determinationsof soil pH and lime requirement. Paper presented at the 7th International Conference on Precision Agriculture, Minneapolis MN, USA.