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COLLEGE OF SCIENCE AND TECHNOLOGY

AFRICAN CENTRE OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: Smart Agri-soil monitoring and maintenance through excess water based on IoT and fuzzy inference system

A dissertation Submitted in partial fulfilment of the requirements for the award of

MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS: EMBEDDED COMPUTING SYSTEM

Submitted By

Mathieu ITANGUKWISHATSE (REF.NO: 215040884)

October, 2024

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Supervised by:

- **Dr. Jean Baptiste MBANZABUGABO**
- **Dr. Alfred UWITONZE**

October, 2020

Declaration

I, Mathieu ITANGUKWISHATSE, Master 'student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

Ref: 215040884

Signed:

Date: 14/10/2024

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Bonafide certificate

This is to certify that this submitted Research Thesis work report is a record of the original work done by Mathieu ITANGUKWISHATSE (**REF.NO: 215040884**), MSc. IoT-WISNET Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2023/2024.

This work has been submitted under the supervision of:

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ABSTRACT

In Agriculture, water plays a big role, like watering the vegetation and helps the micronutrients to be mixed. The farmlands watering may be drenched from different sources, which include rainfalls, fountains, wells and rivers. The water level monitoring is an essential task in farmlands, as each plant requires its own moderate water level. The deficit of water in a given plant may affect its growth; even the excess of water may affect the life of plant. The development of plant may be affected by the moisture stress. As the water becomes excess at a time of heavy rainfall, the micronutrients become unstable and it affects the life of vegetation. There are different methods, which are currently applied to manage water in farmland, like making manholes in fields, directing water in different rivers, building tanks to capture water from farmlands and using manpower to fetch water from farmlands. These techniques are traditionally used. Today, as technology advances every single step in agriculture, this research aims to deploy an intelligent system that is able to monitor soil temperature and humidity, soil moisture and water level. The system is able to fetch excess water from farmland and let the plant to remain with the required water for its growth. In this research, the NYABARONGO Valley is taken as consideration and divided into sections; each section has its corresponding water irrigation pump, water Drainage pump and mega tank. Each section is enabled to sense, actuate and communicate with the cloud. Sugarcane vegetation is also taken as a sample to be monitored because it occupies a big place in Nyabarongo valley. With the help of sensory prototype results, Matlab fuzzy logic based simulations, and the Matlab Simulink experimental results, the proposed research proves its ability of delivering soil maintenance and minimization of negative effects of excess water.

Keywords: Monitoring farmlands, Control of excess water, fuzzy inference system

LIST OF ACRONYMS

ACEIoT: African Center of Excellence in Internet of Things

UR: University of Rwanda

AI: Artificial Intelligence

SWAMP: smart water management platform

IoT: Internet of Things

LCD: Liquid Crystal Display

pH: potential of Hydrogen

DHT11: Digital Temperature and Humidity sensor

GSM: Global System for Mobile

LED: Light Emitting Diode

PWM: Pulse Width Modulation

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CHAPTER 1: INTRODUCTION

1.1 Overview and Background

In different regions in the world, referring to the extreme change of climate, the excessive rainfall and floods cause the vegetation in farmland to be immersed in water. This affect the yield of vegetation because it makes the soil moisture unstable and some plants cannot resist the water that exceeded its required water. In India, there is the climatic conditions where farming in some regions is challenging because of excessive rainfall and flooding [1]. The water excess in farmland is a challenge everywhere for its consequences especially the locations where rainfall seasons vary frequently. Among those locations, Eastern and Central Africa are included [2]. In Ethiopia, the agriculture yield is challenged by salinity and waterlogged problem. The absence of advanced drainage system and poor management of water, cause waterlogging in the fields [3].

Agriculture is one of the domains; that provides food and serves a lot of people; in smart farming, internet of things plays an important role; and different systems are developed to monitor the crops in fields with help of different Sensors [1], the extreme of climate change that can cause a heavy rainfall, floods and sometimes landslide may affect plants to be immersed in water, In this case the moisture level becomes unsuitable and the production yield is affected [1]. In agriculture sector, water may be managed as resource that plays a big role in growth of crops from sowing until harvesting [4], in these days the agriculture domain use advanced technologies like irrigation system, crops management from diseases and data are precise, centered, and also smart comparing to the previous days [5].
Due to the various limitations like climate change, temperature, movement of population from one place to another and soil quality, the surface of earth, which is suitable for agriculture, is limited. As also the technology advanced the Internet of things, it is expected that the information on statistical pattern of plants obtained from IoT based decision System [5]. Overwatering crops may affect the quantity of oxygen or micronutrients that reach into the roots, which can prevent them from growing normally. Some plants, overwatering can also cause root rot, which may cause the crop to die. Under watering crops usually has the same disadvantages to the plants because it is the same outcome like making plant to dry as overwatering, here without proper irrigation, crops may not grow properly which can affect the production negatively [6].

Water is one of the main resources; that is needed in agriculture, it has different sources like rainfall, rivers and some waters are harvested from external catchment [7]. The ability to use and manage water efficiently increases the yield obtained from agriculture and raise the yield from the livestock. Different innovative technologies are introduced and have improved water management and monitoring in agriculture. Those advanced technologies are Internet of Things, Wireless Sensor Networks and Cloud Computing. They have been used in different projects in agriculture domain. The use of technology helps the farmers to get data, status of crops and the achievement of smoothing the water monitoring process by applying the increase of automation level, which simplify job to the farmers, and it allows the farmers to be connected to their farms anywhere and anytime [8].

Considering the case study of this research, Nyabarongo Valley sometimes get overwatering in the time of heavy rainfall, when the water from Nyabarongo River exceeded, it flows to the farmland and the soil moisture level is affected. Sometimes there is a deficit of water and excess of water. Different measures are taken to regulate water in this farm but the problem remain the same. The agriculture ministry tries to solve the excess of water effects in some farmland by building of ducks but this method protects the land from erosion not the crops, the plantation become destroyed which will be the consequences of getting insufficient and unpredicted production.

The vegetation located in this farm includes beans, maize, potatoes, cane and sugarcane. In this research; we choose to work on sugarcane, to see how it can be affected by the Underwatering and overwatering; and make a prototype of solving this problem by making an IOT based system that can make the irrigation when it is needed and drainage in rainfall season, in case the water exceeds the level beyond the required water of the sugarcane.

In consideration of the selected plantation namely sugarcane, its life style, stages of its life. With evapotranspiration which is nature method for drainage during the growing season of 5 to 6 mm /day and is considered in case there is no serious negative effect to the plantation, the depletion level during the vegetative and yield formation period can be 65 percent of the total available water because in this period the vegetation needs much water and this water has no any serious effects on yields. Sugarcane is among of plantations that needs much water in its life span. The water requirement of sugarcane has been estimated and it has to vary from 2000 to 3000 mm per annum per hectare.
The deficit or excess of soil moisture affects sugarcane yield, juice quality and sugar output, besides predisposing the crop to be attacked by several pests.

Around 20,000 to 30,000 cubic meters is the water requirement per year is to raise a sugarcane crop. This interval of water need is equal to 2000 to 3000 mm. Various factors such as soil type, climatic conditions like rainfall, temperature or wind are required to know the total water that is moderated for sugarcane plantation. The cultivation practices, water application efficiency and crop duration.

In twelve months, approximate water requirement of sugarcane at each growth phase is indicated below (Data are captured from Rwanda Agriculture Board Irrigation Engineer):

Germination phase (0 – 45 days): 300mm, Tillering phase (45 – 120 days):550mm, Grand growth phase (120 – 270 days): 1000mm and Ripening phase (270 – 360 days):650mm.

Protection of crops like sugarcane during rainfall season is major challenge for farmers [9].As the sugarcane is the main plants located in Nyabarongo valley, and need water frequently, The Number of irrigation in sugarcane depends upon the climatic conditions, type of soil, method of planting[10] . In case of Nyabarongo valley, in time of heavy rainfall, the water is become excess and it may take a long time in form of inundation. This water destroys the quality of sugarcane as it is beyond the water needed by that vegetation. In agriculture, the soil could be healthy and well managed, A healthy soil acts as a dynamic living system where multiple ecosystem can be survived, maintaining water quality and plant productivity, it also controls soil nutrient recycling; and its decomposition [11].

1.2 Motivation

As Nyabarongo valley is one of the farmlands that produces foods to the population and sometimes experiences the water overflow that damages the vegetation, and the traditional systems for drainage are not effective, as to decrease the plants that are destroyed by the excess water is an essential, an intelligent system is required to improve the productivity of this farmland by managing water required for sugarcane so that the productivity and quality are increased.

1.3 Problem statement

Previous researchers work on irrigation and drainage for particular vegetation and their works are on one side, if they choose to work on smart irrigation, they remain there and if it is drainage, they work only on drainage. As in Rwanda due to the limited agriculture area, there is a need of making agriculture all the seasons so that the yield will increase to get sufficient agriculture products due to the number of population which is increasing, it means the agriculture in dry season will be helped by irrigation in case there is no enough water in vegetation and agriculture in the rain season will be facilitated by drainage in case there is the excess of water in the farm depending to the water needed by the vegetation.

In some researches, show the use of smart drainage by using various sensors for a smart city to handle many problems that were raised to make the city clean [12]. They insist in underground water drainage and various sensors were used like water flow sensor, gas sensor and Water level sensor to monitor the flow and the level of gases that can cause some diseases. This kind of drainage is taken place in smart water management in a smart city [13].

Using pipes, Manholes and waiting for evapotranspiration are the main methods used to protect soil from excess water traditionally. Many researchers did their work on underground water not upper ground water. The recent system use pipes to make drainage and it has some drawbacks because the pipes may be blocked [13]. Overflow from streams, rivers or rain causes periodic flooding of lands and affects the life of vegetation [14], before the moving of soil, the water that causes that damage remains in that place with some days and make the soil instability.

In general, the vegetation has different soil moisture levels and the quantity of water required for one vegetation is different to the one needed by the other vegetation.

Because of this, some problems about soil maintenance from excess of water depending to the plantation are raised: Some researchers focus on drainage in smart city and they are limited to the farmland, Plantation has different stages in its life span and every stage needs the level of water different to the other stage, The tradition methods of drainage such as using pipes and waiting for evapotranspiration may cause a lot of loss of plant production because as water take a long time in some place, the yield and the quality of plantation will reduce.

The use of one way like irrigation only or drainage only will use the infrastructure that can be used in both actions and give good service as the plantation pass in different seasons. Sometimes, it needs irrigation, otherwise it needs drainage.

To solve all those problems, the system that can work on both sides, which are irrigation and drainage, is needed. From different perceptions, in this research the sugarcane vegetation in Nyabarongo farmland is chosen due to different stages it has, with different water need.

Referring to the case study of Nyabarongo valley, a number of problems raise from excess of water in this valley during heavy rainfall seasons. The heavy problems include flooding, plants and vegetation impairments, soil micronutrients degradation and excess of water in farmland. The vegetation in Nyabarongo valley vary from sugarcane, cane, sweet potatoes and other variety of animal feeding plants. In rainfall seasons, Nyabarongo valley experiences excess water, which destroys vegetation. Even though water is needed in vegetation, there is the interval (limit) in which the life of vegetation becomes good and healthy. When the water from Nyabarongo River exceeded its normal level and starts to arrive in the farmland, it may stay there a long period and that water sometimes is not needed due to the soil moisture needed and water level that is required. The excess of water in the farmland destroys the life of the vegetation namely sugarcane. It also affects the concentration of micronutrients located in the soil due to the soil moisture stress.

As the plant grows up, the need for water and sunshine varies, leading to the need of carefully monitor and maintain water level and micronutrients for the health of the plant. Both of the reasons lead to the need of developing an IoT system that keeps on monitoring the water level, the soil moisture, temperature and humidity of soil in NYABARONGO farmland sections.

1.4 Study objectives

1.4.1 General Objective

The main objective of this research is to design and implement a Smart Agri-soil monitoring and maintenance from excess water based on fuzzy inference system with automated IoT intelligent loads and in case of system failure, there is manual service to make drainage or irrigation depends to the type of problem. This system is able to monitor soil temperature and humidity, soil moisture and water level. The system is able to fetch excess water from farmland and let the plant to remain with the required water for its growth.

1.4.2 Specific Objective:

For water maintenance and monitoring in farmland, the IoT based system must be available to regularize the level of water for given plant, specifically the chosen plant in this research is sugarcane.

General this system has been developed to solve the problem of excess of water by drainage where the farmland experienced the higher water level comparing to the required water depending to the occurring stage of the plant and irrigation where there is insufficient water in the soil.

Because of water level for the plant is not measured for the exact number, where the interval is needed the Design and simulate fuzzy logic based solution should be used.

As the system, result is to regularize water and do irrigation or drainage depending to the need of soil, the Test of the solution to prove its effectiveness is done and it shows good results.

1.5 Hypotheses

The complement of this research will help the Rwanda Agriculture Board (RAB) to have a full control on the farmlands that experience the excess of water level typical sugarcane vegetation.

Nyabarongo valley will increase the yield and quality of sugarcane due to the elaboration of the system that control the water level and moisture of the soil required for sugarcane plantation. The soil micronutrients will be maintained and stabilized because the control of some measures which are soil moisture, water level, pH and, Temperature and Humidity. The system will minimize the plant destruction and predict the return back of the soil at the normal state after being experience the water level excess.

1.6 Study Scope

In conducting this research, Nyabarongo valley is taken into consideration as case study, it is one of the farmlands, which has different plantations, and sugarcane is the preferable plant that is taken into consideration in this research.

1.7 Significance of the Study

The deployment of intelligent Agri-soil monitoring and controlling system based on IoT and fuzzy inference system will contribute and benefit in assisting the minimization of the crops that are destroyed by the excess of water level especially the sugarcane at Nyabarongo valley. With the deployment of Fuzzy Inference System, water level and soil moisture become easier to be measured in efficient manner.

1.8 Thesis Contribution

The use of the Fuzzy logics in soil monitoring through water level and soil micronutrients control, training the available soil parameters which are soil moisture, temperature and humidity, and water level to work under both supervised and unsupervised manners. plant can now use its moderate water level and micronutrients.

1.9 Organization of the study

Chapter one: General Introduction: This is the introductory chapter. It describes the background of the study, the problem statement, and the objectives of the study, scope of the study, significance of the study, project interest or thesis contribution and the organization of the study.

Chapter two: Literature Review: this chapter clarifies the work done by other researchers towards soil monitoring about irrigation and drainage.

Chapter three: Research Methodology: this chapter clearly shows the writer proposed methodology with all corners covered

Chapter four: System Design and Analysis: this chapter shows the prototype, corresponding data dashboard and serial monitor and how the installation of sensor nodes is done

Chapter Five: Conclusion, recommendation and future works: this chapter gives the conclusion of the study and give recommendations for the future researchers, and propose the future works

Appendix: these scripts containing the overall codes for the Arduino based prototype

CHAPTER 2: RATIONALE AND LITERATURE REVIEW

2.1 Introduction

Irrigation and drainage are among of factors that contributes for getting good production in agriculture as they facilitate in water management for crops in the farmland. The water management is required because different vegetation have different water quantity in their different stages for their life span [15].

In IoT based for precise irrigation platform, focused on precise irrigation with different challenges like adaptability where the system is flexible enough for different scenarios, complexity and deployment, which is concerned, by the variety of fog and cloud configurations. In smart drainage using IoT, as they saw poor drainage in smart city in India, they propose the drainage system for smart city, and this system used the water level sensor, gas sensor and flow sensor, all the data are sent to the cloud for further analysis [16].

IoT-Agro integrated collaboration model is introduced and it has three entities that are connected in the single framework of the network. Here the water and power are managed. Its main objective is to reduce any loss of resources such as water, land and electricity [17]. The smart water management platform (SWAMP) layered architecture considers three categories of services to ensure its replication and adaptability, Entirely replicable services deal with IoT services, storage services, data analytics and machine learning[15].

In project called Water Management in Agricultural Field using IoT, the implementation of the system in the field definitely helps to improve the production of the crops and manages the water resources effectively[18].

Digital Drainage System Using IOT: In this project, the information from environment are monitored by sensors, and predictive system is used to give the details of the level of water in the place so that the action may be taken. The system is read to give the alert about the location where there is clogging[19]. The drainage system is coming to replace the manholes. Sensors are placed inside the manhole and they detect and transfer the information about the water, sticky contents, to detect elevated flow levels of drainage and clogging. Sensors monitor the water levels, based on the values given by the sensors, drainage water levels and location identification and those appropriate information are sent to the Gateway and then be stored to the cloud[19] and this system is important to maintain cleanliness, health and safety of cities.

Underground Drainage Monitoring System Using IOT: It is the underground infrastructure that is used also to make clean, safety and health of the city. this drainage system helps to monitor the water level, atmospheric temperature, water flow and toxic gasses and then If drainage system catch blocked and water overflows, the sensor system can identify, after it sends information by the transmitter which is situated in that area to the managing station[20].

Smart drainage monitoring system-using IoT: This system comes to limit the overflowing of water on the streets and sometimes mixes in the drinking water that damages people's health. Sensors that track the level of water, flow of water and harmful gases, compose it. The range of values are stored in the cloud storage, so that they can be analyzed. The drainage status is observed by SMS sent to the Blynk application [13].

An IoT based Drainage Overflow Forecast Monitoring System: The drainage system uses mobile application to monitor the status of water flow via the dashboard. The microcontroller will sense the water level detected by the sensor connected to it. Whenever the water level shows an abnormality, then these sensors can send the signal to the main server [22].

In the paper published called IoT based Agro soil maintenance through micronutrients and protection of crops from excess water, the development of a smart system based on IoT was developed and the irrigation is done by drone, also the threshold is determined where the notification may come in case of the water become higher or less than what was expected[23],the drawbacks of this system is remarquable in case of the rainfall season where after the irrigation the climate may change and the rain causes the soil to become overwatering where the drainage can take place.

Among of literatures, the related work in farmland this is project called IoT based Agri_soil maintenance through micronutrients and protection of crops from Excess water. In this project, soil in farmland are protected where the water logs are managed, the soil moisture is monitored by using moisture sensors, at a time the moisture level exceed the required level, the cloud service commands the relay to switch on a motor, and the sanction motor take away the excess water from the land. This system is semi-automated where it can work for itself or be controlled by a mobile application [1].

2.2 Sensors required for soil monitoring based on irrigation and drainage

In soil monitoring different sensors are used to detect moisture, pH, micronutrients, water flow, temperature and humidity, rainfall, and water level.

Soil moisture sensor: is used to measure the quantity of water in the soil[1],this quantity may be sufficient ,insufficient or excess. In case the water is sufficient, the vegetation is in good time and it may grow in perfect way, when other factors are stable.in case there is insufficient water in the soil, the vegetation is on need of irrigation. When the water exceeds the required water, the soil is on need of drainage, so that the plantation be stable for its moderated water.

pH sensor: this sensor is used for detecting the alkalinity and acidity in the soil or other solutions.

Water flow sensor: is a sensor that detect the amount of water flow**.**

Temperature and humidity sensor: Those sensors are helpful in detecting any changes in environment, as evapotranspiration is one of methods of water drainage, the increase of temperature increase the speed for water drainage in natural way.

Water float sensor is the sensor that is fixed in the surface of the field, after measuring the water flow quantity, the farmers need to know the level that cannot be extended and fix the water level sensor, as the water reach that level and float to the float sensor, the system remove that exceeded water.

2.3 The drawbacks of the existing solutions

In general, the existing solutions show different limitations, some literature shows that the role of their systems is to identify where there is a waterlogging and use the traditional method to remove it, other limitation is the incapability of the system to remove the identified water [23].

The existing systems are familiar in smart city applications where they try to make the city clean not in farmland.

The existing systems also choose one direction not two directions, it means in farmland there is the need of irrigation where the water is insufficient in the farm depending to the vegetation and the farm requires drainage at time where the water become excess depending to the vegetation.

CHAPTER3: RESEARCH METHODOLOGY

3.1 Introduction

Fuzzy inference system is chosen in this system because its algorthim working in cases of uncertainity. It is difficulty to know the single measure of water that is required in the soil for sugarcane vegetation , the use of fuzzy logic helps in putting different parameters in range so that the given task it taken.with clear boundaries ,it is easy to know the water level required for sugarcane, the temperature required for making the evapotranspiration in case of natural drainage and the pH range in the soil so that the sugarcane may be protected.

With fuzzy logic,the system has the ability to handle troubles with non precise data,it is also easy to develop and the changes can be easly detected,it means change in soil moisture,temperature and humidity and also the pH in the soil.

3.2 The ways of fuzzy inference system functionality

Fuzzy inference system has two types,which are Mamdani and sugeno,in this research,Mamdani is chosen to be used.It has six steps to be fullfiled:the first is define and setting fuzzy rules,the second is fuzzifying the inputs basing on the input membership functions,the third is multiplexing the fuzzified inputs basing on fuzzy rule to form rule strengh,the fourth is getting the consequences of the settled rule by merging the rule strengh and membership function,the fiveth is Finding the consequence of the rule by combining the rule strength and the output membership function, the sixth is to combine the consequences to get an output distribution and defuzzifying the output distribution.

Fuzzy inference system has this form: if (input 1 is a membership function1) and/or (input 2 is a membership function 2) and /or (input n is a membership function n) then (output n is a membership of water level in the soil) so the task is taken accordingly.

3.3 Components used in this system

This system has four parts:

1.Sensing :to detect the changes in the environment,different sensors were deployed,which are pH sensor, water float sensor,Temperature and humidity sensor.

Below there are the details of different sensors needed to establish this system,and the Nyabarongo valley was taken as case study:

pH sensor:this sensor detects the variation in acidity and basisity in soil.

Water float sensor:It detects the quandity of water upground the soil, at a time it floats ,the threshorld reaches, and as the quantity of water pushes the water float sensor,the command of removing that water is sent.

Capacitive soil moisture sensor: It detects the quantity of water in the soil, as there are so many methods of removing the excess water,this sensor shows the quantity of water so that some activities may begin which is irrigation or drainage**.**

Temperature and Humidity sensor(DHT11): It detects the changes in environment,as among of drainage methods ,there is the need of evapotranspiration,this sensor can help in controlling the quatity of water that can be consumed in a given temperature and humidity.

2. **Data Processing Microcontroller side**: ATMega Microcontroller is used in this system for its numerous analogue ports and its flexibility towards different applications. The Arduino UNO is also used for uploading codes to ATMega.

3. **Gateway and Data Transmission side**: In this project, GSM is chosen to be used, because it is flexible and general its speed meets the user requirement.

4**.Actuation side**: Buzzer, RED, and Pumps are used.

5. **Analysis and Data visualization**: Thinkspeak cloud is chosen, because its flexibility of being accessed with connected different devices like computer, tablet or smart phone. The end-user needs to analyze the data by using dashboard. He or she needs also the storage of given data for future use.

3.4 Nyabarongo valley features

Nyabarongo valley is devided into small fields called plots.Each plot has a given number of sugarcane planted in that surface,in this project,each plot is considered and a sensor node is assigned for a plot.

3.5 Sensor distribution in the Nyabarongo farmland

As the Nyabarongo farm is devided into plots,each plot is assigned a sensor node.each sensor node is made up: water float sensor,capacitive soil moisture sensor,pH sensor and, temperature and humidity sensor, at the sensing side,the arduino Uno and Atmega 328 at controlling side,and also irrigation pump and drainage pump in the actuation side.

3.6 System architecture

The architecture of this system from sensor to the cloud,and from the cloud to the end user

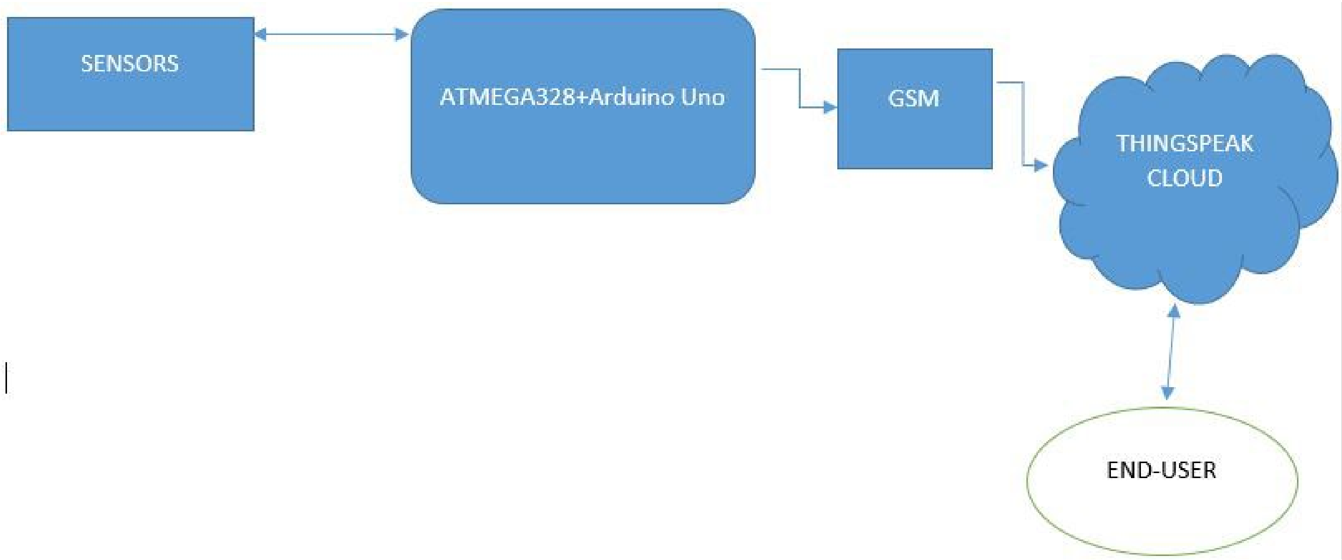

Figure 1:System architecture

The sensors collect the information from the field, all the data collected are controlled by ATMega microcontroller, then through GSM module, the fetched data are sent to the Thinkspeak Cloud, where the further analysis occur. The End-user may access the data through Smart phone, Tablet or Computers connected to the Internet.

3.6.1 System components deployment

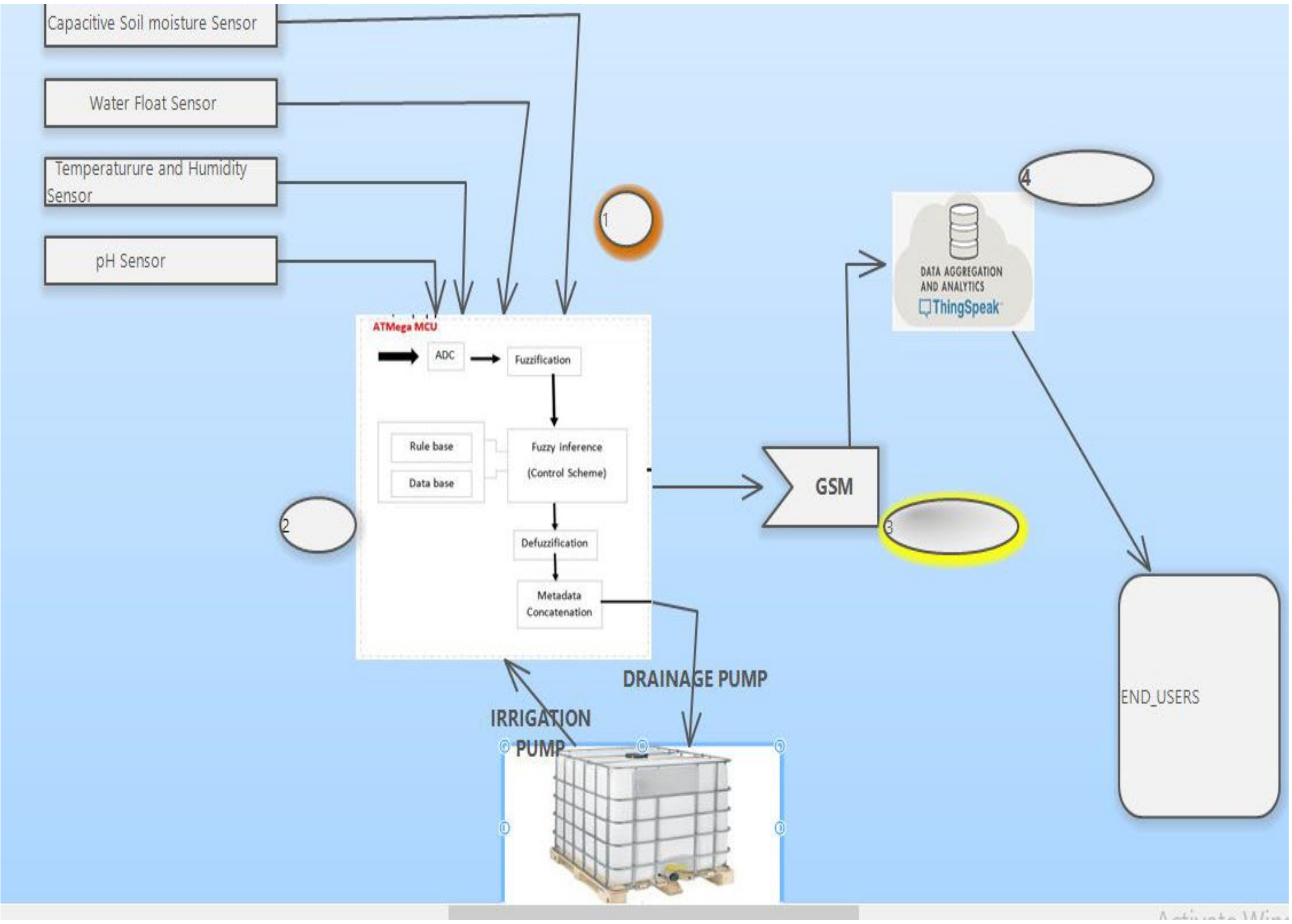

Figure 2:Components deployment

As shown at this figure, the **part1** is made by different sensors, which are: capacitive soil moisture sensor which detects the volume of water in the soil. The soil moisture sensor module is used to measure the moisture level of the soil. It detects the volumetric content of water in the soil and gives the moisture level as output.

Figure 3:Capacitive soil moisture sensor

The water float sensor which detects the water that reaches the threshold

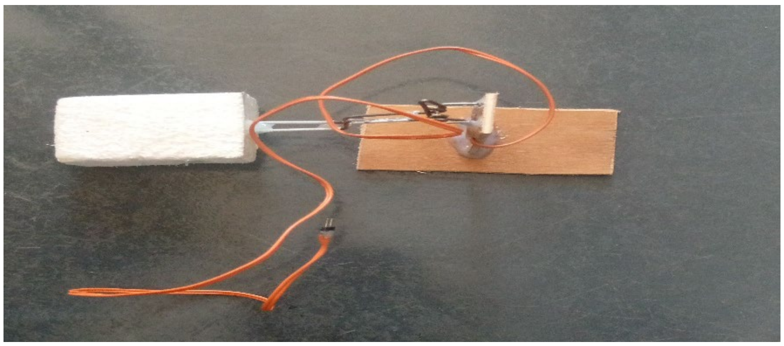

Figure 4:Water float sensor

,The temperature and Humidity sensor which will detect the level of temperature and humidity that will help the system to know if the system will do the total drainage or partial drainage.

Figure 5:Temperature and Humidity sensor

Temperature and Humidity sensor specifications

Sn	**specification**	**Value**
1	**size**	**15.5mm x 12mm x 5.5mm**
2	**Working voltage**	**3 to 5V**
3	**temperature readings**	**±2°C**

Table 1:Temperature and Humidity sensor specifications

The pH sensor will detect the acidity and alkalinity level in the soil. Soil can be acid, neutral or alkaline, according to its pH value. Most plants prefer a pH range from 5.5 to 7.5; but some species prefer more acid or alkaline soils. every plant requires a particular range of pH, for its optimum growth.

Figure 6:pH sensor

Second **part2,** is made by ATMega board microcontroller**,** advantages of using ATMega, it runs on 5V , Inside ATMega Microcontroller board, is defined the Fuzzification process, creation of rules and data, Defuzzification process, and concatenation process.

Figure 7:Atmega328

ATMega board microcontroller specifications

SN	**Specifications**	Value
1	Operating Voltage	5V
2	Digital Inputs/Output Pins	14 (6 provide PWM output)
3	Microcontroller	ATmega328P
4	Clock Speed	16 MHz

Table 2:ATMega Board specifications

The third **part3,** describes the communication channel of data transfer from ATMega to the thinkspeak cloud, which is GSM

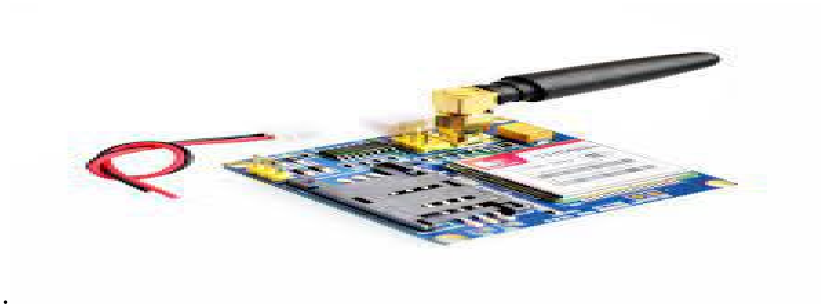

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Figure 8:GSM module

GSM module specifications

Sn	specification	Value
1	Working voltage	3.3 and 5V
2	Antenna circuit	increase the signal strength
3	Simcard	SIM900A serial port output terminal

Table 3:GSM module Specifications

Part 4, is made by Thinkspeak cloud where the field data are stored and help the end user to make further analysis.

Other parts are made by pumps, which are made by irrigation pump and drainage pump and Mega tank.

Figure 9:Water pump

Water pump specifications

Sn	specifications	Value

1	**working Voltage**	**DC 6V to 12V (1 amps)**
2	**The flow rate**	**from 1liter – 3Liters/minute.**
3	**Pump Size**	**90mm * 40mm * 35mm**
4	**Life span**	**up to 2500 Hours**

Table 4:Water pump specifications

POWERING SIDE: A solar panel is connected to a rechargeable battery of 12V, as the pumps are using 12V,and by using step down component the 12 voltage become 5v as many components connected to the board are using the 5V.

CHAP 4: SYSTEM ANALYSIS AND DESIGN, PROTOTYPING AND EXPERIMENTAL RESULTS

4.1 Introduction

The design and prototype of this project is obtained and some results are analyzed.

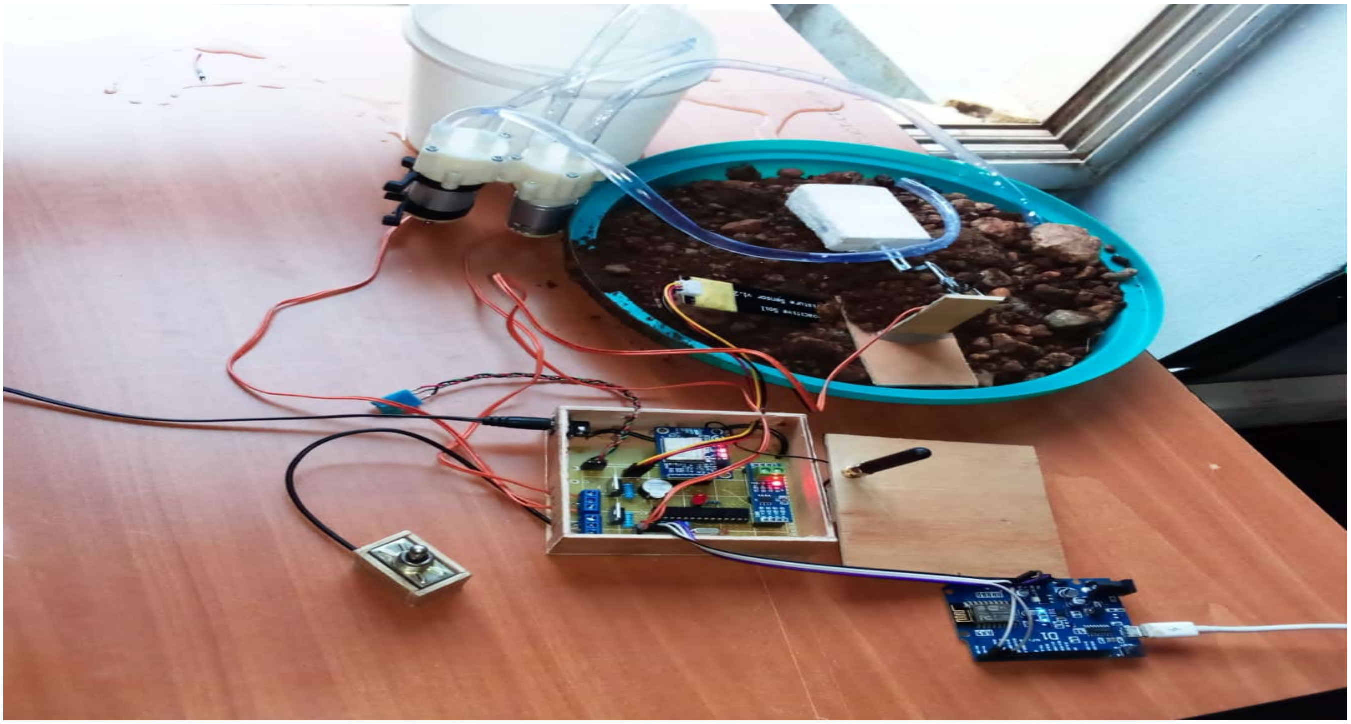

Figure 10:System prototype

This figure shows a prototype this system.

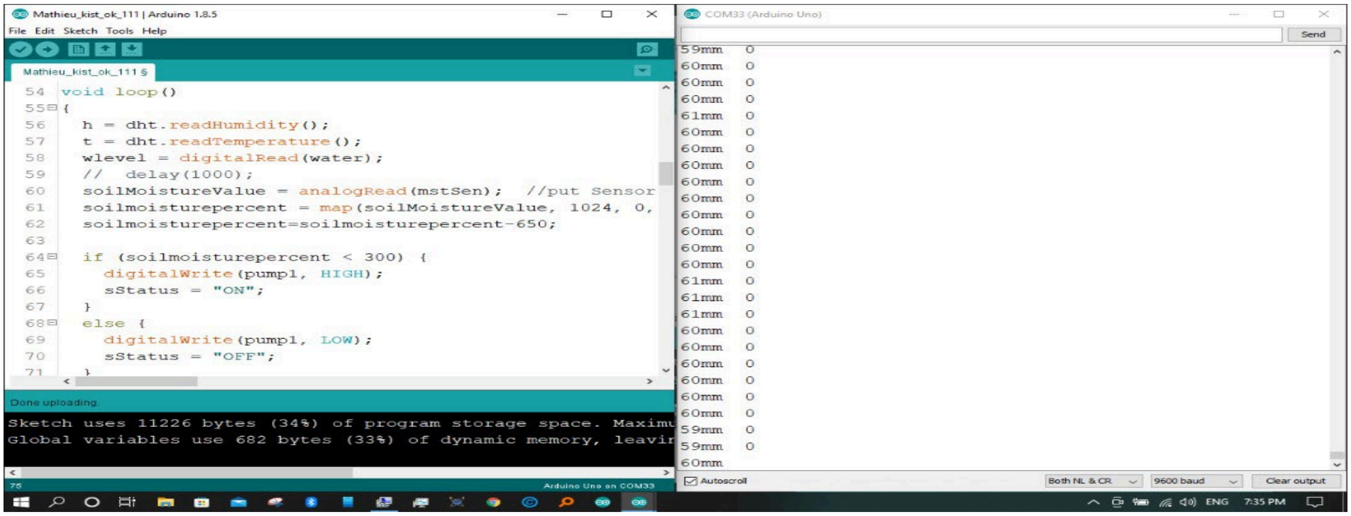

Figure 11:Arduino codes when the system working on irrigation

Let the germination period be considered ,and the maximum water needed in this period is 300mm,the data fetched are below 300 mm ,then the task is irrigation because the soil moisture is below 300mm.

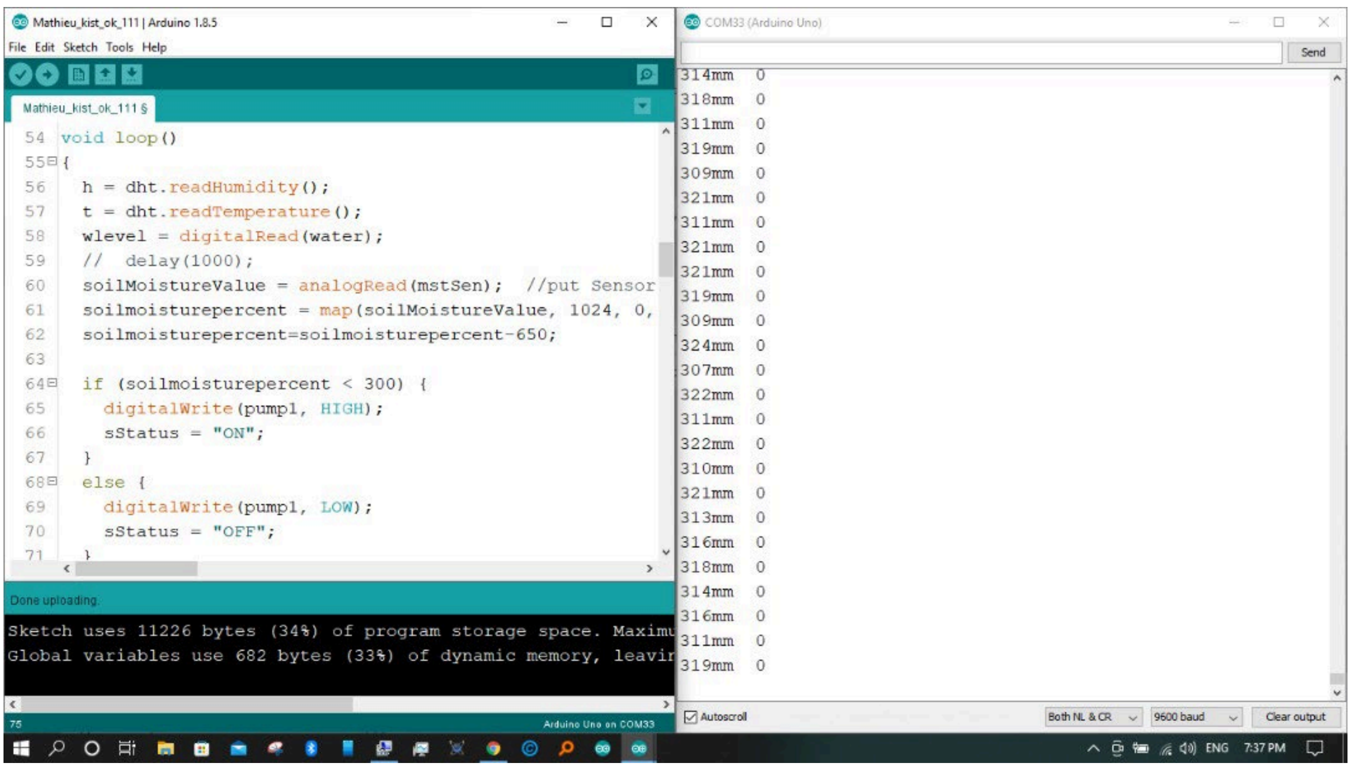

Figure 12:Arduino Codes when the system is working on drainage

As germination period is considered as example for sugarcane and the moisture soil is above 300mm,the assigned task is drainage.

4.2 SIMILATION IN MATHLAB

In fuzzy logic, the input and output are required. In this research, the soil moisture, Temperature and humidity, and pH are the Inputs, then the Irrigation and drainage are the Outputs.

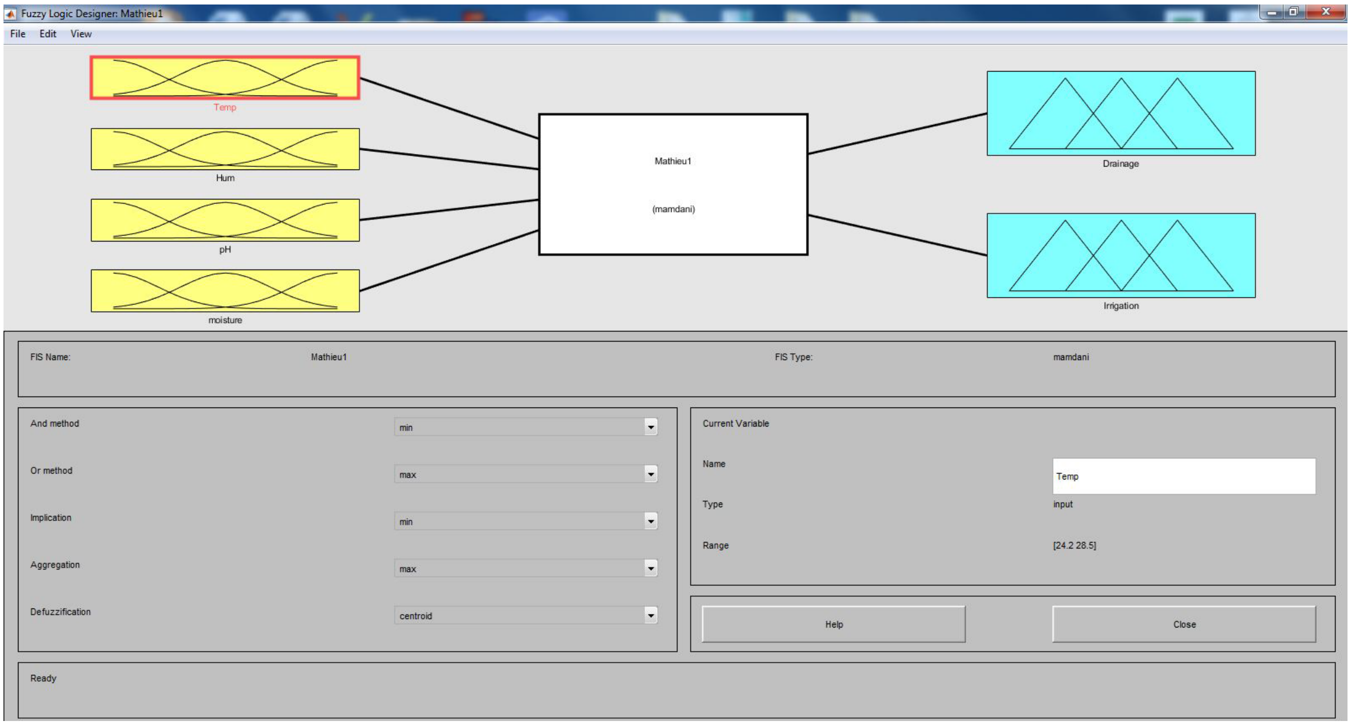

Figure 13:input and Output diagram in Mathlab

The outputs depend to the behavior of the inputs, it means here the drainage or irrigation depends to the changes of moisture soil, and temperature and humidity.

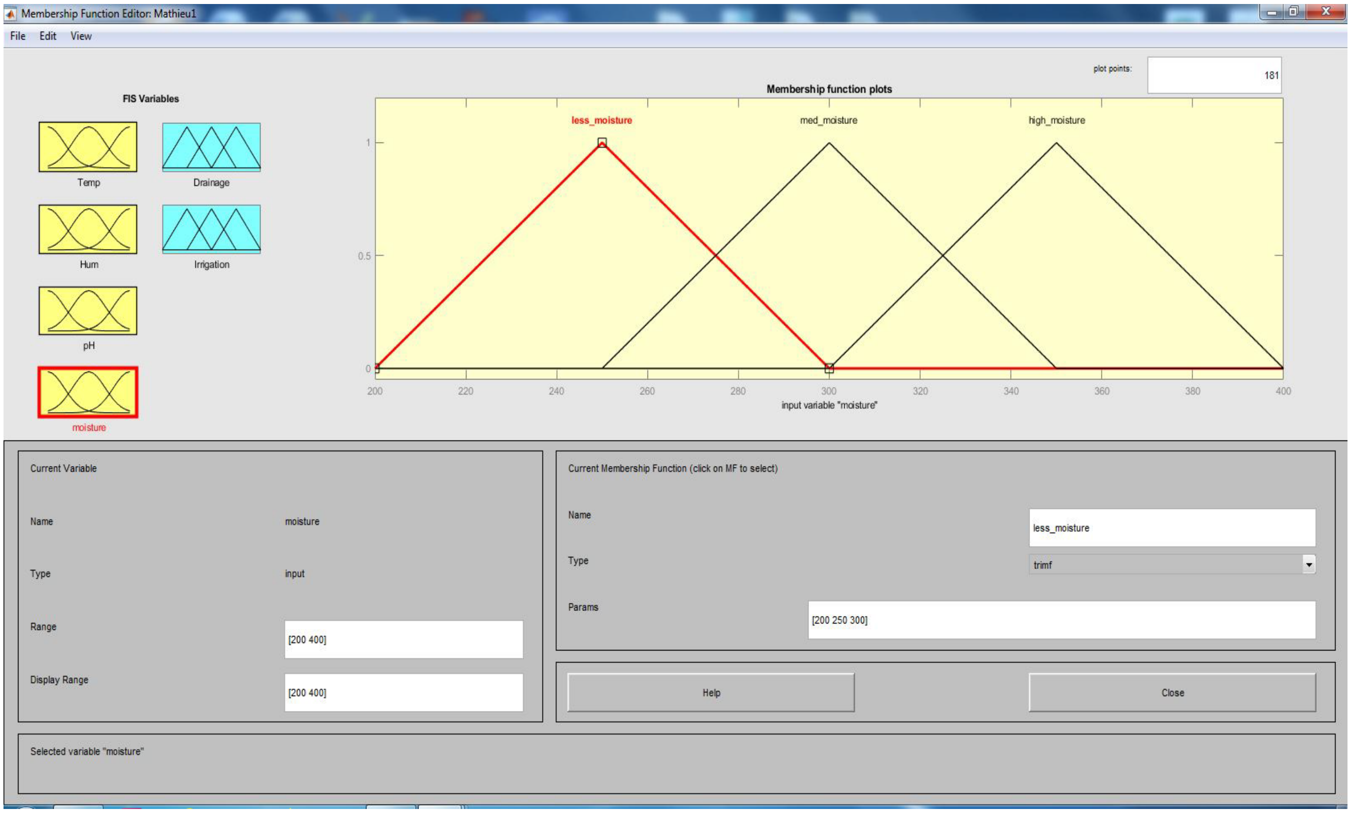

Figure 14:Soil moisture membership

The soil moisture may be change from less moisture level, required moisture level and excess moisture level. Here as the system is intelligent, it will combine the changes of moisture level with other factors such as temperature and humidity so that some task may be taken.

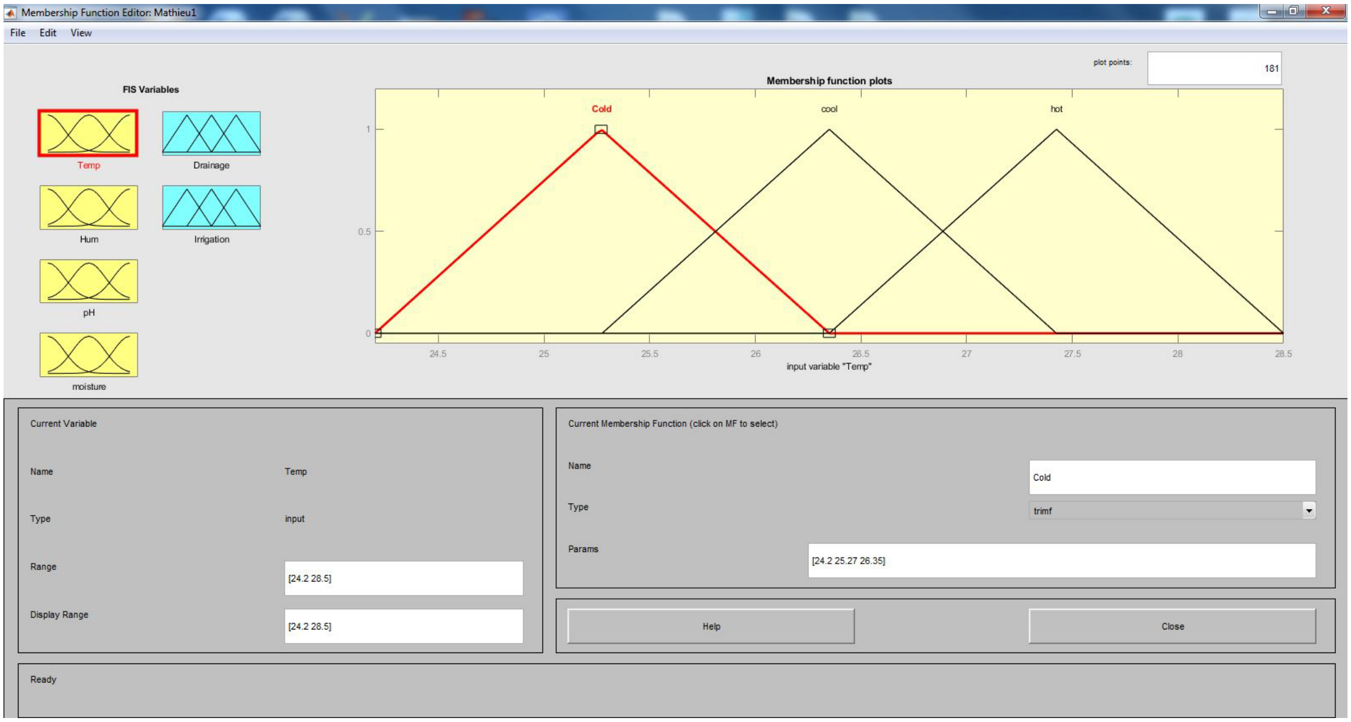

Figure 15:Temperature and Humidity membership

As Temperature increases the evapotranspiration is facilitated and the system will combine the variation of temperature and Humidity with the changes of moisture level to assign the output if the moisture level is high and the temperature is high then the task is partial drainage.

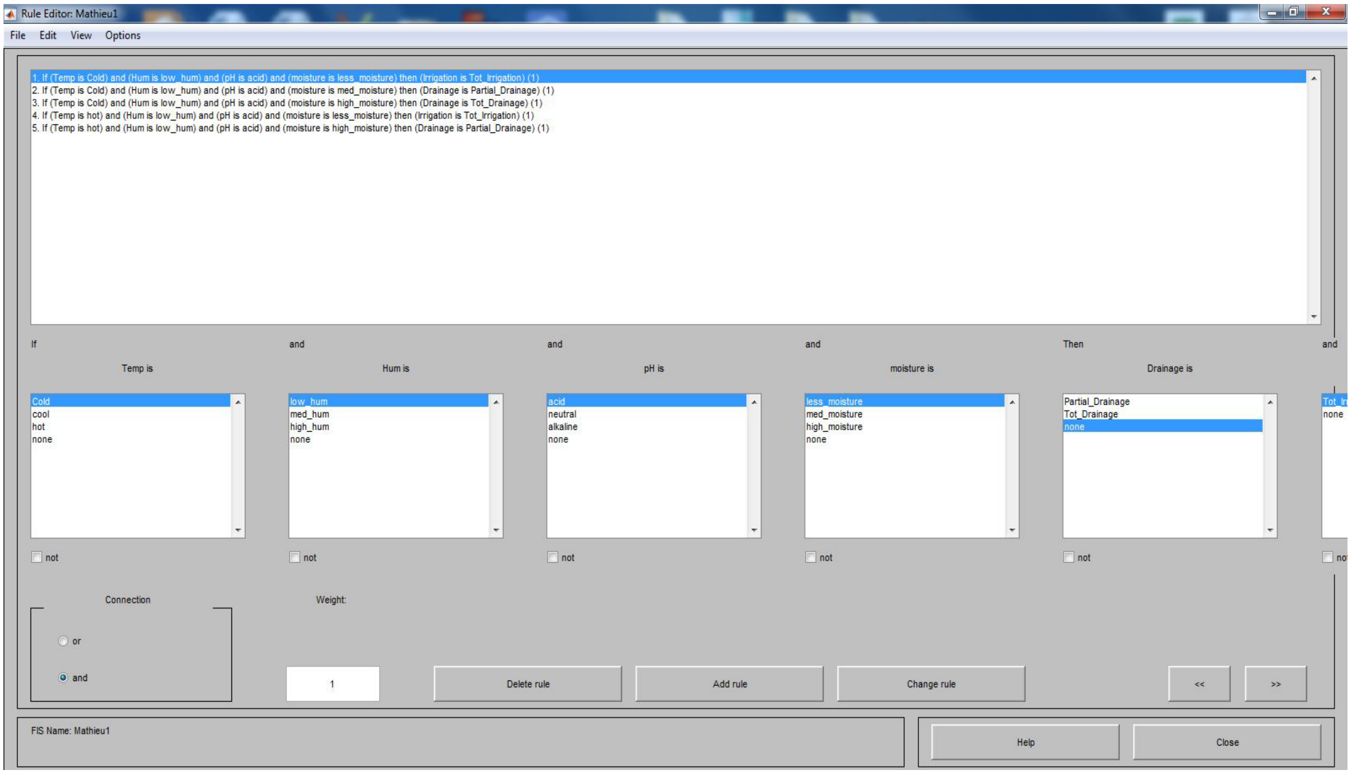

Figure 16:Set of rules in fuzzy inference system

All those are the rules that will be guide the system to assign the task. Each rule is independent. this the list of the rules that will be followed by the system:

1. If the temperature is cold and the Humidity is low, the moisture level is less, then the system assigns the irrigation.
2. If the temperature is cold, humidity is low, the moisture level is medium then the system assigns the partial drainage.
3. If the temperature is cold, the moisture level is high the task is total drainage.
4. If the temperature is hot, the moisture level is less ,then the task becomes irrigation.
5. If the temperature is hot, the moisture is high then the task becomes partial drainage.

After simulation, the system shows that as the temperature increases and the soil moisture reduced, the system makes the total drainage, and as the temperature reduced and the soil moisture increased, the system work on partial drainage.

If the temperature is high and the soil moisture is less, the system works on irrigation.

All those rules are shown in this figure:

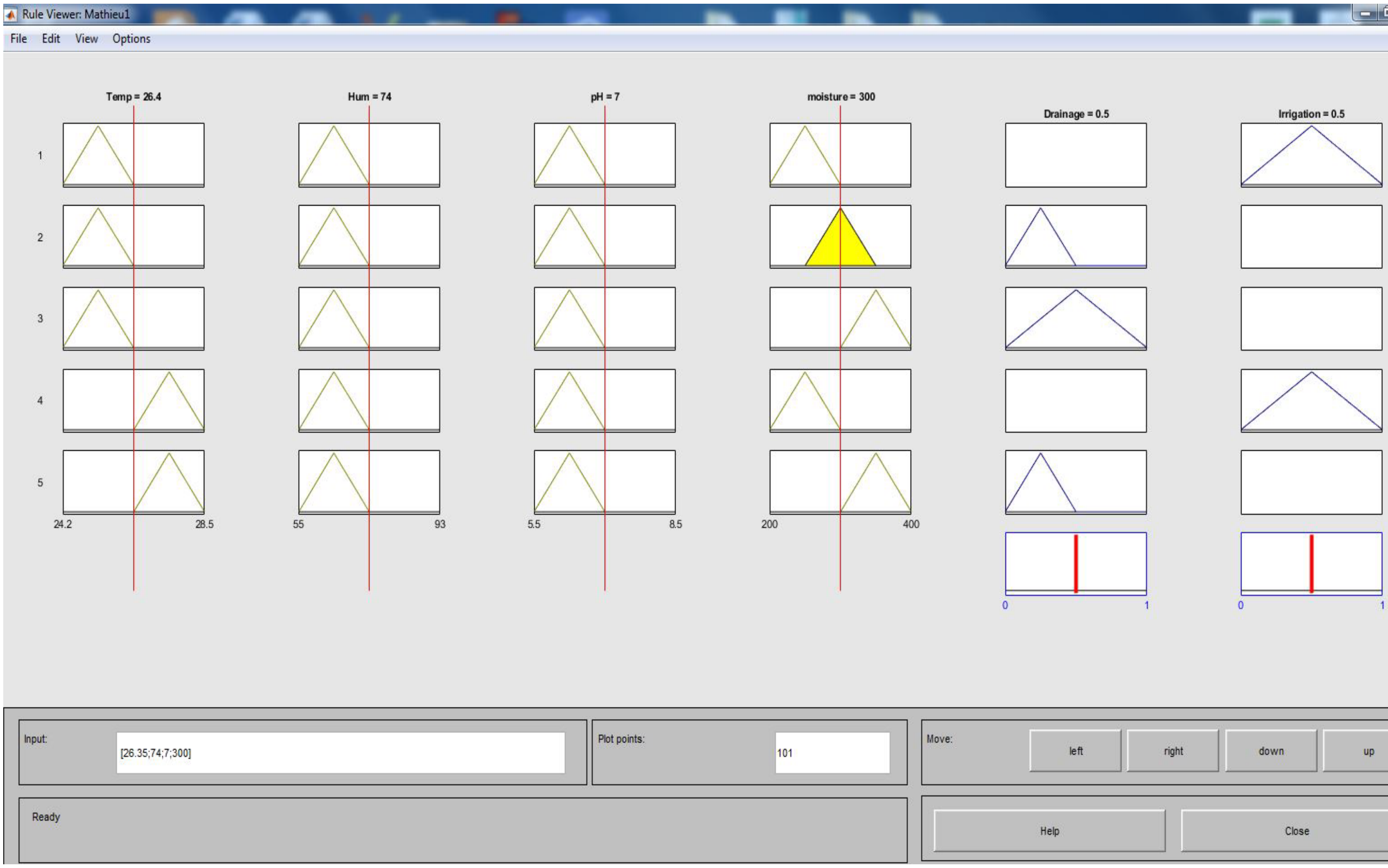

Figure 17:fuzzy Rules viewer

CHAP 5: CONCLUSION, RECOMMENDATION AND FUTURE WORKS

This research aims to design and make the prototype of agri_soil monitoring from excess water, in Nyabarongo valley, referring to the sugarcane plantation. The methodology is to deploy an IoT system where the sugarcane plantation lives with its moderated water. The water management is now reached by using this system, because as this sugarcane vegetation life span pass in different stages with different need of water level, in this research by considering one stage of sugarcane in germination period where the maximum water needed is 300mm,this system is able to detect this water interval and find if the data fetched are included in the range of sugarcane water in germination period, if the water is less 300mm,the system itself makes the irrigation until the water reach to 300mm,if the water level is above 300mm ,the system itself makes the drainage until it reaches to 300mm.The system may be updated when there is a change in stages where there is different need of water.

Fuzzy inference system helps by combining different factors which are Temperature and Humidity with the soil moisture level, at time the temperature is high and the moisture level is high, there is the partial drainage. This system regulates the quantity of water in each stage after being updated from stage one to stage two. At a time, the temperature is low and the moisture of the soil is high, the system makes the drainage. If the system has a problem in commanding the pump to make drainage or irrigation, the commands are ordered by the user manually. If there is insufficient water in the soil, the user uses the switch and gives water to the soil through the irrigation pump. In rainfall seasons, where the soil moisture may experience the excess water, there is a need of drainage of water from soil. A failure to the system to make automatic irrigation or drainage, there is manual way to irrigate or to make drainage by using Switch.

Recommendation:

I recommend that this project be implemented in Nyabarongo farmland, to minimize the vegetation that are destroyed by the effect of excess water or insufficient water.

Future works:

This project should be extended from Nyabarongo valley to other farmlands and different vegetation so that the agriculture sector produces enough agriculture resources to the population. The extension of this system will also include the system ability to predict how long it will take for the valley to gain back its normal water level after rainfalls period.

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Appendices: Project Arduino codes

```
/*dht d9, ms a0, bz d4, led d12,
  p1 d2, p2 d3, ro d8,
  re d7, de d6, di d5
*/

#include <SoftwareSerial.h>
SoftwareSerial gprsSerial(10, 11); //TX...RX
#include "DHT.h"
#define DHTPIN 9
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
float h;
float t;
float ph = 5.9;
#define pump1 2
#define pump2 3
#define mstSen A1
#define bz 4
#define led 12

int soilMoistureValue = 0;
int soilmoisturepercent = 0;

String devID = "MFD21-A";
String sStatus = "";
String tStatus = "";

const int water = A3;
int lwater = 1;
```

```
int wlevel;

long gprsTime = 0;
long startTime = 120000;
long  currentTime;

void setup() {
  dht.begin();
  gprsSerial.begin(9600);               // the GPRS baud rate
  Serial.begin(9600);
  pinMode(mstSen, INPUT);
  pinMode(water, INPUT_PULLUP);
  pinMode(pump1, OUTPUT);
  pinMode(pump2, OUTPUT);
  pinMode(bz, OUTPUT);
  pinMode(led, OUTPUT);
  digitalWrite(pump1, LOW);
  digitalWrite(pump2, LOW);
  digitalWrite(bz, LOW);
  digitalWrite(led, LOW);

}

//==============================================================
void loop()
{
  h = dht.readHumidity();
  t = dht.readTemperature();
  wlevel = digitalRead(water);
  //  delay(1000);
  soilMoistureValue = analogRead(mstSen);  //put Sensor insert into soil
  soilmoisturepercent = map(soilMoistureValue, 1024, 0, 0, 1250);
```

```
soilmoisturepercent=soilmoisturepercent-650;

if (soilmoisturepercent > 300) {
  digitalWrite(pump1, HIGH);
  sStatus = "ON";
}
else {
  digitalWrite(pump1, LOW);
  sStatus = "OFF";
}

Serial.print(soilmoisturepercent);
Serial.print("mm");
Serial.print("  ");
Serial.println(wlevel);

if (wlevel == 1) {
  digitalWrite(pump2, HIGH);
  tStatus = "ON";
}
else {
  digitalWrite(pump2, LOW);
  tStatus = "OFF";
}
if (gprsSerial.available())
  Serial.write(gprsSerial.read());

currentTime = millis();
if ((currentTime - gprsTime) >= startTime) {
  gprsTime = currentTime;
  pushData();
}
```

```
}

//==========================================================

void sendSMS() {
  gprsSerial.println("AT+CMGF=1"); // Configuring TEXT mode
  ShowSerialData();
  gprsSerial.println("AT+CMGS=\"+250788630874\"");
  ShowSerialData();

  String msg = ("Ambient temperature of" + String(t) + "*C and"); //text content
  msg += (" relative humidity of" + String(h) + "% from");
  msg += (" field: " + devID + " with acidity of" + String(ph) + " pH is now operating");
  msg += (" where irrigation pump is " + sStatus + ", while water remover one is " + tStatus);

  gprsSerial.print(msg);
  ShowSerialData();
  gprsSerial.write(26);
}

//==========================================================
void pushData() {
  gprsSerial.println("AT");
  delay(1000);

  gprsSerial.println("AT+CPIN?");
  delay(1000);

  gprsSerial.println("AT+CREG?");
  delay(1000);

  gprsSerial.println("AT+CGATT?");
```

```
delay(1000);

gprsSerial.println("AT+CIPSHUT");
delay(1000);

gprsSerial.println("AT+CIPSTATUS");
delay(2000);

gprsSerial.println("AT+CIPMUX=0");
delay(2000);

ShowSerialData();

gprsSerial.println("AT+CSTT=\"internet.mtn\"");//start task and setting the APN,
delay(1000);

ShowSerialData();

gprsSerial.println("AT+CIICR");//bring up wireless connection
delay(3000);

ShowSerialData();

gprsSerial.println("AT+CIFSR");//get local IP adress
delay(2000);

ShowSerialData();
gprsSerial.println("AT+CIPSPRT=0");
delay(100);
ShowSerialData();

gprsSerial.println("AT+CIPSTART=\"TCP\",\"api.thingspeak.com\",\"80\"");//start up the connection
```

```
  delay(2000);
  ShowSerialData();

  gprsSerial.println("AT+CIPSEND");//begin send data to remote server
  delay(2000);
  ShowSerialData();

  //  Serial.print("GET https://api.thingspeak.com/update?api_key=U2OBVB3ZHDOPUL8C&field1=" + String(devID) + "&field2=" + String(t) + "&field3=" + String(h) + "&field4=" + String(ph) + "&field5=" + String(sStatus));
  //  Serial.println("&field6=" + String(tStatus));

  Serial.print("GET https://api.thingspeak.com/update?api_key=U2OBVB3ZHDOPUL8C");
  Serial.print("&field1=" + String(devID));
  Serial.print("&field2=" + String(t));
  Serial.print("&field3=" + String(h));
  Serial.print("&field4=" + String(ph));
  Serial.print("&field5=" + String(soilmoisturepercent));
  Serial.println("&field6=" + String(tStatus));

  //  gprsSerial.print("GET https://api.thingspeak.com/update?api_key=U2OBVB3ZHDOPUL8C&field1=" + String(devID) + "&field2=" + String(t) + "&field3=" + String(h) + "&field4=" + String(ph) + "&field5=" + String(sStatus)); //begin send data to remote server
  //  gprsSerial.println("&field6=" + String(tStatus));

  gprsSerial.print("GET https://api.thingspeak.com/update?api_key=U2OBVB3ZHDOPUL8C"); //begin send data to remote server
  gprsSerial.print("&field1=" + String(devID));
  gprsSerial.print("&field2=" + String(t));
  gprsSerial.print("&field3=" + String(h));
  gprsSerial.print("&field4=" + String(ph));
```

```
  gprsSerial.print("&field5=" + String(soilmoisturepercent));
  gprsSerial.println("&field6=" + String(tStatus));

  delay(3000);
  ShowSerialData();

  gprsSerial.println((char)26);//sending
  delay(3000);//waitting for reply, important! the time is base on the condition of internet
  gprsSerial.println();
  ShowSerialData();

  gprsSerial.println("AT+CIPSHUT");//close the connection
  delay(100);
  ShowSerialData();
}

//=====================================================================

void ShowSerialData()
{
  while (gprsSerial.available() != 0)
    Serial.write(gprsSerial.read());
  delay(500);
}
```