**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

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**FACULTY OF INDUSTRIAL TECHNOLOGY**

**DEPARTMENT OF INDUSTRIAL AND MANUFACTURING**

**ENGINEERING**

**FINAL YEAR PROJECT [TIE5009]**

**For**

**TINASHE TANYARADZWA MABIKA (N01519975J)**

**SOIL MOISTURE PREDICTION FOR SMART IRRIGATION SCHEDULING**

**SUPERVISOR:**

# 

# DECLARATION

I, **TINASHE TANYARADZWA MABIKA** declare that:

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**PERMANENT ADDRESS: 5289 Nkwisi Gardens, Tynwald, Westlea, Harare**

**DATE: ..............................................................**

# DEDICATIONS

# ACKNOWLEDGEMENTS

# ABSTRACT

Water balance is essential for high quality yields. Under-wateredcrops suffer from nutrient deficiencies while over-watered plants are more prone to diseases and can lead to root death through choking. Also, over-watered plantsare not able to withstand dry spells during dry seasons. Water-saving agricultural practices and sound watermanagement strategies are therefore required to ensureviability of the farming industry.

With great advancements in Internet of Things and Artificial Intelligence its high time we leverage the beauty of these technologies in Zimbabwe as it answers to most of the challenges we are facing. Reduction in production costs through automation of manual tasks, remote monitoring, high output yields and better land fertility are some of the advantages of applying these technologies into farming.

This study is aimed at developing a smartirrigation controller which acquires soil moisture contents, temperature, humidity, volume of water used, solar radiation and whether it’s raining or not. The controller cleans the signals, stores to a local database before storing to an online database. Server-side JavaScript controller fetches data from the database and feed to a dynamic artificial neural network (DANN) which responds with predictions of soil moistures for the coming days to the irrigation controller and decisions can be made to best optimize water to be irrigated. The controller is able to send SMS and email notifications to the farm operators. This data is also relayed to aweb application where it can provide valuable information to any operator concerned and can remotely control the irrigation processes.

The heart of the controller circuit isthe WeMos atmega2560 Wi-Fi based micro-controller that uses C++ as a high-level programming language. Message notifications are achieved by interfacing with sim800L GSM module. The dynamic neural network is made from MATLAB neural network toolkit.

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# CHAPTER ONE - INTRODUCTORY CHAPTER

## Introduction

World climate change is causing a major blow on global water supplies. 70% of world’s fresh water is used for irrigation purposes, it is therefore important to develop and leverage trending technologies to monitor and control agricultural fields for sustainable and efficient water use (Victor et al., 2009). Irrigation should meet specific plant water demands to avoid overand under irrigation. This can be attained by performing irrigation operations basing on time, forecast and present soil moisture contents. Precision irrigation aims to find and quantify plant water needs in a smart way (Smith, 2011). This field of study is very helpful in estimating farming parameters like fertilizers and other input needsby assessing soil conditions, thus preventing inflexiblepractices in farming. The irrigation amount and timing is based on measurementsof soil, plant, and climatic variables from which the plant water need is inferred. Precisionirrigation and artificial intelligence applications have shown to improve water use efficiency, reduce energy consumption, and enhancecrop productivity by leveraging advances in control systems, and optimization algorithms.

## Background

With the drive to rebuild and grow our economy, it is now imperative that we utilize our abundant resources on the agricultural front. Agriculture occupies a central space in the Zimbabwean economy and has the potential to significantly reduce poverty, enhance economic growth and with time entrench economic stability.

According to the Food and Agriculture Organization, 70% of Zimbabwe’spopulation depends on agriculture. Climate change is threateningagriculture productivity and making worse some of Zimbabwe’s key agriculture challenges which arelow soil fertility and reliance on rain fed systems. In 2012, 76% of rural households lived below the poverty datum line and 32%of children under five were stunted as a result of malnutrition

The continuous increase in food demand requires a rapid improvement in food productiontechnologies. Food insecurity is a major challenge in developing countries. In a country likeZimbabwe where the economy is mainly agriculture based, use of technology to improve on yields isparamount.



Figure 1.1 Poor yield due to under irrigation (krcu.org, 2013)

Most ofirrigation controllers that are locally available are ON/OFFtype and these cannot give optimal results inirrigation costs and crop yield.

Picture below shows a major problem of over irrigation experienced by traditional open loop irrigation systems. Water is wasted, crops become more vulnerable to water borne diseases, land fertility decreases as vital minerals are washed away with excess water and as a result poor yields are experienced.

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Figure 1.2 Picture showing over irrigated land (Columbia.edu, )

## Aim

To develop a smart irrigation system that is able to predict soil moisture contents to optimize irrigation schedules.

## Objectives

* Design an irrigation controller based on AVR micro-controller.
* Design SMS notification interface and web application for remote monitoring.
* Create a Neural Network Model to predict soil moisture contents.
* Size pipe work for a 100m2 prototype

## Scope

The scope of this project entails the design and implementation of a micro-controller based irrigationsystem driven by an artificial neural network to help on watering scheduling. Also the design of a notification interface which will be sending important data about the field to the farmer via SMS’s. An online dashboard is also going to be made for monitoring and controlling irrigation processes.

## Justification

The proposed project will help the country as a whole as it is a step towards minimizing water supply wastages through run-off and evaporation of excess water as a result of over irrigation. Every farmer in Zimbabwe has a goal of producing healthy crops and high yields and this can be achieved by introducing smart technologies which makes use of big data and learning strategies to assist in farming (Baiphethi and Jacobs, 2009). By doing so, Zimbabwe will gain back its fame in food security. This will reduce manual work of controlling the system, thereby reducing production costs, it is with no doubt that this technology will be of great help to farmers as it requires few operators in the field to monitor and control

Irrigation is one of the most reliable method of crops production.More land now is being under irrigation and there is a need for optimal use of water. With the great advancement in electronics, microcontrollers and microprocessors has been used together with various sensors to gather data and control physicalquantities like temperature, humidity, heat and light. Using these technologies automation of processes is greatly increasing. Irrigation systems in crop production can also be automated. The systems help in saving water and thus more land can bebrought under irrigation. Crops grown under controlled conditions tend to be healthier and thusgive more yields.

Every farmer wants to know what’s happening to the crops so that good decision can be made in time. This project makes it possible for remote monitoring of soil moisture, outdoor humidity and temperature, volume of water usage.

## Methodology

To achieve the project research techniques and tools are going to be used in the development phase. Secondary information to be used in the review will be developed from mainly journals,  
internet, hand books, eBooks and books. In building the controller, software api’s and hardware documentations are going to be reviewed.

Methods to be used:

* Data Gathering to obtain training data for soil moisture predictive model
* Concept selection through scoring of possible solutions.
* Developing an Artificial Neural Network in Matlab to create soil moisture content forecasts
* Developing cloud server controllers to interface backend services.
* Programming WeMos atmega2560 micro-controller for hardware controlling system.
* Building a prototype.

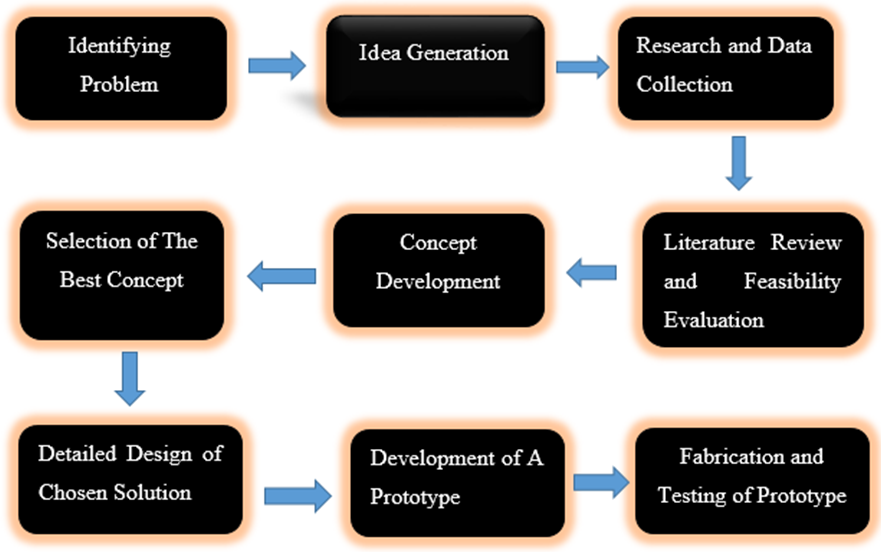


Figure 1.3 The Design and Development model.

## Timeline

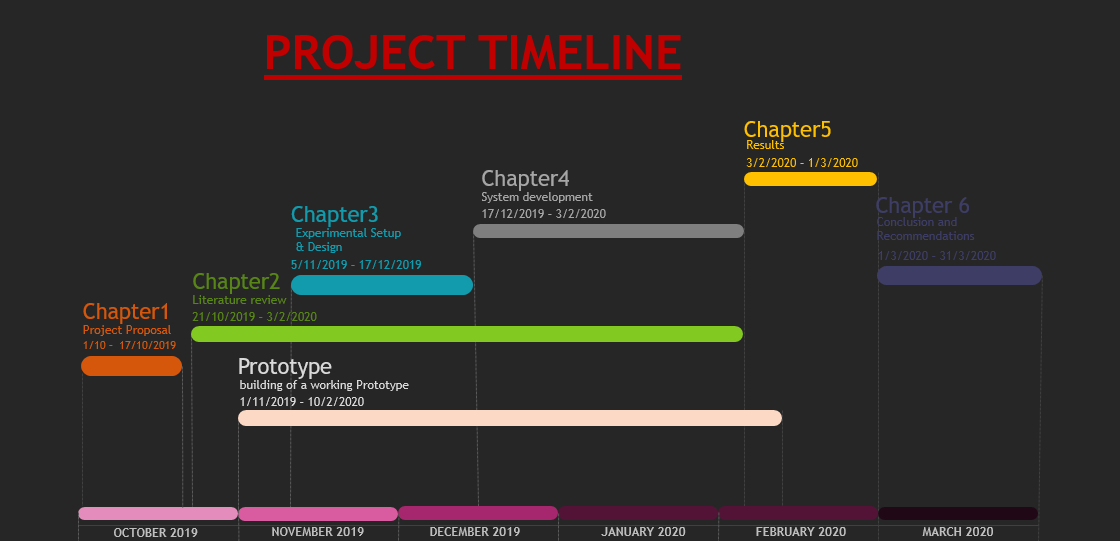


Figure 1.4 Project Timeline

Table 1.1 Scheduled timeline

|  |  |  |  |
| --- | --- | --- | --- |
| MILESTONE | START DATE | END DATE | NOTES |
| Chapter 1 | 1-10-2019 | 17-10-2019 | Project Proposal – Introduction to the project |
| Chapter 2 | 21-10-2019 | 3-2-2020 | Literature Review |
| Chapter 3 | 5-11-2019 | 17-12-2019 | Design and setup |
| Chapter 4 | 17-12-2019 | 3-2-2020 | System Development – detailed design of the concept and flow process |
| Chapter 5 | 3-2-2020 | 1-3-2020 | Project Results – Presentation of the system output |
| Chapter 6 | 1-3-2020 | 31-3-2020 | Conclusion and Recommendation |
| Prototype | 1-11-2019 | 10-2-2020 | Procure hardware components , build the controller and programming |

## Summary

The proposed project intends to use Artificial Intelligent techniques, which are growing in the field of agriculture and engineering as a whole. By gathering soil moisture values the system will be used to generate irrigation schedules and predict on the soil moisture values for the upcoming days and decisions can be made in time. In doing so, the system will encourage maximum efficiency of water usage and plant growth and healthy. With its capabilities, it will wrestle with problems related with under and over irrigation and major decisions will be made in time.

# CHAPTER TWO – LITERATURE REVIEW

## Introduction

## Types of Agricultural Water Use

There are two main ways that farmers and ranchers use agricultural water to cultivate crops

### Irrigation

Irrigation is the process of applying water to the crops artificially to fulfil their water requirements. Nutrients may also be applied to the crops through irrigation. The various sources of water for irrigation are wells, ponds, lakes, canals, tube-wells, and even dams. Irrigation offers moisture required for growth and development, germination, and other related functions.

Water moistens the soil and thus helps in penetration of roots even into the dry field. The frequency, rate, amount and time of irrigation are different for different crops and also vary according to the types of soil and seasons. For example, summer crops require a higher rate of water as compared to winter crops.

#### Types of Irrigation

There are different types of irrigation practised for improving crop yield. These types of irrigation systems are practised based on the different types of soils, climates, crops and resources. The main types of irrigation followed by farmers include:

##### Surface Irrigation

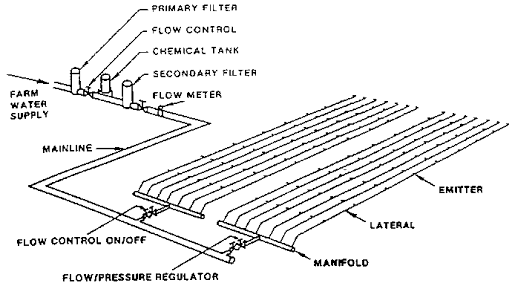
Water is applied and distributed over the soil surface by gravity. It is by far the most common form of irrigation throughout the world and has been practiced in many areas virtually unchanged for thousands of years. Surface irrigation is often referred to as flood irrigation, implying that the water distribution is uncontrolled and therefore, inherently inefficient. In reality, some of the irrigation practices grouped under this name involve a significant degree of management (for example surge irrigation). Surface irrigation comes in three major types; level basin, furrow and border strip.



##### Localized irrigation

Localized irrigation is a method of applying water that results in wetting only a small area of the soil surface and sometimes only part of the root zone. Water is applied near the base of the plant so that the application is concentrated in the root zone. Water is generally applied at a low flow rate, in small amounts, and frequently. The application devices may be small tubes, orifices, nozzles, or perforated pipes. The water may either be applied above or below the soil surface. The main components of a localized irrigation system are the water supply (including flow and pressure regulators), the filtration system, main lines, sub-main lines, laterals, and distributors. Figure 5.27 shows some basic components of a localized irrigation system.

The primary advantages of localized irrigation systems are the high efficiency rates that can be achieved, sometimes as high as 90%. High efficiency may result in very significant water savings. Often a localized irrigation system will allow a farmer to irrigate twice the area possible with surface irrigation. Precise control of water and nutrient application often results in much higher yields and quality. Control of weeds and pests may be better as the entire soil surface is not wetted nor is the foliage. A localized irrigation system may allow the use of more saline water, and can be used effectively with low infiltration soils that cannot be sprinkler irrigated. Some disadvantages are the higher initial costs of the systems, salinity buildups, more limited root development, and higher technology requirements. Later savings may be offset by higher maintenance costs. There are low cost methods, however, for irrigating garden sized plots with localized irrigation.



##### Sprinkler irrigation

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.



##### Centre Pivot Irrigation

The centre pivot (CP) is a low/medium pressure fully mechanized automated irrigation system of permanent assemble. The centre pivot system consists of one single sprayer or sprinkler pipeline of relatively large diameter, composed of high tensile galvanized light steel or aluminium pipes supported above ground by towers move on wheels, long spans, steel trusses and/or cables (Figure 10.1). One end of the line is connected to a pivot mechanism at the centre of the command area; the entire line rotates about the pivot. The application rate of the water emitters varies from lower values near the pivot to higher ones towards the outer end by the use of small and large nozzles along the line accordingly



##### Sub-irrigation

It is a method of irrigation where water is delivered to the plant root zone. The excess may be collected for reuse. Sub irrigation is used in growing field crops such as tomatoes, peppers, and sugar cane in areas with high water tables such as Florida and in commercial greenhouse operations.



##### Manual Irrigation

Manual irrigation systems are very simple, labour intensive, but effective methods for making water available to crops. Manual irrigation systems are easy to handle and there is no need for technical equipment. It is important that they are constructed correctly to avoid water loss and crop shortfall. The systems allow for high self-help compatibility and have low initial capital costs.



#### Methods of Irrigation

Irrigation can be carried out by two different methods:

* Traditional Methods
* Modern Methods

##### Traditional Methods of Irrigation

In this method, irrigation is done manually. Here, a farmer pulls out water from wells or canals by himself or using cattle and carries to farming fields. This method can vary in different regions. The main advantage of this method is that it is cheap. But its efficiency is poor because of the uneven distribution of water. Also, the chances of water loss are very high. Some examples of traditional system are pulley system, lever system, chain pump and dhekli. Among these, the pump system is the most common and used widely.

##### Modern Methods of Irrigation

The modern method compensates the disadvantages of traditional methods and thus helps in the proper way of water usage.

The modern method involves two systems:

* Sprinkler system
* Drip system

#### Irrigation Scheduling

#### Importance of Irrigation

* Agriculture is often greatly hampered due to irregular, insufficient or uncertain rain. Proper irrigation systems can secure uninterrupted agriculture.
* The productivity of irrigated land is more than the un-irrigated land. Crop yields everywhere in the developing world are consistently higher in irrigated areas than in rainfed areas1.
* Seeds cannot grow in dry soil as moisture is necessary for the germination of seeds. With the help of irrigation supply, the required moisture content of soil for the growth of seed can be ensured.
* Multiple cropping in a year is possible through irrigation. This will enhance production & productivity. In many areas of India, two or three crops in a year are cultivated with irrigation facilities.
* Through the irrigation, it is possible to supply the required amount of hydrogen & oxygen, which is important for the proper development of plant root.
* A plant can absorb mineral nutrients from the irrigated soil. Thus irrigation is essential for the general growth of the plant.
* Bringing more land under cultivation is possible through irrigation.
* Insufficient rain may also cause drought & famines. Irrigation can play a protective role during the period of drought & famines.
* Irrigation contributes to the economic growth and poverty reduction2. As income and employment are closely related to output and irrigation increases production, substantial increase in income is achieved in the countryside.

### Rain-fed Farming

Rain-fed farming is the natural application of water to the soil through direct rainfall. Relying on rainfall is less likely to result in contamination of food products but is open to water shortages when rainfall is reduced. On the other hand, artificial applications of water increase the risk of contamination.

## Specific Plant Water Requirements

### Soil Moisture for Optimal Crop Growth

Soil moisture and its availability to support plant growth is a primary factor in farm productivity. Too little moisture can result in yield loss and plant death. Too much causes root disease and wasted water. Just as important, water is a delivery mechanism for any nutrients that are not tightly bound to the soil. Whether these nutrients are delivered to the field through the irrigation system or through other means, movement of water within the soil governs how they are delivered to the plant roots. Good water management is important within itself, but good water management also means good nutrient management. Precise control over the root zone environment, in terms of both water and nutrient content, leads to healthier crops and higher yields.

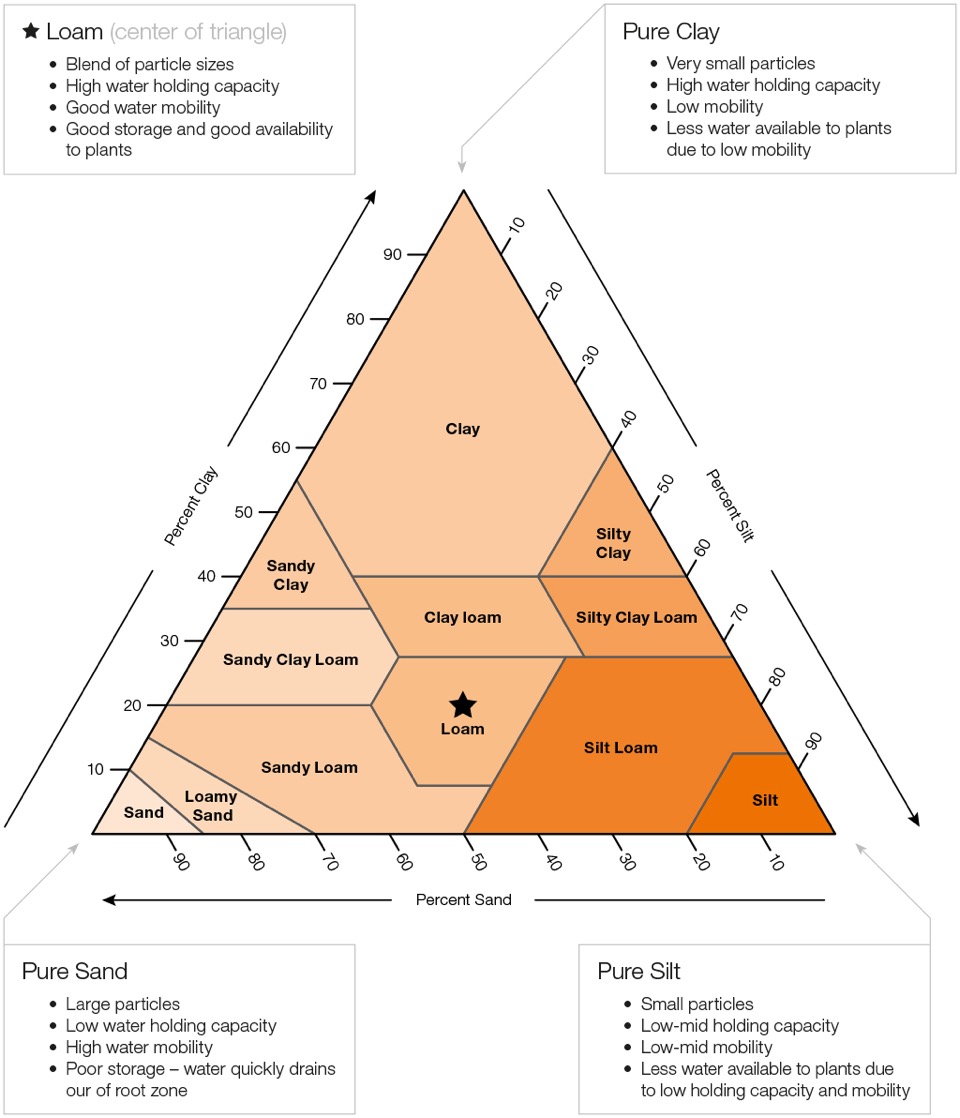
#### Water Holding Capacity

Water resides in the spaces between soil particles. The force of gravity constantly acts on water in the soil to move it downward and out of reach of plants. The counterbalancing force which keeps it from moving downward is surface tension, which causes the water to 'stick' to soil particles. The smaller the soil particles are, the more combined surface area they have, and the more they are able to hold onto water through its surface tension. Therefore, the ability of water to move through soil and be stored in soil depends heavily on soil type.

When water enters a soil with large sandy particles, only a small amount stays attached to the particles, and the remainder quickly drains downward. Sand has low 'water holding capacity.' Conversely, a volume of clay soil has huge numbers of small particles with large surface area. When water enters a clay soil, surface tension holds it tightly to the soil particles and only a small remainder drains downward. A soil with a high water holding capacity can store large amounts of water relative to its own volume after a rain event and, under the right conditions, this stored water can remain available for plants to use.

In a soil with very small particles, the same surface tension forces that allow for a large water holding capacity also make it difficult for plants to extract and use the water. Water does not move easily through a fine-particle soil and requires a large amount of energy for plants to extract and use it. The force a plant must exert on water to separate it from soil particles and move it into the root system is referred to as 'tension'. In most on-farm applications tension is measured in centibars (1/100 bar) as a negative pressure or vacuum (plants 'suck' the water out of the soil to use it).

The interaction between soil type, water holding capacity and water availability is illustrated in the Soil Texture Triangle shown in Figure 1.



### Seasonal Crop Water Needs

|  |  |  |
| --- | --- | --- |
| **Crop** | **Crop water need (mm/total growing period)** | **Total growing period (days)** |
| Beans | 300 - 500 | 70-95 |
| Citrus | 900 - 1200 | 240-365 |
| Cotton | 700 - 1300 | 190-195 |
| Groundnut | 500 - 700 | 90-100 |
| Maize | 500 - 800 | 95-120 |
| Sorghum/millet | 450 - 650 | 120-130 |
| Soybean | 450 - 700 | 135-150 |
| Sunflower | 600 - 1000 | 125-130 |
|  |  |  |

There is a large variation of values not only between crops, but also within one crop type. In general, it can be assumed that the growing period for a certain crop is longer when the climate is cool and shorter when the climate is warm.

### Drought sensitivity

Crops differ in their response to moisture deficit. This characteristic is commonly termed "drought resistance" (Table 7 summarizes sensitivity to drought). When crop water requirements are not met, crops with a high drought sensitivity suffer greater reductions in yields than crops with a low sensitivity.

|  |  |  |
| --- | --- | --- |
| Group One | (low sensitivity) | Groundnuts |
| ¯ | Safflower |
| Group Two | ¯ | Sorghum |
| ¯ | Cotton |
| ¯ | Sunflower |
| Group Three | ¯ | Beans |
| Group Four | (high sensitivity) | Maize |

### Importance of Water to Plants

* Plants contain 90% water which gives turgidity and keeps them erect.
* Water is an essential part of protoplasm
* It regulates the temperature of the plant system
* It is essential to meet the transpiration requirements
* It serves as a medium for dissolving the nutrients present in the soil
* It is an important ingredient in photosynthesis

## Control Systems

A control system is a set of mechanical or electronic devices that regulates other devices or systems by way of control loops. Typically, control systems are computerized.

Control systems are a central part of industry and of automation. The types of control loops that regulate these processes include industrial control systems (ICS) such as supervisory control and data acquisition (SCADA) and distributed control systems (DCS).

Control systems are used to enhance production, efficiency and safety in many areas, including:

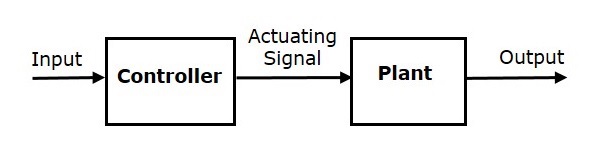
* Agriculture
* Chemical plants
* Quality control
* Power plant
* Environmental control
* Treatment plants
* Food and food processing
* Refining plants

### Types of Control Systems

#### Open Loop

It is a type of continuous control system in which the output has no influence or effect on the control action of the input signal. In other words, in an open-loop control system the output is neither measured nor “fed back” for comparison with the input. Therefore, an open-loop system is expected to faithfully follow its input command or set point regardless of the final result.

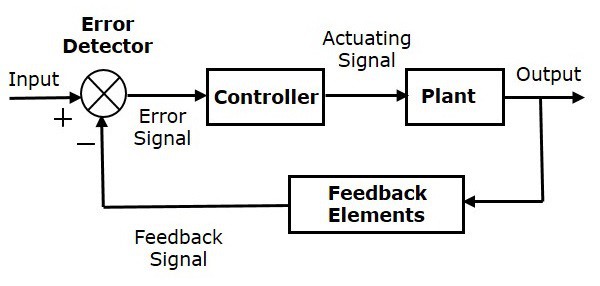
Also, an open-loop system has no knowledge of the output condition so cannot self-correct any errors it could make when the preset value drifts, even if this results in large deviations from the preset value.



#### Closed Loop

A Closed-loop Control System, also known as a feedback control system is a control system which uses the concept of an open loop system as its forward path but has one or more feedback loops between its output and its input. The reference to “feedback”, simply means that some portion of the output is returned “back” to the input.

Closed-loop systems are designed to automatically achieve and maintain the desired output condition by comparing it with the actual condition. It does this by generating an error signal which is the difference between the output and the reference input. In other words, a “closed-loop system” is a fully automatic control system in which its control action being dependent on the output in some way.



## Cloud Services

## Data Forecasting

## Hardware

# Chapter three - Methodology

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