A BASIC OVERVIEW OF THE

IOT BASED CROP FIELD MONITORING

July 29, 2020

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SYSTEM OVERVIEW

An estimated one third of the food produced in the world for human consumption every year, approximately 1.3 billion tons is lost or wasted at a cost of roughly US $680 billion in

industrialized countries and US $310 billion in developing countries. In developing countries, 40% of losses occur during the post-harvest and processing phases of food production. Food waste contributes up to 70 gigatonnes of greenhouse gases, or 11 percent of total emissions therefore directly contributing to Climate Change. (UN Engineering for change). Most of the losses are caused by human incapacitation or inadequate prediction of general trends of conditions affecting soil and the plants.

The system represents a crop field monitoring system. It makes use of several variables that include temperature sensing (ambient temperature), humidity sensing (measures moisture of air around the designated area), air pressure, rain sensor, light intensity sensor and soil moisture sensor. The soil moisture sensor works in conjunction with an irrigation system if there is to be one. The system checks deviations from the set parameters and decides whether to actuate the irrigation system pump or shut off. The variables give the farmer the general picture of measures to be undertaken and proper decision making rather than prediction based decisions.

The basic functionality of the system is based on sensors and a display unit that shows results obtained from the sensors. A Wi-Fi connectivity aids the design by allowing one to assess, through an IoT dashboard, to access the results shown on the display screen away from the farm. WLAN has got low area coverage allows coverage of up to 100m radius thus preferred for use. A wide area network through the port forwarding option of the router allows access to the system from anywhere in the world only if you have internet access.

IoT has grown rapidly in the past decade. The need for both big data and small data in system operation for monitoring and control needs has become a necessity rather than a luxury. The prototype developed is a smart, solar powered, IoT agriculture crop field monitoring system. The intended system is divided into two sections. This is the sensor nodes (field stations), which measures field parameters and the central station, which acts as a sensor node as well as the system server. The system uses Wi-Fi technology in the link layer for connectivity between the broker at the central station and the client at field stations.

EFFECT OF DIFFERENT ELEMENTS ON PLANT GROWTH

TEMPERATURE

The rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. A recent review on the effect of temperature extremes, frost and heat, in wheat revealed that frost caused sterility and abortion of formed grains while excessive heat causes a reduction in grain number and reduced duration of the grain-filling period. Responses to temperature differences among crop species throughout their life cycle. For each species, a defined range of maximum and minimum temperatures forms the boundaries of observable growth. Vegetative development (node and leaf appearance rate) increases as temperatures rise to the species' optimum level. For most plant species, vegetative development usually has a higher optimum temperature than for reproductive development. The reproductive stages in plants are more sensitive to temperature extremes than other stages of plant growth in the plant lifecycle.

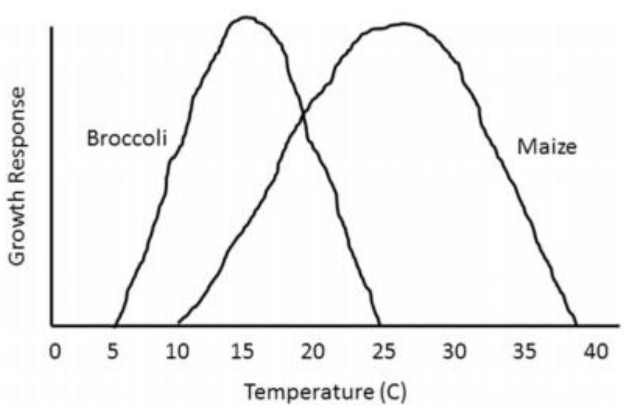

Figure 1 Temperature response for maize and broccoli plants

Fig 1 shows that the extreme and optimum growth conditions of plants depend also on the species. We see that the optimum temperature for maize is higher than that of broccoli where the maximum temperature for growth is 25 °C compared to 38 °C. Extreme high temperatures during the reproductive stage will affect pollen viability, fertilization, and grain or fruit formation. Chronic exposures to extreme temperatures during the pollination stage of the initial grain or fruit set will reduce yield potential. However, acute exposure to extreme events may be most detrimental during the reproductive stages of development. Thus to maximize crop development and production, temperatures must be maintained at an optimum value that corresponds to the respective stage of the plant life cycle.

RELATIVE HUMIDITY

The relative humidity is the ratio of actual water vapour content to the saturated water vapour content at a given temperature and pressure expressed in percentage (%). Relative humidity directly influences the water relations of plants and indirectly affects leaf growth, photosynthesis, pollination, the occurrence of diseases and finally economic yield.

The dryness of the atmosphere as represented by saturation deficit (100- relative humidity) reduces dry matter production through stomatal control and leaf water potential. The very high or very low relative humidity is not conducive to high grain yield. Under high humidity, relative humidity is negatively correlated with grain yield of maize. The yield reduction was 144 kg/ha with an increase in one percent of mean monthly relative humidity. Similarly, wheat grain yield is reduced in high relative humidity. It can be attributed to the adverse effect of relative humidity on pollination and the high incidence of pests. On the contrary, an increase in relative humidity during panicle initiation to maturity increased grain yield of sorghum under low humidity conditions due to the favourable influence of relative humidity on water relations of plants and photosynthesis. With a similar amount of solar radiation, crops that are grown with irrigation give less yield compared to those grown with an equal amount of water as rainfall. This is because of the dry atmosphere, which is little affected by irrigation, independently suppresses the growth of crops.

SOIL PH

Soil pH is a master variable in soils because it controls many chemical and biochemical processes operating within the soil. It is a measure of the acidity or alkalinity of a soil. The study of soil pH is very important in agriculture because soil pH regulates plant nutrient availability by controlling the chemical forms of the different nutrients and also influences their chemical reactions. As a result, soil and crop productivities are linked to soil pH value. Though soil pH generally ranges from 1 to 14, the optimum range for most crops is between 5.5 and 7.5. However, some crops have adapted to thrive at soil pH values outside this optimum range. An increase in soil acidity is caused by the use of fertilizers, acid rain, high rainfall, oxidative weathering, etc. Both acid and alkaline soils influence crop growth and development. For instance, crops grown in acid soils may experience some stresses such as AI, H, and Mn toxicity as well as Ca and Mg nutrient deficiencies. Aluminum toxicity, which is the most widely spread problem of acid soils, occurs when aluminum is present in ionic Al^{3+} form. Generally, crops are varied in terms of suitability for soil pH range. Some crops can be intolerant of a particular soil pH due to a particular mechanism. For instance, soil pH 5.5 is not suitable for soybean plants when molybdenum is low in the soil, but the same pH 5.5 becomes optimum for soybean when molybdenum is sufficient in the soil. Most crops perform optimally around soil pH 7.0 (neutral). This shows that it is very important to bring both acidic and alkaline soils to neutral soil pH value for the optimum performance of crops. It affects crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity which influence key soil processes. Soil pH can be managed by measures such as applying the proper amount of nitrogen fertilizer, liming, and cropping practices that improve soil organic matter and overall soil health.

LIGHT INTENSITY

The whole purpose of agriculture is to produce food and other beneficial items to man, but in the absence of light, plants will not be able to sustain their own life or produce their food. Light is one of the most important elements that affect plant growth. Photosynthesis is defined as the process by which green plants and some other organisms use sunlight to synthesize nutrients from carbon dioxide and water. Photosynthesis in plants occurs in the presence of the green pigment in plants called chlorophyll and generates oxygen as a by-product.

Light intensity during the development of a leaf can modify its anatomy and morphology including the number and dimensions of mesophyll cells. Plants or populations grown in strong light are often capable of greater maximum photosynthesis than the same plants or populations grown in the weak light. This is because light intensity levels can have a significant effect on photosynthesis rates, which are directly related to a plant's ability to grow. While soil nutrients help to fortify plant structures, light is an essential component in producing actual food for the plant. As with other living organisms, food fulfills a vital requirement for overall health and growth, so the presence of light can have a direct bearing on a plant's rate of growth. Light intensity has to do with the amount of light energy made available to a plant, which can vary according to color and the actual strength of the light. This energy becomes the fuel used to manufacture glucose or sugar molecules.

SOIL MOISTURE

Soil moisture refers to the water molecules that are temporarily bonded to the soil particles. As soil is the medium in which plants grow, the plat roots are always in the soil. Roots that are in the soil allow the uptake of these water molecules into the plant. As we all know that water is life, 90% of the plant weight is water and it is not only its source of livelihood but also of food. During the process of photosynthesis, plants make carbohydrates and oxygen using carbon dioxide and water in the presence of sunlight and chlorophyll. The absence of water will result in poor fruit formation, poor growth, death of flowers and leaf death. This makes soil moisture one of the most important elements for plant development.

Monitoring System

The crop field monitoring system provides a platform that allows the farmer to be able to monitor all of these parameters in the crop field and be able to control them if it is possible by the use of wireless connections and IoT technology. The field variables that are measured by the system include the soil moisture content, rainwater amount, light intensity, soil pH, temperature, humidity, pressure, air smoke content, wind speed wind direction, barometric pressure and altitude. These values are displayed on an IoT dashboard that can be viewed on a browser. GSM mobile alerts can also be sent to the user in the case on an extreme condition in the field being reached (eg low/high soil moisture or field fire).

The watering pumps and electronic valves can the opened and closed wirelessly by the use of either the online IoT dashboard or GSM text messages and calls.

TECHNOLOGY USED

This section will just give us a general overview of the technology used for implementation of the design.

Wi-Fi TECHNOLOGY

The wireless communications technologies usually referred to by the (trademarked) term "Wi-Fi" are those technologies based on the IEEE 802.11 standards. Wi-Fi (Wireless Fidelity) is the single most popular IoT communication protocol for wireless local area networks (WLAN). Intended as a general wireless communications protocol (think of Ethernet without 26 wires), 802.11 implementations are by far the most common form of wireless communication between PCs.

Its designers recognized the need for security early on and included a security protocol in the original specification: Wired Equivalent Privacy, or WEP. It utilizes the IEEE 802.11 standard through 2.4 GHz UHF and 5 GHz frequencies. Wi-Fi provides internet access to devices that are within the range of about 100 meters from the source [13]. Wi-Fi has a data rate of up to 600 Mbps maximum, depending on channel frequency used and the number of antennas.

MQTT TECHNOLOGY

MQTT (Message Queuing Telemetry Transport)

"The MQTT protocol uses a publish/subscribe (pubsub) messaging model that works in an extremely lightweight way. It is useful for making connections with remote locations where a small code is required and network bandwidth is at a premium." MQTT has the fastest data rates of most of the application layer protocols used, this is the same application layer protocol used for applications such as WhatsApp and Facebook.

MQTT-SN (MQTT for Sensor Networks) – Is a lightweight publish/subscribe application protocol which is designed specifically for machine-to-machine communication and mobile applications

Project Costing

This section of the document looks at the various costs involved in the building installation and running of the system. The Enviro-monitor is constructed from various components, procured from overseas and some locally procured components. The system is to be costed per hectare according to the Grid model. For quote contact UmojaTech umojalands@gmail.com

THE GRID MODEL

The grid model is the simple model used to show the arrangement of the various stations in the crop field when the system is running in the field. The stations are to be organized with a central station shown with a red dot and the field stations signified by the blue ones. The one-hectare field space is then divided as shown below.

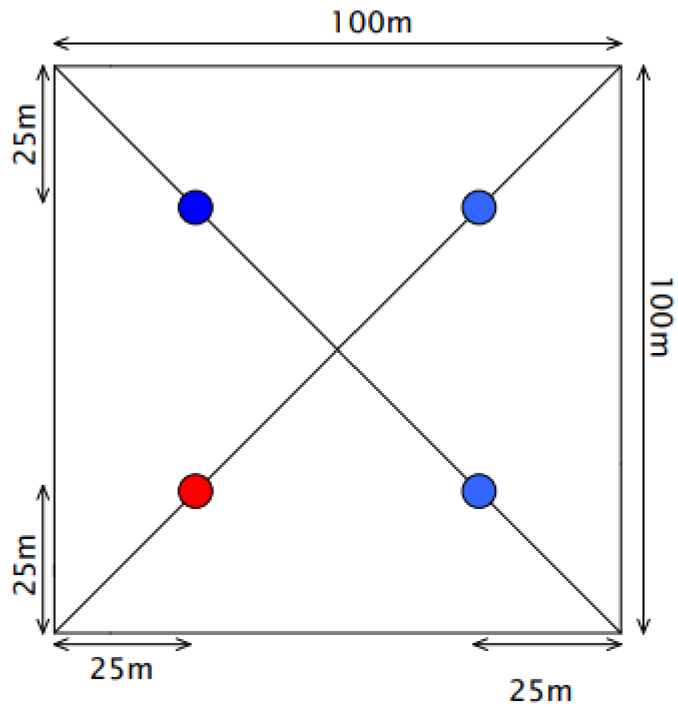

Figure 2: Grid structure of the monitoring system

A 1ha field measuring 100m*100m will contain a minimum of four stations that can be increased to any number as per requirement of the user. It will have 3 field stations and one central stations that will be the broker for that particular area. The spacing of the central station to the furthest field station will be 70.5m, which is less than the maximum distance for Wi-Fi connections, which will be a max of 100m. Each station is responsible for a specific square area measuring 50m*50m as shown by the grid model below.

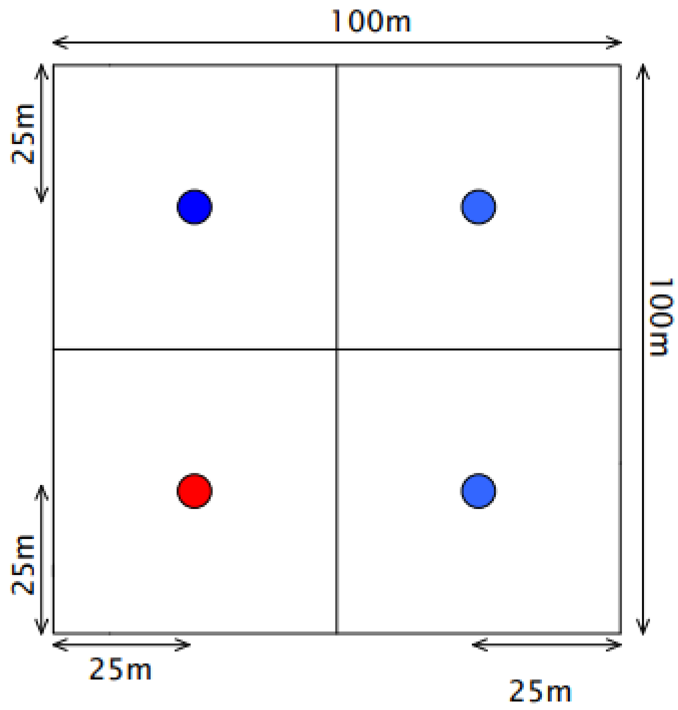

Figure 3: Area covered by a field station in Grid format

THIS MODEL IS USED TO STRUCTURE THE FIELD STATIONS AS WELL AS THE CENTRAL STATIONS FOR CONTROL OF THE VARIOUS ACTUATORS. THE SYSTEM CAN CONTROL VARIOUS VALVES TO OPEN AND WATER THE PLANTS, MANUALLY (BY SWITCHING ON AND OFF ON THE IOT DASHBOARD) AND AUTOMATICALLY (WHEN THE MOISTURE LEVELS ARE TOO LOW OR TOO HIGH). THE MOST FAVORABLE MODE OF IRRIGATION WOULD BE DRIP IRRIGATION BUT OVERHEAD SPRINKLERS CAN ALSO BE CONTROLLED BY THIS METHOD OF CONTROL.

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UMOJATECH
SMART FARMING SYSTEM
ABOUT US
Umojalands Team has developed a system to monitor crop-field using sensors (soil moisture, temperature, humidity, Light intensity) and automate the irrigation system. The data from sensors are sent to web server database using wireless transmission. The irrigation is automated if the moisture and temperature of the field falls below the brink. In greenhouses light intensity control can also be automated in addition to irrigation. The notifications are sent to farmers' mobile periodically. The farmers' can able to monitor the field conditions from anywhere.
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