# Relation Between Relative Humidity & Soil Moisture

19313

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# ABOUT US

Abstract


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# PRESENT AND JUSTIFY A PROBLEM AND SOLUTION REQUIREMENTS

# Egypt’s Grand Challenges

## Climate change in Egypt:

Climate change is the unescapable consequence of human acts and effects on the surrounding environment, and this consequence has proven itself to be powerful enough that it can’t be ignored anymore. However, unlike what many people think, climate change is not only limited to global warming; it has many forms, like drought, iceberg melting, and increasing sea levels.

Egypt, like any country, has problems managing climate change as it is highly vulnerable to water scarcity, droughts, rising sea levels, and other adverse impacts of climate change.

Climate change has many forms that affect Egypt in several ways. Two examples of these forms are greenhouse gases (global warming) and desertification.

## Greenhouse gases (Global warming)

The assessment of GHG emissions for Egypt in the year 2000 revealed that total emissions in the year 2000 were approximately 193 $MtCO_2e$, compared to approximately 117 $MtCO_2e$ in 1990, representing a 5.1% annual increase. Total GHG emissions in 2008 are estimated to be around 288 $MtCO_2e$. $CO_2$ accounts for 66% of GHG emissions, with $CH_4$ accounting for 20%, $N_2O$ accounting for 13%, PFCs accounting for 1%, $SF_6$ accounting for 0.06%, and HFCs accounting for 0.03%. (Sterling, 2022)

The energy sector is the primary contributor to emissions of GHGs in Egypt, followed by agriculture, industrial processes, and then the waste sector. GHG emissions per capita show a 37% increase in the year 2000 relative to 1990. Meanwhile, GHG emissions per thousand US dollars of GDP in Egypt fell from 3.32 tons of $CO_2$ to 1.98 tons of $CO_2$, indicating a shift toward low-carbon activities. The share of Egypt in the total world GHG emissions in 1990 was 0.4% and was still limited to 0.58% in 2000.

# Desertification

The increase in the average temperature of Egypt has resulted in a lot of factors that support the phenomenon of desertification. For example, that increase caused a sharp decrease in the relative humidity of the Egyptian farmlands' air, triggering an increase in the plants' transpiration rate due to the increase of the transpiration driving force, therefore increasing the plants' water demand by absorbing more water than they are watered by in the usual way, resulting in the loss of soil water content and moisture, decreasing the cohesion between its molecules, making a lot of mud cracks along the surface, and making it more vulnerable to wind erosion, which in turn results in the loss of the fertile top soil. Such a thing can be fatal to Egypt, as only 3% of its total area is used for agriculture, with the rest being a desert, which makes it even easier for it to be weathered by the effects of wind erosion, which results in:

- Vegetation cover and grazing resources: As agricultural land shrinks, it causes a lot of problems, such as a drop in the amount of natural vegetation cover, a rise in the number of harmful species, and the growth of plants with low forage value, etc.
- Water and Soil Resources: Water and soil are both affected by desertification due to the following: Loss of topsoil, salt encrustation, increasing dust storms, soil salinity, and water logging significantly decrease the yield of most crops, and other reasons.
- Socio-economic impacts: Both water and land resources have public health impacts on society and public health as it contaminates the sources of drinking water, exposes them to pathogenic bacteria and parasites, contaminates the sources of fish and food production, and has buried several villages under the sand throughout the last three decades. (Egyptian National Action Program To Combat Desertification)

# Improving technological and industrial base for all

Since the industrial revolution, many countries have been striving for developing their industrial and technological bases. A good example of that is the use of IOT systems, which allow the user to collect data and share it with a website or program using Wi-Fi. This allows the country to better control its lands, projects, and some institutes like hospitals.

For years, data analyses in Egypt have been performed by human personal, which takes a long time and magnifies the problem's impact on its subject, demonstrating a significant challenge to Egyptian development. That is why improving the technological and industrial base has been a goal in the Egypt 2030 vision through building a digital Egypt. These plans include developing the ICT infrastructure, fostering digital inclusion, and increasing the use of IOT systems instead of human personal. (*Egypt ICT Strategy* 2022)

# Problem To Be Solved

Wind erosion is a natural process, that can cause a lot of problems for soil, from drifting the surface soil away to making the soil less fertile and harder to revegetate. This process has been happening in Egyptian deserts for ages, but lately that problem started to slowly consume the Egyptian farmland due to recent changes in relative humidity, which in response changed the soil moisture, structure, and texture, making the soil more vulnerable against erosion.

Lately, Egypt's land was hardening more and more because of the lack of water, which made it harder for vegetation to survive, creating even more problems.

- **If the problem is solved: -**
  - When the problem is solved, it will have an impact on many aspects of the country, including the economy, agriculture, public health, and much more, by conserving farming lands, maintaining food supplies, and even making more arid areas suitable for agriculture without fear of losing farmland.
- **If the problem is not solved: -**
  - The problem will only worsen as more farmland becomes dry land with mud cracks, making it less fertile, causing a food shortage, lowering public health and even causing famine in the long run.

# Research

**Topics related to the problem: -**

- As the amount of greenhouse gases in the atmosphere rose due to human activity, the greenhouse effect got worse, trapping more heat in the atmosphere and causing a number of problems, such as a drop in relative humidity and an increase in the amount of ice on Earth.
- The relative humidity goes down. When humidity goes down, plants lose more surface moisture, which speeds up the process of transpiration. This means that plants need more water to bring humidity back up, which causes soil moisture to evaporate.
- Increasing the rate of wind erosion: When soil loses moisture because of high humidity, the particles don't stick together as well. This makes the soil more susceptible to wind erosion, which blows away the top fertile soil and reduces soil fertility even more.
- Soil salinity and water logging reduce crop yield significantly: the decrease in soil moisture, which is associated with a lack of water in the soil, increases the amount of salts in every litre of soil water, resulting in an increase in soil salinity, and If the level of salt in the soil water is too high, water may flow from the plant roots back into the soil. This causes the plant to dehydrate, resulting in a decrease in yield or even death. As a result, Egypt is experiencing food shortages and other problems.

**Topics related to the solution: -**

- Gamma soil moisture detectors: a type of soil moisture detector that detects the gamma rays emitted by "CS-137”, which is found in the fertile topsoil of the land; if a decrease is detected, then this means that area is under the influence of wind erosion.
- Internet-integrated system: By connecting the detection system data to an online website, it is possible to easily show recent changes and the problems associated with them, increasing people's awareness of the problem and encouraging them to contribute to slowing its progress by reducing their own impact on climate change

# Prior Solution

## Gamma spectroscopy

IAEA gave Egypt and Senegal two gamma spectroscopy detectors to help study and combat soil erosion, a type of land degradation that was one of the land-threatening factors in Egypt, especially in the northeastern Nile Delta. (*Egypt and Senegal receive gamma detectors to help combat soil erosion* 2018)

Soil erosion is a phenomenon caused by environmental and human factors that gradually weather away the topsoil of land, causing the soil to lose its most fertile layer and become unusable for agriculture.

The detectors measure the amount of gamma rays emitted by some radionuclide tracers, mainly cesium-137 (Cs-137), which is widely found in the fertile topsoil layer. If a decrease was detected, this means that the land was subject to the effects of wind erosion and needed to be dealt with, therefore fully utilizing the amount of money, workers, and care each piece of land needs and better distributing them.

- **Advantages: -**
  - Very accurate at making its measurements.
- **Disadvantages: -**
  - Expensive.
  - Relatively new technology, which is hard to obtain and mass produce.

# Medusa soil moisture sensors

Medusa soil moisture sensors

Another type of gamma spectrometry sensor was developed by the Medusa Institute to directly measure soil moisture. The system is a stand-alone system that measures the soil moisture of the land on an hourly basis over the long term, using a solar panel as its energy source. It uses a 100-ml CsI scintillation crystal installed in its detector, which has the ability to measure the amount of gamma rays coming from the land beneath it and is not limited to topsoil. If the soil has a high amount of water, which absorbs gamma rays coming from the soil's radioactive elements, then the detector will detect a decrease in the amount of gamma rays detected, while a decrease in the soil's water content will show an increase in the amount of gamma rays detected. The data is then collected every hour to aid in the study of the land's soil moisture. (Medusa, 2022)

- **Advantage**: -
  - Measures average soil moisture of the top 30 cm.
  - Is independent of atmospheric conditions.
  - Measures one sample per hour.
- **Disadvantage**: -
  - Expensive technology, which is hard to distribute due to its price.

# GENERATING AND DEFENDING A SOLUTION

# Solution Requirement

**1-** Provide a reliable data base and graphs of the changes in humidity and soil moisture, to give the authorities the chance of taking actions in early times of the change.

**2-** Making an official website showing the recorded data, to raise the level of awareness between the citizens of the country to ensure a higher level of civilian contribution in fighting the addressed challenge.

# Design Requirement

**1-** User interface should be easily understandable

**2-** Accurecy by calculating systematic error

## Why have we chosen this design requirments?

1- User interface: having raw data tables will be confusing to deal with and hard to code and organise in their archives; they are also inaccessible for civilians. Using a user interface through an online website will allow that data to be automatically arranged in tables and graphs that civilians can access to ensure civilian cooperation.

2- Sensor systematic error: Using a sensor with a large systematic error will be inconvenient for the detection process because large errors can have various impacts on the country strategy to solve the addressed challenge, making sensor accuracy critical for the process.

# Selection Of Solution

After presenting the problem and the solution requirements, we have now reached the next step in creating our project, which is identifying and presenting a solution. After thoroughly researching the best possible idea, we have come up with a solution that we believe will adequately solve the problem.

The idea that we achieved at the end was calculating the effect of air humidity on soil moisture and describing their relationship. Our hypothesis is that humidity and soil moisture are directly related, since soil moisture decreases when humidity decreases due to an increase in transpiration rate, which affects vegetation all over the country and therefore its food production.

We have decided to study these effects by creating a simulated environment where we can control the variables of the weather inside it. With this environment, we can calculate the soil moisture with respect to humidity without taking into consideration other factors that may change outside of our control

# Selection Of Prototype

After selecting the solution and design requirements, we started to choose the design of the prototype. The hardware and the software are two different parts of our prototype that both work at the same time.

## The hardware: -

The prototype will consist of a glass box containing the moist soil that will be tested at its bottom. Inside the soil lies the plant that will be used to test the results. Next, the soil moisture and humidity sensors will be installed inside the soil and on the box's side, respectively. Finally, the ESP32 board will be installed outside the box with the jumper wires connecting it with the soil and humidity sensors. The ESP32 will then be connected to the laptop, and this is where the software comes in.

## The software: -

Using the Arduino IDE, we will program the ESP32 to do the following: First, it will calculate the soil moisture and humidity. Then, it will start the heat lamp at a constant temperature. The temperature will change the humidity as time passes, which will cause the plant to do transpiration faster, which will result in decreasing the soil moisture. The values will be measured again with respect to time, therefore creating a relationship between them, and uploaded to ThingSpeak to be drawn into graphs to describe their relationship.

# CONSTRUCTING AND TESTING THE PROTOTYPE

# Materials

| Number | Item | Amount | Usage | price | Picture |
|---|---|---|---|---|---|
| 1 | Infrared lamb | 1 | Heat source | 200 LE |  |
| 2 | Electric wire with stand | 1 | Fix the lamp in a stationary position, and supply its electricity | 20 LE |  |
| 3 | Glass box | 1 | Soil container | 35 LE |  |
| 4 | ESP32 | 1 | Analyzing and Wi-Fi unit. | 235 LE |  |
| 5 | DHT11 | 1 | Measuring the humidity and temperature. | 35 LE |  |
| 6 | Capacitive Soil Moisture Sensor V2.0 | 1 | Measuring the soil moisture. | 65 LE |  |
| 7 | Jumper wires | 20 | Connect the project units | 20 LE |  |
| Total cost | | 610 LE | | | |

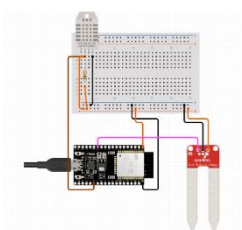
# Methods

In order to build a testable prototype, four parts had to be constructed: the simulation box, the lamp stand, the ESP32 communication system, and the user interface.

First, the simulation box was made from glass with the dimensions 10*10*15cm (±0.1), so the soil mass inside it, can be supported without any potential fractures. After the box is filled with the soil, the plant is put inside carefully, before led it put on the top of the box to negate excessive interactions with the outer environment, as shown in figure (1).

Next is the lamp stand, which is made using a long wire, that is attached to a lamp socket. This wire is then supported by an isolated metal rod. Next, the lamp is attached to its sockets, and then the stand is finished as shown in figure (2).

The upcoming part is the ESP32 communication system. The soil moisture, and DHT11 sensors 3 are being connected to the ESP32 with the connection viewed in Figure (3). Next comes the code. It starts by connecting the ESP32 to the Wi-Fi. Then, it will read both the humidity and soil moisture values and upload them to ThingSpeak, which will in turn upload the data to our website. The code is uploaded with more details in the following GitHub repository: https://github.com/AhmedElshentenawy/Group-19313.git



Next is the user interface, which was made via the program visual studio, using HTML, java and css programming languages, and was determined to be a website, which was made of three components, the portfolio and poster buttons, where more information about the project can be obtained by the user ; the graphs of the prototype, which is changed with every reading taken by prototype, because it was connected to project graph code on the website thingspeak; and lastly the team members section, where contacting the team member for further information is allowed for the user via E-mail, which can be observed in the website:

Some steps were taken in order to carry out a successful test plan. First, the dry soil is weighted, before being put in the box with water before proceeding with the test. Next, the heat lamp and the IOT system are turned on to take multiple readings until the final result is displayed on the user interface.

# Test Plan

**In order to have a successful test plan, we had to follow the following steps: -**

- To begin, we will weigh the prototype box with dry soil.
- Then, we shall water the soil and seal the box, then weigh the wet soil.
- Then, we turn on the heat lamp.
- Next, we will turn on the system to take multiple readings over time.
- After the second reading is taken, we shall weigh the soil box again and see the amount of water lost and if it agrees with the sensor readings.
- In the end, the results will be displayed on the user interface in the form of two graphs, showing the relationship between humidity and soil moisture over time.

**In order to carry out the test plan, we shall follow some safety proportions:**

- Wearing gloves so the electricity won’t harm us.
- We were wearing sunglasses to shield our eyes from the heat lamp radiation.

# Data Collection

After prototype construction, 2 primary tests were made to ensure design requirements were fully met, in addition to 1 secondary test to ensure the prototype's availability to do its assigned tasks.

**First test: - (primary test)**

The test was conducted through a three minutes time period. A decrease in the humidity was detected, but it soon recovered by decreasing a negligible amount of the soil moisture percentage, which did not show the factors' relationship.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 minutes | Soil Moisture% | 28% | 28% | 28% | 28% | 28% | 28% | 28% |
| | Relative humidity % | 69% | 69% | 68% | 68% | 69% | 69% | 69% |

**Second test: - (primary test)**

This was also conducted over a three-minute time period. A continued decrease and increase in both soil moisture was detected. This shows the instability of the environment, and so this test cannot be considered a successful one.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 minutes | Soil Moisture% | 35% | 35% | 35% | 34% | 35% | 35% | 34% |
| | Relative humidity % | 65% | 65% | 65% | 66% | 65% | 65% | 66% |

## Third test: - (secondary test)

This test lasted ten minutes and was evaluated every five minutes. A sharp decrease in humidity was detected, which then triggered a decrease in soil moisture, stabilizing the relative humidity levels, then increasing them beyond their initial level. This happened twice in the ten-minute period, and when it was all over, the overall humidity went up because the soil moisture went down. The sensor accuracy was estimated to be (±0.3%), which was acceptable as the sensor doesn't read decimal increases or decreases.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 minutes | Soil Moisture% | 30% | 30% | 30% | 27% | 28% | 28% | 28% |
| | Relative humidity % | 70% | 66% | 62% | 62% | 65% | 71% | 74% |
| 10 minutes | Soil Moisture% | 28% | 28% | 25% | 26% | 26% | 26% | 26% |
| | Relative humidity % | 75% | 74% | 72% | 73% | 75% | 76% | 76% |

# EVALUATION REFLECTION AND RECOMMENDATION

# Analysis & Discussion

An IOT system is made of several web-enabled smart devices. For example, their usage for sensors to collect data such as the acquired data from the surrounding environment. The data collected by the IOT system is then shared via a Wi-Fi module to the cloud to be analyzed or sent in the form of results of analyzing it locally by an analyzing unit like the ESP32, for example. These data can then be shown in the form of tables or graphs, which is the reason it is used in climate analysis projects. A lot of time is also saved by IOT systems because most of the work is done via these devices without human intervention.

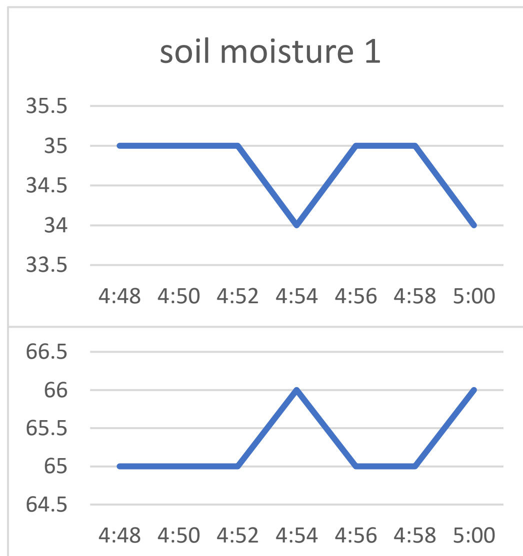
A significant decrease in the relative humidity has a huge effect on the soil moisture because when it decreases, the amount of water stored in the outer layer of the plant leaves also decrease. As a result, it triggers the plant's response to increase its transpiration rate for water delivery, keeping its leaves from dying, leading to an increase in the plant demand for water, consuming more water from the ground, and increasing the humidity beneath its initial level, before it decreases again. Accumulation of these changes results in a decrease in the amount of soil water content and its moisture. The behavior of increasing transpiration, while watering the plant with the same amount of water, results in a decreased productivity of the plant, reducing its growth and curling its leaves while increasing the salinity of the soil. Moreover, decreasing the soil adhesion makes it more vulnerable to the effects of the wind erosion, which weather the fertile topsoil away. (Kimball,2022)

The increase in the environment temperature is significantly higher from outside it to the point of effecting the humidity, which is due falling of some rays on the glass with a critical angle, reflects it back into the box, due to the concept of total internal reflection. (Serway & Jewet, 2013)

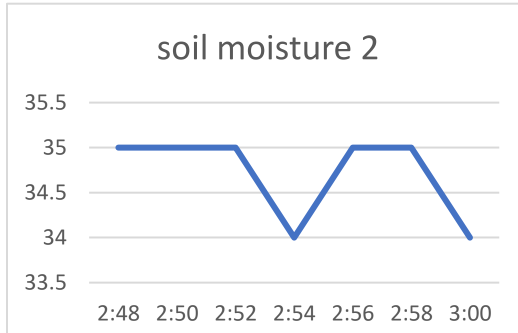
After the enclosed environment has been prepared for the conduction of the test via turning on the heat lamp and the IOT system, the information about the environment is then collected via the IOT system sensors. The project is then left for 10 minutes as the graph is drawn, on ThingSpeak, step by step from the accumulating of several readings over time, and finally, the graphs are sent via Wi-Fi to the user interference, so it can be shown and used by several users. (Internet of things from hype to reality: The road to digitization 2022)

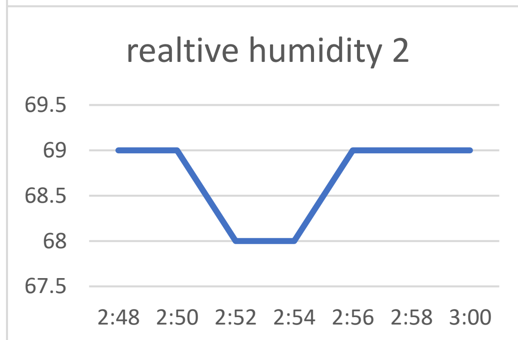
## First test: - (negative result)

In this first test, the sensors' readings show a slight decrease and increase in humidity between 69% and 68%, as shown in graph (1). while the soil moisture remained stable. The reason for this was the lack of enough heat for the phenomenon to start. The lack of thermal energy was associated with the use of a normal tungsten lamp, which didn't emit the required energy for the phenomenon to occur.



## Second test: - (negative result)

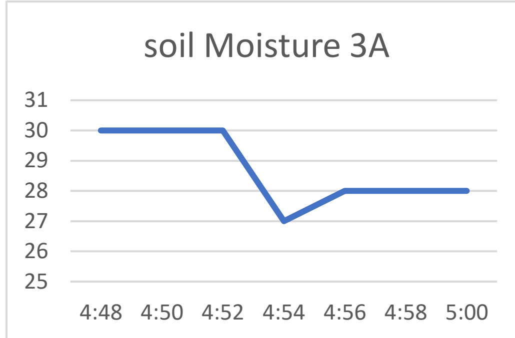


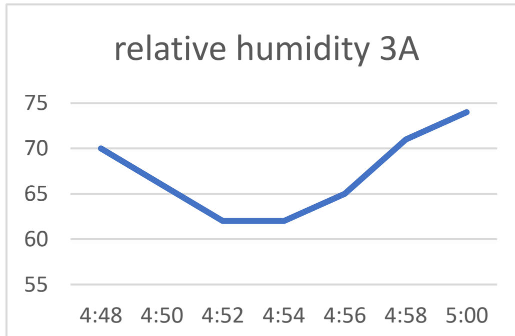



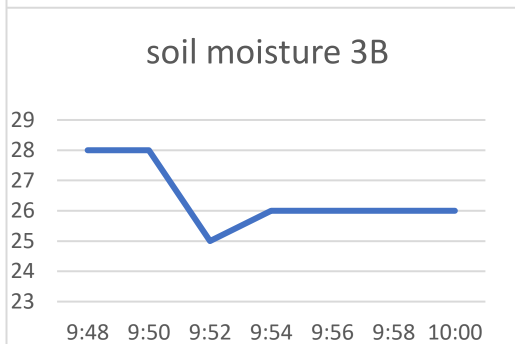

Before the second test, the tungsten lamp had been replaced by a heat-infrared lamp. Although the lamp emitted the required amount of heat per minute, the phenomenon didn't occur; rather, a decrease in soil moisture percentage and an increase in relative humidity percentage were observed, as shown in graph (2). The reason for this was the short duration of the experiment, as the enclosed environment didn't have enough time to reach the required temperature..

## Third test: - (positive result)

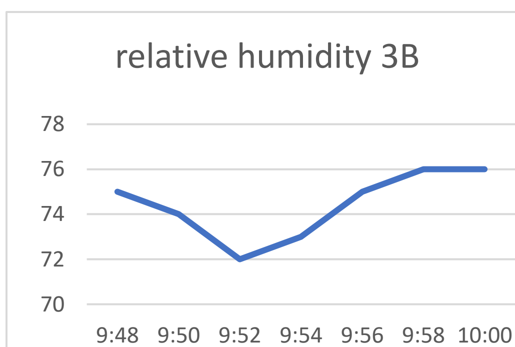
In the third test, the period of the experiment was extended to 10 minutes and was observed every 5 minutes. This time the phenomenon fully occurred as the observed decrease in relative humidity percentage was followed by a decrease in soil moisture, stabilizing the humidity level and increasing it beyond its initial level, as shown in graphs (3) and (4). The soil moisture percentage was measured via the use of a scale, which showed the error rate to be ± 0.3%. Finally, the general trend of the graph of the relation between the relative humidity level, and soil moisture percentage was inversely proportional, mostly following a slope of -0.175 as shown in graph (5).



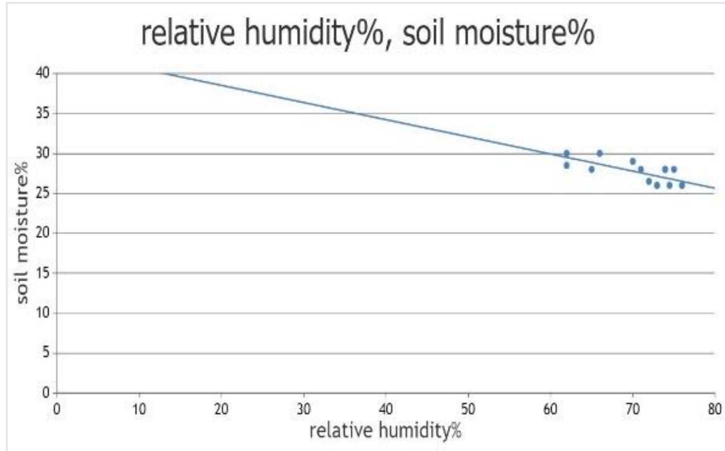




The type of bulb used for dehumidifying the soil through heating was chosen based on the study of light reflection. The WiFi is used to transfer the data to the interface, and sampling was used to discover how the interface utilizes this data to generate the result graphs. The law of conservation of mass was employed to validate and calibrate the measurements of the sensors by measuring the soil's mass before and following the use of the lamp. and the difference (which implies a mass loss) is the soil moisture loss. Choosing the most suitable sensors for



the measurements couldn't be done without understanding the sensation, sensor types, and sensory pathways. In the path, the sensory neurons are represented by the WiFi, the brain is represented by the interface, and the operations of the brain are represented by the graphs.



# Recommendations

In the process of making the prototype, a lot of useful information was gained, which gave us some better ideas to help improve the project: -

- The most effective method for reducing wind erosion is to keep the wind off the soil's surface. Growing plant shields the soil from the wind and keep it above the surface.  Windbreaks and other obstacles are helpful at reducing the transmission of soil particles.
- Utilize a 2- to 4-inch (5–10 cm) thick layer of mulch for moisture retention while mulching. Although it is not advised to pile mulch thickly around the crown or base of plants, it is a good idea to mound mulch in a donut-like shape.
- You may also use "vermiculite" which is a natural mineral, by heating it until it forms a white material that prevents a lot of soil problems, such as mold, and also retains a lot of moisture, and then mixing it with the soil. There are soil element measures when using this mineral because it contains a great deal of water; the measurements are 1/6 vermiculite, 2/6 leca/perlite/sand, and 3/6 soil. (Jasa, 2021)
- Conservation tillage is an agricultural management that minimize the frequency or intensity of tillage operations. It improves soil health, reduce runoff, and limit the extent of erosion. A well-developed conservation tillage practice can help to reach the sustainability of an agricultural system. (Doval, 2021)
- Strip cropping, which is a technique that depends on growing erosion permitting crops with erosion resisting crops in alternate strips. This method stabilizes the moisture level of the land soil, and prevent erosion and saltation of the soil. (Soil Moisture Conservation Techniques 2017)
- in real life application of the project it is recommended to use custom made sensors, that is designed to have a higher accuracy, permitting it to measure the value in whole and decimal number.

# Learning Transfer

## Physics

### PH.3.03:

- We studied the reflection of light and the type of mirror, which helped us determine the type of lamp to use in heating the soil to reduce its moisture, as the infrared lamp contains a concave mirror to concentrate the light and enhance the temperature.

### PH.3.04:

- We studied the antenna and its operation, which assisted us in transmitting data from the sensors to the interface.

### PH.3.05:

- We studied Wi-Fi and sampling. We used Wi-Fi to transmit data to the interface, and sampling let us learn how the interface used the data to make our graphs of the results.

## Chemistry

### CH.3.01

- We studied scientific methodology, which aided us in generating our idea and building the prototype with the proper procedures.

### CH.3.02

- We studied the law of conservation of mass, which we utilized to validate and calibrate the measurements of the sensors by measuring the soil's mass before and after using the lamb. and the difference (which represents a mass loss) is the quantity of soil moisture lost (water).

## Biology

**BI.3.03**

- We studied the anatomy and function of the brain, which enabled us to comprehend and identify what each component of the code does and how it operates.

**BI.3.04**

- We investigated the feeling, types of sensors, and sensory pathway, which allowed us to select the appropriate sensors for our measurements and comprehend the information pathway from the sensors to the interface. In the path, wifi represents sensory neurons, the interface represents the brain, and the graph depicts the brain's actions (reflex).

**Geology**

**ES.3.02**

- The GPS system is a complicated communication system that uses 24 satellites at a height of 20,200 km above the ocean surface, in addition to many stationary units to detect plate motion. This helped us to understand IOT systems, which helped in constructing the IOT system.

**ES.3.06**

- A seismograph is the primary earthquake measuring instrument that records ground motion and can be used to detect an earthquake in advance and prepare for it. This helped in determining the major task of the project, which is to detect the change in relative humidity and soil moisture to help detect future change and fight it..

**English**

Various subskills increased the efficiency and calibre of the team's writing on the poster and portfolio.

- First: Peer assessment (Module 1A)
  The strategies employed in class assisted us as a group in analysing our poster and portfolio. swapping assignments in order to proofread and identify any grammatical or functional issues.
- Second, recognising the distinction between fact and opinion (read for thinking, Chapter 8).
  To create the poster and portfolio, it was necessary to have a comprehensive understanding of the distinction between facts and opinions. The distinction between the appropriate writing style for writing about facts and writing about opinion facilitated our work, particularly in the analysis (facts) and discussion (closer to opinion) sections.

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