Relation Between Relative Humidity & soil Moisture

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Abstract

Egypt faces a lot of climate change-related challenges which, in turn, threatens the Egyptian environment. To face such challenges, a huge amount of data collection and analysis is required. However, doing such measurements manually is inefficient and would cost a lot of time. On the other hand, making automating will provide more accurate results without needing as much time, while providing 24/7 monitoring of the live data. Our project uses a fully automated system to collect the data from the soil, moisture, and humidity sensors, then proceed to upload it online, and use an IoT system to further study the phenomenon of decreasing soil moisture, and help fight the problems associated with it like wind erosion of the fertile topsoil.

Introduction

The phenomenon of climate change harms the planet and environment we live in due to the results of human acts, which was shown in the assessment of GHG emissions for Egypt in the year 2000, as it was revealed that total emissions in the year 2000 had a 5.1% annual increase since 1990. That change increased the amount of greenhouse gases in the atmosphere, increasing the average temperature, decreasing relative humidity, and increasing the driving force of transpiration, resulting in an increase in plant water demand and draining more water from the soil, making it infertile and vulnerable to wind erosion. (Sterling, 2022)

Lack of communication is one of the major problems in Egypt. Humans conduct land analyses, which take up a lot of valuable time that could be spent fighting this phenomenon. This allows the harmful phenomenon to have a greater effect on the land before the government intervenes.

Wind erosion is a major cause of land degradation in Egypt, as well as one of the most significant contributors to soil loss. This was shown when the annual rate of wind erosion in rainfed agricultural areas on the Northwest Coast was calculated and found to be between 71 and 100 tons per hectare. Such a phenomenon decreases the vegetation cover percentage and increases the ratios of plants of low forage value, decreasing the productivity rate of Egyptian soil by 45% in the last 35 years, which is considered a huge challenge for food security in Egypt as agriculture represents 12% of Egypt's GDP. (Ahmed, 2015)

Some endeavors were done by IAEA to help Egypt detect the erosion rate and thus help in fighting its factors. The gamma detector detects the presence of some radionuclide tracers, such as caesium-137 (Cs-137), as it is found in the topsoil of fertile lands. If a decrease was detected, that meant this area was under the effect of erosion, and vice versa, which helped Egypt to know where to focus its efforts to fight the wind erosion. The major defect of this solution is that this technology is expensive and relatively new, which makes it hard to obtain. (Egypt and Senegal receive gamma detectors to help combat soil erosion 2018)

Medusa Instate took on another project to solve the problem. Their project depended on making a soil moisture sensor using a CsI scintillation crystal installed in its detector, which detects the amount of gamma rays coming from the radioactive elements beyond the top soil. Depending on the fact that water is a gamma ray's insulator, if the sensor measures a decrease in gamma rays, it means this land is filled with water, and vice versa. This technology was able to measure the soil moisture in the top 30 cm of soil and was unaffected by the environmental conditions, yet it is considered an expensive technology and thus cannot be used widely in Egypt. (Medusa, 2022)

The goal of this project is to use both a humidity Arduino sensor (DHT) and an Arduino soil moisture sensor to measure the percentage of water in the soil using the concept of electric conductivity. The sensors are measured for their error rate to ensure better accuracy. Using an IOT system to connect the whole system to an online website, showing the data in the form of a graph, to help Egypt further study the problem and take the necessary measures to solve it.

Materials and Methods

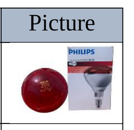
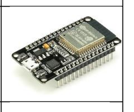
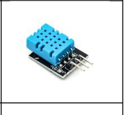
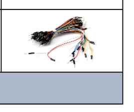
Number	Item	Amount	Usage	price	Picture
1	Infrared lamb	1	Heat source	200 LE	
2	Electric wire with stand	1	Fix the lamp in a stationary position, and supply its electricity	20 LE	
3	Glass box	1	Soil container	35 LE	
4	ESP32	1	Analyzing and Wi-Fi unit.	235 LE	
5	DHT11	1	Measuring the humidity and temperature.	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			

Table.1 materials

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 15*15*20 cm (±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).

Figure 1. glass box

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).

Figure 2. heat lamp stand

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

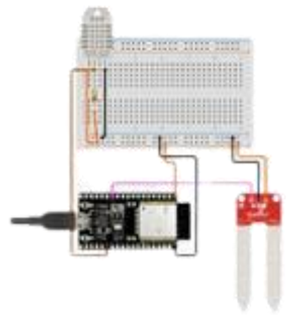


Figure 3. ESP32 circuit

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. https://ahmedelshentenawy.github.io/Group-19313/19313.html

Results

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: -

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%

Table.2 first test

Second 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%

Table.3 second test

Third 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%

Table.4 third test

Analysis

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.

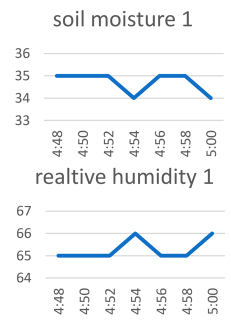
A significant decrease in the relative humidity has a huge effect on the soil moisture because when it decreases, the amount of water stored in the outer layer of the plant leaves also decrease. As a result, it triggers the plant's response to increase its transpiration rate for water delivery, keeping 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)

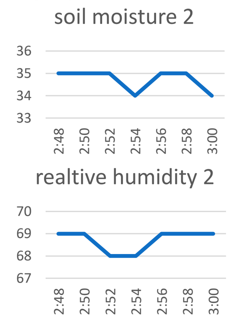
In this first test, the sensors' readings show a slight decrease and increase in humidity between 69% and 68%, as shown in graph (1). while the soil moisture remained stable. The reason for this was the lack of enough heat for the phenomenon to start. The lack of thermal energy was associated with the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



graph.1 first test

Second test: - (negative result)

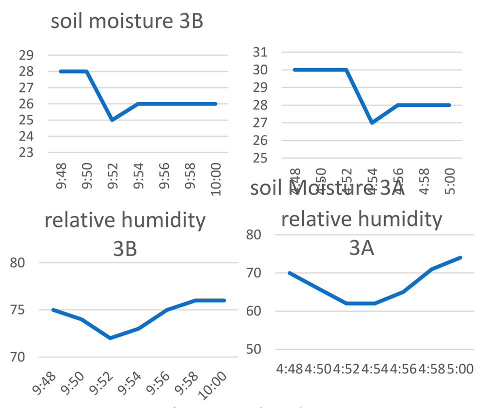
Before the second test, the tungsten lamp had been replaced by a heat-infrared lamp. Although the lamp emitted the required amount of heat per minute, the phenomenon didn't occur; rather, a decrease in soil moisture percentage and an increase in relative humidity percentage were observed, as shown in 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.



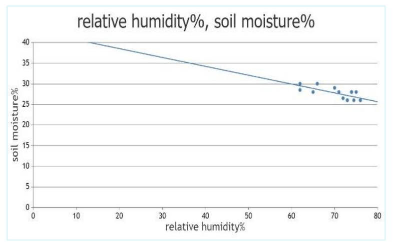
graph.2 second test

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).



graph.3&4 third test A&B



graph.5 relative humidity and soil moisture relation

The type of bulb used for dehumidifying the soil through heating was chosen based on the study of light reflection, as we learnt in **ph.3.03**. 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, as we learnt in **ph.3.04**. 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, as we learnt in **ch.3.02**. Choosing the most suitable sensors for the measurements couldn't be done without understanding the sensation, sensor types, and sensory pathways, as we leant in **bi.3.03**. 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, as we learnt in **bi.3.04**.

conclusion

During the process of making the prototype, we were able to conclude many useful pieces of information that can help further develop the prototype. For example, the higher the amount of water the plant demands, the quicker the soil drying process, which categorize the plants into two sections: moisture-saving plants, and moisture-wasting plants. In low humidity environments, plants tend to lose water in the outer layers of their leaves, which causes an increase in the plant's transpiration rate, which is the primary cause of soil moisture loss. The heat required for the phenomenon to occur is around 40C. The increase in humidity of the phenomenon is soon raised to a higher layer of the atmosphere, decreasing the humidity again, which is the reason for both humidity and soil moisture to decrease in real life applications. Different modules of sensors have different accuracy, the resistive soil moisture sensor has an error of ± 1%, while the capacitive soil moisture sensor has an error of ± 0.3%, for example.

Recommendations

- 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.

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