PEST-WATCH

Keywords:

Soilless Farming - Pests - Fungal activities - Feedback - Sustainability

GROUP 212

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I. Presenting and Justifying Problem and Solution Requirements

Introduction

Egypt is one of the third world countries, which means it is one of the developing countries, but unlike other third-world countries, Egypt has the potential to have great achievements and be a first-world country. Like many other countries, Egypt is facing some problems that need to be solved to achieve greatness, and these problems are called Egypt Grand Challenges, which are various issues affecting the economy, ecology, social life, and long-term viability. These issues are a roadblock in the way of its progress. To tackle these problems, we must view them as challenges that we are attempting to solve with difficulty, and we must think about and come up with innovative solutions to such problems.

In this semester, it is recommended to develop Egypt's agricultural sector to be more reliable on technology. Therefore, a feedback system was created to build a sustainable agriculture system in the project.

Figure 0: Egypt Grand Challenges

Improve the Scientific and Technological Environment

Overview

Improving the scientific and technological environment is a vital process for both developing and developed countries, as all nations are facing challenges related to environmental pollution, climate change, food insecurity, and pandemics. Therefore, it is essential to enhance a strong approach towards developing the environment. According to the World Bank, a 10% increase in research and development (R&D) spending as a percentage of GDP can lead to an increase in productivity of up to 0.3%. This indicates the importance of overcoming this challenge worldwide.

A report by the World Intellectual Property Organization (WIPO) found that renewable energy technologies account for almost half of all patent applications related to climate change mitigation technologies. As shown in figure 1, investing in patenting can have a crucial impact on the development of clean energy and recycling sectors. One of the rapidly growing sectors is electricity generation using wind energy. All of this emphasizes the importance of developing an approach towards developing the scientific and technological environment for saving the planet.

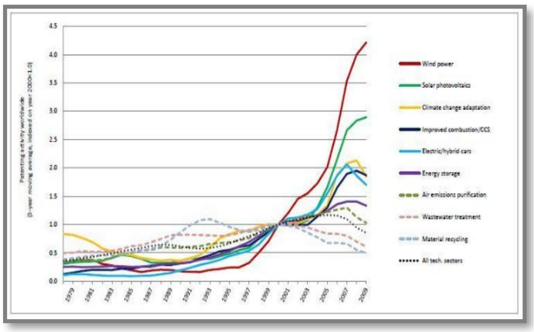


Figure 1: The effects of patenting on the development of environmental sectors.

Causes

Lack of funding scientific research:

Scientific research requires great investment in terms of time, money, and effort. In 2019 it was estimated the United States spent over $581 billion on scientific research, followed by China which spent around $496 billion, and Japan with $170 billion.

As scientific research requires huge amounts of money, not all countries are capable of spending the sufficient money for it. According to world bank Egypt only spend 0.9% from its GDP on scientific research as shown in figure 2, which is massively low compared to other developed countries.

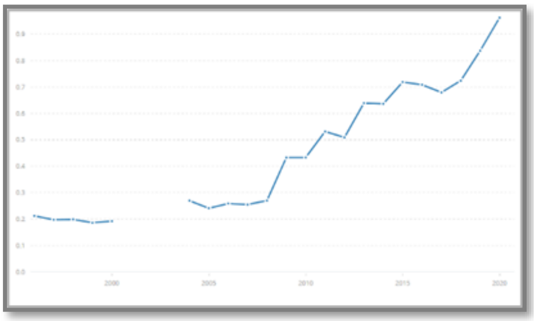


Figure 2: Percentage of GDP invested in scientific research in Egypt from 1990 to 2020.

Inadequate international collaborations:

International collaboration is vital when it comes to solving global challenges, especially the improvement of scientific and technological environment. According to the world intellectual property organization, around 82% of all patents filled were from the top 10 countries that collaborate with each other. The opposite figure shows a scientific line drawing of collaborations between the United States, Canada, European countries, and Australia, which shows how they are well connected in the scientific research sector.

On the other hands Africa is facing several challenges for achieving collaborations in the research field, which result in huge development hole in Africa compared to Europe and The United States.

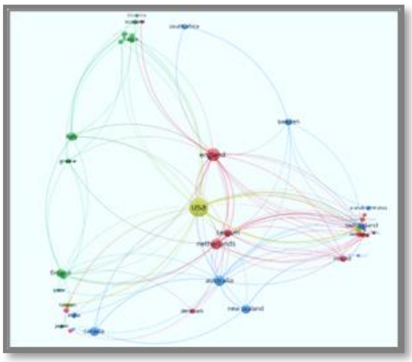


Figure 3: lined map of global collaboration between the US, Europe and Australia.

Limited access to education:

Having access to education resources can massively affect the development of scientific and technological research, which would help in the development countries. According to UNISECO, only about 20% of students in Africa and 40% in Asia complete their secondary education. In 2018 literacy rate was estimated to be 75.3%. All these factors take part in the late development of scientific and technological research.

Impacts

Slowed progress and development:

According to the global competitiveness report made by the World Economic Forum in 2019. The first 10 countries such as the US, Singapore and Hong Kong has some traits in common. Mainly they are all highly developed in scientific environmental research. Otherwise, Egypt is ranked as the 93rd; due to its weak collaboration with developed countries in the sector of developing environmental technologies. Which can indicate the slow progress for developing countries compared to developed ones.

Weak environmental performance:

According to the EPI (Environmental Performance Index), which ranked 180 countries on their progress in providing a clean environment. The first ten countries also share a common pattern: their enrollment in global collaborations for saving the environment and their developed technology, as shown in figure 4. On the other hand, Egypt is ranked 127th in the same classification. Egypt is trying to overcome this by hosting COP 27 (the 27th Conference of the Parties), which aims to increase global awareness of climate change and other environmental risks.

COUNTRY	RANK	EPI SCORE	10-YEAR CHANGE
FILTER BY REGION: ALL REGIONS			
Denmark	1	77.90	14.90
United Kingdom	2	77.70	23.00
Finland	3	76.50	21.00
Malta	4	75.20	25.40
Sweden	5	72.70	15.80
Luxembourg	6	72.30	13.50
Slovenia	7	67.30	8.60
Austria	8	66.50	7.20
Switzerland	9	65.90	8.20
Iceland	10	62.80	4.40

Figure 4: Top 10 countries in the EPI (Environmental Performance Index).

Health and wellbeing:

According to a World Intellectual Property Organization report, low-income countries have massively lower rates of innovation and technological development than high-income countries, which can limit the ability of these countries to develop new and effective treatments, vaccines, and public health interventions to address pressing health challenges. A study on public health in 2017 has shown that 70% of deaths from non-communicable diseases occur in low-income countries, due to the absence of technology updates and research in the medical field.

Increase Industrial and Agricultural Base

Overview

Developed countries have concentrated on growing the industrial and agricultural sectors for decades to improve the economy. Influencing the availability of finance and the quality of human resources.

This method benefited them, which brought them economic stability, a surge in maintaining foreign currency reserves, assisting the agricultural industry and other economic sectors, and improved spending and investment. Even though Egypt is one of the best nations, it is not one of the globally most advanced in terms of industrial development in Arab nations. Countries with progressive industrialization. Figure 5 shows that Egypt came in at 37 out of 40 on GMCI for 2016, or the Global Manufacturing Competitiveness Index, according to "The Council on Competitiveness in the U.S."

Agriculture and industry play significant roles in forming Egypt's GDP (Gross Domestic Product) of Egypt). According to the Egyptian Ministry of Planning, the GDP from Agriculture in Egypt increased to 285421.80 EGP Million in the third quarter of 2022 from 112071.20 EGP Million in the second quarter of 2022, while at the same time, the GDP from Manufacturing in Egypt increased to 314607.70 EGP Million in the third quarter of 2022 from 142232.80 EGP Million in the second quarter of 2022, as shown in figure 5.

Figure 5: GDP of agriculture and manufacturing sectors in Egypt.

Causes

High spread of aridity:

According to Alfred Weber, the sector is situated where the cost of transporting raw materials and finished goods is low. This makes it challenging to construct factories in arid regions since it will be expensive to transport goods to marketplaces in populous areas. Egypt needs manufacturers because 86 percent of its land is arid, and the remaining 14 percent is semi-arid and crowded. In addition, arid areas in Egypt represent about 95% of their area, and most of them need to be more suitable for agricultural processes, making it challenging for the country to reclaim them.

Limited access to finance and investment:

FDI (Foreign Direct Investment) plays a significant role in developing industry or reclaiming arid areas. FDI support should be continuous and stable to achieve stable and fast growth in developing industrial and agricultural projects. The FDI Egypt receives does not support the previous conditions, as it changes rapidly due to economic crises, inflation of the local currency, and global status. As shown in figure 6, the amount of FDI Egypt receives could be more stable and shows many ups and downs, slowing the local plans for industrial and agricultural projects.

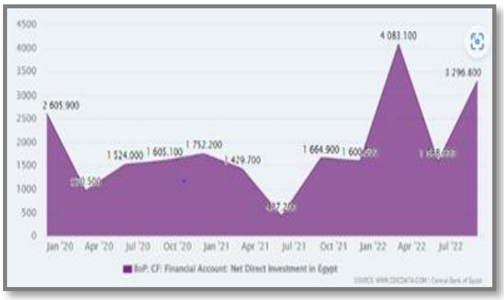


Figure 6: FDI rates from June 2020 to – July 2022 in Egypt.

Water scarcity crisis:

According to UNICEF, Egypt is facing a severe crisis for its water resources, with a deficit of around 7 billion cubic meters annually. As a result, the United Nations is warning Egypt to run out of water by 2025. As shown in figure 7, Egypt became a water-scarce country with an amount of 555 m3 of fresh water per capita in 2018 annually, which is supposed to go below 450 m3 by the end of 2025.

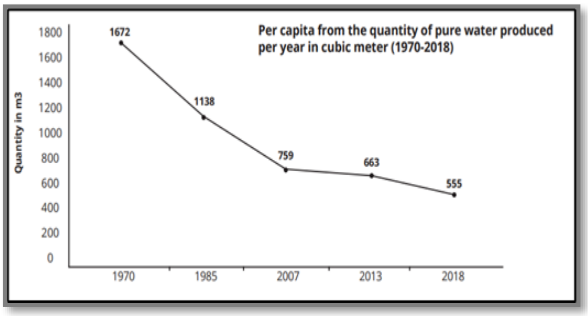


Figure 7: Water per capita in Egypt from 1970 to 2018.

Impacts

Food insecurity:

Egypt heavily depends on the industry and the agriculture sector; to provide its food demands. If it could not develop these sectors, it would face food insecurity, as the country would struggle to produce enough food to meet the demand of its population. According to the Food and Agriculture Organization of the United Nations, Egypt's food import bill reached $4.4 billion in 2020, which increased the country's reliance on imported food and raised the risk of food insecurity.

Economical fail:

Agriculture and industry sectors together account for about 40% of its GDP. If Egypt couldn't improve its industrial and agricultural bases, it would fall in a significant negative impact on its economic growth. According to the World Bank, Egypt's GDP grew at a rate of 3.6% in 2021. However, this growth could be hindered if the country does not invest in its industrial and agricultural sectors, which can result in several crises, such as unemployment, and economic fail.

Making large purchases on imports:

The World Bank reported that Egypt's imports rose from $60 billion in 2015 to $81 billion in 2019, with machinery, petroleum products, chemicals, and food being the most popular imports. This excessive dependence on imports can have negative consequences for the economy of Egypt, as it increases the trade deficit and puts a load on the country's foreign exchange reserves.

Improve Use of Arid Areas

Overview

An arid area is a dry area that lacks available water resources besides the harsh climate in this area that prevents the growth and development of plants and animal life. In Egypt, only 4% of its area is agricultural and used, while about 96% suffers from desertification and non-usage. According to UNICEF, about 7.7% of Egypt's total area is inhabited, making a tiny usage of the whole area, which is 1,002,450 km^2.

Arid areas can be observed in three main areas. The first one is the western desert, which covers more than 700,000 km^2, followed by the eastern desert, with an area of 220,000 km^2, and Sinai, 61.000 km^2. Egypt's population reached about 111 million citizens in 2022, which is rapidly increasing by 1.68% compared to the previous year (2021). In order to combat challenges with overcrowding and food insecurity, it became crucial to cultivate arid areas.

Figure 8: Arid areas classification according to the Ministry of Agriculture and Land Reclamation.

Egypt's aridity is divided into three primary categories, as illustrated in Figure 8, by the Ministry of Agriculture and Land Reclamation: hyper-arid, arid, and semiarid. Egypt's aridity ranges from 14% arid, which is only appropriate for a few types of agriculture, to 86% ultra-arid, which is unsuitable for most. As a result of these analyses, Egypt should pay great attention to planting suitable kinds of plants depending on their aridity.

Causes

Population growth and urbanization:

The population in Egypt increased from 22 million in 1952 to approximately 110 million in 2022, as shown in Figure 9. This high population increment without cultivating more land leads to high demand for the same available lands for higher food production. The extensive demand for soil can lead to soil erosion, turning it into an arid area. As a result, expanding citizens to new cities made in deserts to cultivate it would be highly recommended to solve the arid areas challenging.

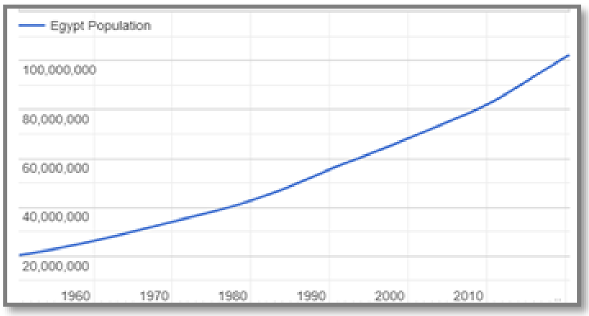


Figure 9: population growth in Egypt from 1952 to 2022.

Energy resources management:

Egypt is facing a crisis in supplying energy supplies for agricultural activities as recorded energy production increased from m 53,090 to 80,357 between 2000 to 2014. According to IEA (International Energy Agency), agricultural energy consumption increased by 751.3%. As a result, it was expected that about 17% of Egyptians would suffer from food insecurity. Which also makes it harder to cultivate arid areas.

Lack of clean water resources:

According to UNICEF, Egypt is estimated to be a water governor country as clean water per capita was reduced to 500m3 annually. Arid areas depend on clean water resources for planting, which forms an excellent challenge for Egypt to improve its clean water resources to plant arid areas.

Impacts

Food insecurity:

Egypt has more than 5 million acres of arable land in addition to an extensive area for cultivation. However, due to limited clean water resources, Food resources are limited and only satisfy Egyptians' needs. It was estimated that Egypt imports about 60% of its primary food, which costs more than 10 billion dollars/per year.

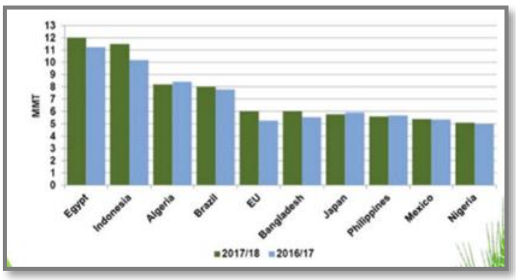


Figure 10: Major World Wheat importers for 2016/2017 and 2017/2018.

According to the US wheat supply and report, Egypt is on the top list of wheat importer since the year 2005 until now, with average imports in February 2017 of 12 million tons, as shown in figure 10.

Increase in urban congestion:

Leaving arid areas without planting or entering service would lead to an unequal concentration of Egyptians for land; as mentioned before, only 7.7% of Egypt's area is inhabited. As the population is rapidly growing, cities get denser with population. As a result, urban congestion would be noticed in these areas.

Lack of energy resources:

Arid areas in Egypt are excellent natural gas and oil source for energy production. According to the U.S. Energy Information Administration, Egypt is Africa's largest natural gas producer, with a production rate of 580,000 barrels per day. Most of the gas comes from the Western desert, where several oil fields are located, such as Khalda, Qarun, and Bahiriya.

Without improving the usage of arid areas, Egypt would face a local energy crisis, followed by an economic crisis, as it earned a total of $5.2 billion from petroleum exports, according to The Central Bank of Egypt.

Reduce and Adopt to the Effects of Climate Change

Overview

Climate changes are the changes in weather patterns of rain, precipitation, temperatures, and wind. These changes put the world at many risks, such as rising sea levels, melting ice, and increasing extreme weather events, as shown in figure 11, over the last century, the world's average temperature has been increasing from -0.08 °C to 0.85°C, a hugely significant change. In the atmosphere, greenhouse gas (GHGs) emissions, such as carbon dioxide, methane, and nitrous oxide, are the antagonist in climate change. The pursuit of industrial development in Egypt neglects its adverse environmental effects.

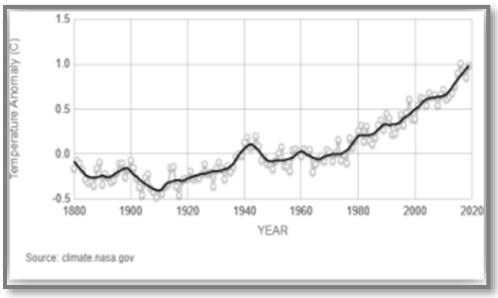


Figure 11: World's average temperature from 1880 to 2020.

In addition, Egypt is one of the largest emitters in the MENA Region, as in 2019, Egypt's CO2 emissions reached 245 million metric tons in the energy sector only. Those emissions could contribute to more global warming, as now; Egypt is already experiencing intense heat waves that could be deadly for children and elders. Climate changes are challenging Egypt, as they may cause a rise in the sea level. As the Nile delta is already subsiding by 3-5 mm each year, a rise of 1m will lead to a flood of one-fourth of the Nile Delta. Climate change also can result in changes in public health, as greenhouse gases can cause severe and dangerous diseases.

Causes

Manufacturing goods and power:

According to the International Energy Agency, the energy sector accounted for 60% of global greenhouse gas emissions in 2020, making it the most significant contributor to climate change (IEA, 2021). In Egypt, the energy sector also significantly contributes to greenhouse gas emissions. In 2019, the country's carbon dioxide emissions from energy consumption amounted to 231.1 metric tons, an increase of 2.6% from the previous year (World Bank, 2021). As a result, Egypt is expected to have an increase in water stress in the coming years, according to the United Nations. Those significant climate changes require urgent action to transition into a more suitable environment.

Urban congestion:

Transports account for 25% of global CO2 energy-related CO2 emissions. Most transports like cars, trucks, ships, and planes run on fossil fuel that enters the combustion energy and emits CO2 as an out-turn of the system. In developing countries, emissions from transportation are increasing rapidly due to the increase in car ownership and road infrastructure. In Egypt, the car fleet is growing, with an estimated 1.8 million new cars added to the roads in 2019.

Global warming and greenhouse effects:

Global warming changes climate as the Earth's temperature increases due to greenhouse gas emissions. According to Egypt's profile on OurWorldInData, Egypt's annual CO2 emissions is increasing and reached 249 million tons in 2021, as shown in figure 12.

According to the World Meteorological Organization, the average temperature in Egypt has increased by 1.8°C since the 1970s, with temperatures expected to rise further by 2-3°C by the end of the century if emissions continue at the current rate, which is making it crucial for Egypt to look for efficient solutions to reduce its greenhouse emissions.

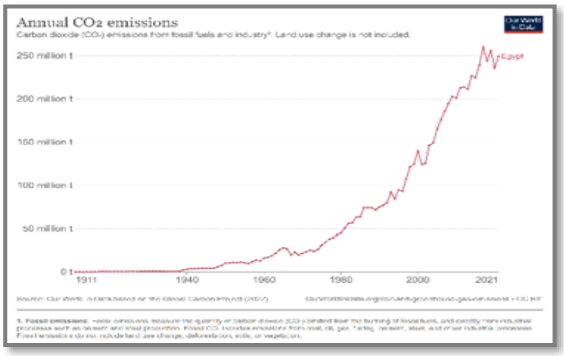


Figure 12: This study shows the inline of CO2 emissions through the last century.

Impacts

Decrease in clean water and increase in draught:

Climate change affects water availability, as it may end with more scarce water. Global warming can create new water-stressed regions, leading to the drought of agricultural lands. Moreover, drought can stir the different soils with each other, as it can stir destructive storms with drought sand to expand deserts, so Egypt geographically could be prone to be water-stressed regions. According to reports, Egypt's water supply is expected to decline by 20% by 2025. Also, clean water per capita is affected, as it has declined to below 1000 m3 per year, as shown in figure 13.

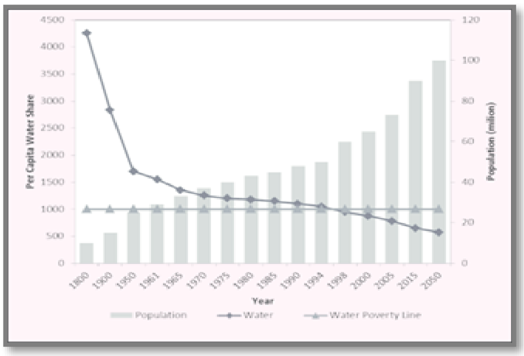


Figure 13: Water per Capita from 1800 to 2050.

Rising of sea level:

According to a report by the United Nations Development Programme (UNDP), sea levels in Egypt have risen by an average of 3 millimeters per year within the past 25 years. This is due to a combination of factors, including melting ice sheets and glaciers, thermal expansion of seawater, and changes in ocean currents. In addition, saltwater intrusion is threatening the country's freshwater resources, which are already strained by population growth and agricultural demands. Moreover, Sea level rise has many impacts, such as erosion of beaches and inundation of deltas. Egypt's coastal cities, including Alexandria, Port Said, and Damietta, are among the region's most vulnerable to rising sea levels, with nearly 7 million people living in the affected areas.

Health risks:

Climate changes are already hurting human health through air pollution, diseases, and extreme weather events. Furthermore, higher temperatures and increased air pollution could exacerbate respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). A Ministry of Health and Population report demonstrated that air pollution is responsible for around 50,000 premature deaths in Egypt each year. Particulate matter (PM) and sulfur dioxide (SO2) are two common pollutants emitted by industrial facilities in Egypt that cause series diseases like respiratory problems such as bronchitis and can irritate your nose, throat, and lungs.

Problem to be Solved

High crop losses from pests and fungal activities and the hazardous effects of chemical pesticides

According to Food and Agriculture Organization (FAO), Egypt is an essentially agricultural country, as it counts for 12% of the country's GDP and employs around 30% of the population. However, pests are a significant threat that can harm agricultural production in Egypt. According to the Ministry of Agriculture and Land Reclamation, the economic losses from pests in Egypt's agriculture sector are estimated to be around 15-20% annually.

Pests and fungal activities are not just local challenges. According to the Food and Agriculture Organization (FAO), in 2019, it was estimated that global crop losses due to pests and fungal activities exceeded more than 40% of the total crop production. At the same time, another study emphasizes that wheat yields could decline by 6% annually in places that get hotter by 1 degree Celsius. These losses can be monitored in tropical and temperate countries with rising rates compared to other countries, as shown in Figure 14. Pests and fungi also risk the local economy and production. In 2016 Cotton Bollworm infestations resulted in a loss of around $160 million, making it a severe challenge for Egypt to avoid these massive losses.

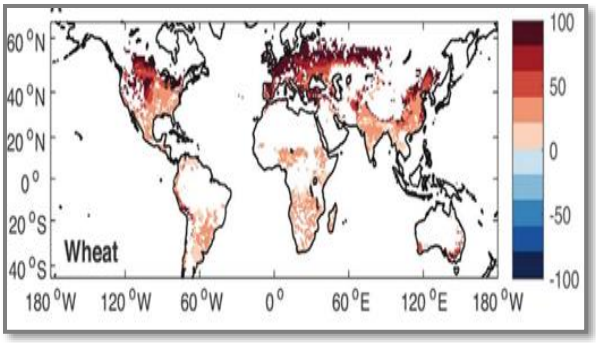


Figure 14: Wheat yields loses worldwide due to pests and fungal activities.

Traditional methods of treating pests and fungi can be dangerous and pose more challenges, as chemical pesticides and fungicides contaminate the soil and groundwater, damaging soil fertility and water quality. According to a study by the Ministry of Environmental, pesticides and fungicides residues were detected in 60% of the soil samples taken from agricultural lands in Egypt, exceeding the maximum residue limits (MRLs) set by WHO and FAO.

As a result, it became necessary for all countries to think of new and creative ways to reduce their crop losses for pests and fungal activities without using harmful chemical pesticides or fungicides; to maintain a clean environment and achieve high economic growth and production.

If the Problem is Solved

Increased Crop Yield:

In Africa, crop losses due to pests and diseases can be as high as 50%. Identifying threats like pests and fungi activities in plants will contribute to taking action to save the plant and the whole land from the transmission of infection. This will help us to reduce risks and increase crop yield and profits. Moreover, the quality of the crop can be a new export market and boost the economy. A study made by FAO found that using integrated pest management (IPM) techniques in rice production in Egypt led to a 13-18% increase in yield, which highlights the importance of solving that challenge.

Reduced Use of Pesticide:

A study by the Central Agency for Public Mobilization and Statistics (CAPMAS) found that the use of pesticides in Egypt has led to soil degradation, water pollution, and biodiversity loss. Due to the negative impacts of pesticides and fungicides, reducing them can positively impact health and environmental effects. Detecting those pests and fungal activities will reduce farmers' reliance on pesticides, resulting in lower pollution levels and reduced exposure to harmful chemicals. Therefore, it can protect biodiversity and warn farmers of the invasive spread of certain species, which can affect the environment. It decreases risks to human health so that food safety can be improved.

Improved Resilience to Climate Change:

According to the Food and Agriculture Organization (FAO), the chemical pesticides industry is responsible for emitting more than 1.5% of the total world's greenhouse gas emissions. In addition, according to the United Nations (UN), the production and use of chemical pesticides can contribute to air and water pollution, besides soil degradation. By implementing a sustainable system that removes pests and fungi safely without the use of chemical pesticides, that would help in building safer environment and much healthier crops.

If the Problem is not Solved

Environmental Damage:

The presence of pests leads to using the pesticide, which leads to contamination of the surrounding environment. According to a report by the Egyptian Environmental Affairs Agency, 1.2 million tons of pesticide products are used in Egypt every year, with some pesticides found to be persistent in the environment for years. As well as having harmful impacts on wildlife like fish and birds. Pesticides lead to biodiversity loss, as they kill non-beneficial and beneficial insects on the plants. This can hurt natural pest control and pollination. Moreover, pesticides can produce volatile organic compounds into the air, contributing to air pollution and harming human health.

Economic Losses:

Pests and fungi cause significant economic losses in agriculture globally and in Egypt. These losses can reach up to 40% of global crop yield annually with economical loss of $10 billion in the US only. Studies show that pests damage tomato and potato crops in Egypt by 5-40% and 15-20%, respectively, which comes with economical crop losses for Egypt. As a result, management and monitoring strategies are needed to minimize losses and maintain a stable agricultural economy.

Health Risks:

Pests and fungal activities can pose health risks for humans through direct transmission or through consuming contaminated food before pesticides. Pests or bacteria that contaminate food, causing symptoms like diarrhea, vomiting, and fever, and can be hazardous for young children, the elderly, and people with weakened immune systems can cause Foodborne illness. Using chemical pesticides makes the situation worse. It exposes us to allergies and causes skin and eye irritation. They can be toxic to humans if they are not used probably. A World Health Organization (WHO) study stated that more than 10,000 cases of acute pesticide poisoning are reported annually in Egypt, which highlights the risks of the challenge.

Research

Topics related to the Problem

Fungal diseases and plant health issues:

When fungal activities begin to appear on the plant, farmers must deal with it immediately; otherwise, it can lead to fungal diseases appearing on the plants. Fungal diseases have huge impacts on plants and can sometimes weaken the plant or lead to death. One of these diseases that can cause significant loss in crops is wheat rust, as shown in Figure 15. Wheat rust is an orange fungal infection caused by the fungus puccinia that can cause up to 70% of yields losses if it is left untreated, which highlights the importance of fast taking reactions once a fungal disease appears.

Figure 15: Wheat rust caused by fungus puccinia.

Loss in soil fertility and appearance of soil erosion:

Soil erosion is a significant problem associated with the massive usage of chemical pesticides to remove pests and fungal activities. According to the Food and Agriculture Organization (FAO), about 25 billion tons of soil are lost annually due to erosion. Another study compared two samples of soils; the first one contained chemical pesticide contaminations, and the other didn't; the results showed the first had 58.5% less organic carbon, 54.8% less total N, and 55.0% less microbial biomass compared to the soil without contaminations. As pesticides and fungicides account for more than 50% of the total pesticides used, as shown in Figure 16, it is crucial to develop a sustainable solution to deal with pests that can save the environment by reducing more than half of the pesticides used.

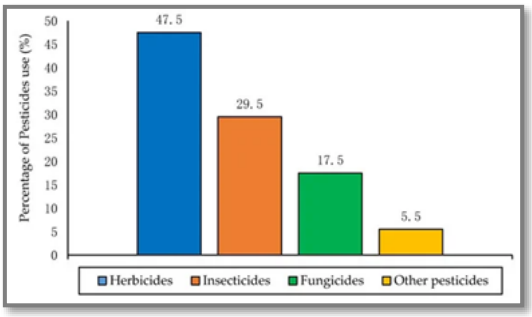


Figure 16: Percentages of various types of pesticides used globally.

High concentrations of heavy metals in the soil:

The extensive use of chemical pesticides and fungicides can lead to high concentrations of heavy metals in the soil, such as lead, copper, and zinc., which has massive negative impacts on the growing plants and the health of humans and animals who feed on these plants. According to Environmental Health Perspectives, a 23% increase in lead levels in the soil was detected in soil samples that used phosphate pesticides to treat pests. Another study observed an increase in soil contamination of up to 10mg/kg when chemical pesticides were applied. This problem indicates the importance of applying eco-friendly pesticides to conserve the environment.

Topics related to the Solution

Hydroponics Soilless agriculture:

Figure 17: Hydroponic (soilless agriculture) farm.

Hydroponics, as shown in Figure 17, is a soilless agriculture type, a modern method of growing plants without using soil. Planting in a soilless medium is usually done inside indoor closed places, which reduces the risk of getting pests in the plants. Besides, it also reduces the risks of fungi growth, as the system eliminates the use of the soil, which is the growing medium for fungi and plant diseases. Instead of using soil, the system depends on spraying tiny drops of a nutrient solution containing all essential nutrients for plant growth, which is dropped on the plant's roots. Planting with soilless agriculture methods has saved more than 90% of water usage compared to traditional farming. As soilless agriculture mainly occurs in closed indoor places, it has shown to be a more protective and manageable solution for pests compared to traditional farming.

Natural Extracted Biopesticides:

Figure 18: Neem oil trees.

Biopesticides are a natural solution for removing pests and fungi without the use of chemical pesticides that cause short-and-long-term harm. Biopesticides were an eco-friendly and efficient solution for removing various pests and fungi. Biopesticides are also more challenging for the pests to develop resistance to it, forming a sustainable and safe solution for pests and fungi. One of the most common compounds used in biopesticides is azadirachtin, a compound extracted from neem oil trees, as shown in Figure 18. This compound has shown exciting results by removing an enormous variety of pests, insects, and fungi.

Autonomous detection of pests:

Automatic detection of pests plays an excellent role in automating pest removal systems. Autonomous detection relies on some technologies and sensors, such as motion sensors, cameras, and machine learning algorithms, to automatically monitor, identify, and report pests in the agricultural fields. It enables accurate detection of pests even at early development stages. The system generates a large amount of data that can be analyzed to optimize pest management strategies. In addition, those systems can be easily updated to recognize new pests or adapt to the changing environment. Implementing this system will be the crucial process of automatically removing pests.

PRIOR SOLUTIONS

Aerofarms

Overview

Aerofarms is a farming company that has innovated technology to grow indoor vertical farms, as shown in Figure 19. The project aims to provide fresh food for people while reducing environmental impacts. According to an official study, Aerofarms uses 95% less water than other traditional farms and records higher yields rates, more than 390 times compared to other traditional ways. Through these farms, plants grow naturally without adding pesticides and herbicides, producing higher-quality produce. Aerofarms also can adjust environmental conditions to prevent the growth of fungi or diseases on plants.

Figure 19: An Aerofarm plant.

However, the limitation of not using pesticides and herbicides can limit its potential market. With a total growing area of about 250,000 square feet, Aerofarms aims to reduce global pollution by establishing farms in high urban areas, which helps reduce pollution in these areas. Besides solving other global challenges, such as water scarcity, by providing new technologies for using less water for farming.

Mechanism

Aerofarms use a special technique for growing plants known as aeroponics. This technique makes plants' suspended in the air without using soil; then the nutrient is delivered to them through a fine rich mist, allowing the plant to grow more efficiently without needing soil.

This technique also uses LED lighting as a more efficient alternative to sunlight, which has some special properties, such as the ability to be adjusted to make the best environment for each plant.

The plant's growth is monitored using a feedback system mechanism with data for each stage of the growing process, such as temperature and nutrient level, which helps adjust the best growing condition for the plant in each stage. Making crops produced has higher quality and yields compared to traditional plants.

Strengths

Water efficiency:

Aerofarms has a unique closed-water system that can save up to 95% of the water used compared to other traditional farming methods. The aeroponic system, which does not depend on the soil, also saves a significant amount of water. According to a report from AeroFarms, only 0.4 gallons are used per pound of grass produced. Compared to traditional farming, which takes 80 gallons per pound.

Reduced land use:

The vertical farming system, as shown in the previous figure, helps expand the production area for each square foot of land compared to traditional farming. The company reported that it could produce up to 390 times more green per square foot compared to other lands with traditional farming. As a result, it can be the best solution for farming in urban areas.

Increased crop yield:

Aerofarms achieve about 30 times higher crop yield than traditional farming; because of the flexible environment that suits each growing phase in the plant, the precise nutrient delivery leads to faster growth and higher yields.

No pesticides and herbicides:

AeroFarms' indoor vertical farming system eliminates the need for pesticides and other harmful chemicals typically used in traditional farming, resulting in a healthier and safer product. The system uses a complex environmental control system that prevents diseases and pests, eliminating the need for pesticides.

Weaknesses

High capital investment:

Aerofarms required an initial cost ranging between $50 to $100 million. This massive cost makes applying harder in many areas worldwide, especially in developing countries. Also, it requires highly developed research labs and experts to monitor the performance, making the cost heavier.

High energy consumption:

The use of LED lighting and HVAC systems in AeroFarms' indoor vertical farming system results in high energy consumption, which can increase operating costs. While AeroFarms claims to use up to 95% less energy than traditional lighting methods, the high energy consumption is still a concern.

The complexity of technology:

The closed system of delivering water and nutrient requires advanced Technology and experts who can operate and maintain the system. Another challenge for countries is forming a well-educated staff with modern Technology, especially using automation systems, sensors, and software.

Potential for product uniformity:

AeroFarms' indoor vertical farming system relies heavily on controlled environments, which may result in product uniformity at the expense of natural variations in taste and texture. This may limit the product's appeal for some consumers who value natural variations in taste and texture.

RobHortic

Overview

RobHortic robot, as shown in Figure 20, is a short-distance robot used to detect and monitor the plant's health and the presence of diseases or fungal activities. The project uses advanced hyperspectral camera sensors to capture data and detect any health issues with the plant. If it notices something abnormal with plant health, it sends feedback to the company's connected computer to report the issue. It sends the location coordinates of the plant to the device using a GPS sensor implemented in the system. The robot also is developed with automatic treatment response allowing farmers to treat their infected plants automatically with no effort.

Figure 20: A RobHortic pests robot.

The robot has been developed and tested over three campaigns in carrot fields; to test its ability to detect plants infected with Candidatus Liberibacter solanacearum (bacterium infection). The robot successfully detected the locations of the infected plants and ran timely feedback with high accuracy.

Mechanism

RobHortic robot consists of a frame with four fat bike wheels, cameras, sensors, a control computer, a 100-watt spotlight, 24V 250W direct current (DC) motors, lithium batteries, and a GNSS receiver; to receive coordinates of infected plants. The project system is made in a telescopic structure. Cameras are established closer to the plants to capture images with resolutions of 0.5 mm/pixel, 2.5 mm/pixel, and 0.75 mm/pixel, respectively.

The system then uses trained algorithms to compare the captured images with reference images; to check the plant's health. Once an abnormality is detected with the plant, it automatically runs its feedback system, which sends the coordinates of the infected plant using a GNSS receiver and reports the infected plant on the company's connected computer. The robot is customizable and can be modified to implement specific feedback depending on certain conditions and specific detections.

Strengths

High accuracy of detection:

The system was tested on a carrot farm to detect specific plant bacterium infections. After the reported plants were checked using molecular analysis using a specific real-time Polymerase Chain Reaction (PCR), to determine the presence of the target bacterium and compare the results with the data obtained by the robot. Results showed that the system with high accuracy reported the infected plants and sends their location coordinates to the connected computer device, which makes the project a perfect solution for accurate detection and feedback.

Customizable feedback:

The feedback system in this robot can be customizable to serve any demands depending on what the system should detect and the frame of the desired feedback. As the system is constructed on an electronic board, it is also possible for users and companies to add cameras, sensors, and other components to make different ways of detection rather than the camera sensor.

Fast feedback for small farms:

Many field tests were performed on the robot from 2016 to 2018 in commercial carrot crops cv ‘Soprano F1′ in Villena (Alicante, Spain). During the tests, the robot advanced at a speed of 1 m/s, capturing images with all cameras every 80 cm and storing them in an SSD, reflecting its great capabilities for scanning whole small farms to check plants’ health.

Weaknesses

Short distance of detection:

The system is based on light and small camera detection, which has limited range and requires to be established near the plant, which will result in many challenges if the project is applied for large-scale projects that contain hundreds of acres.

Large establishing costs:

The system is estimated to require more than 750$ to build just one robot with all the materials used. This number can be massively great for small scaled farms. The solution is expensive compared to another competitive large-scale project that detects pests.

Lack of experienced human resources:

The project is complicated and requires well-trained staff to ensure the stability of the project and the accuracy of the results. The project requires human resources skills in different fields, such as embedded system engineers and data analysts, which makes the project harder to be applied in narrow developing countries without the help of external resources.

Semios Project

Overview

Semios project, as shown in figure 21, is a pest management system established in Vancouver, Canada. It uses pheromone-based sensors, data analytics, and automated controls to improve the effectiveness of pest control in agriculture. Studies have shown that the pheromone-based sensor can reduce pest population by up to 90%, compared to traditional pesticide-based approaches. In addition, they are highly targeted, which means they control specific pest species while minimizing the impact on non-targeted organisms. Despite the high cost of the sensor, they are more sustainable and minimize the development of pesticide resistance. The platform and the system proved their efficiency and effectiveness depending on various factors. However, pheromone-based pest sensors have shown great promise in improving the sustainability and efficiency of agriculture.

Figure 21: Semios Project.

Mechanism

It uses a combination of pheromone sensors to detect the presence of pests. Pheromones are chemicals insects released to communicate with each other and detecting them can determine when and where pests are present. Semios system includes automated controls used to manage pests in real-time. For example, this system can release pheromones to interrupt mating patterns. The system also can release natural predators or other beneficial insects to control the pest population. It also depends on a cloud-based analytics platform to analyze data from pheromone sensors and other sources. The platform can give farmers insights into pest activity, environmental conditions, and other factors impacting pest management strategies.

Strengths

Sustainable:

The Semios project is highly targeted and specific to the pests being managed, which can reduce and minimize the usage of pesticides. Moreover, it automates the action based on the entered database from the sensors to manage the pests. It helps the effectiveness of pest control.

Real-Time Monitoring:

Semios Project provides real-time information to the farmers through their platform -like mobile devices- to make informed decisions about crop management. That is why it uses cloud-based analytics that analyzes that information through advanced machine learning algorithms to identify patterns and trends.

Cloud-Based Analytics:

Cloud-based analytics allow them to vast the amount of data from various sensors, including weather, soil, and pest traps, and send it to the cloud for analysis. It provides the computational power and storage required to process this data in real time. The cloud-based infrastructure can be expanded to take more information if the growing demand for the land increases.

Weaknesses

High establishing cost:

Like a semios project, real-time monitoring could be costly, especially for small-scale farmers. The cost of purchasing and installing the hardware and software is expensive for the farmer. Moreover, ongoing maintenance and support can be a significant barrier for some farmers.

Connectivity:

The semios project requires a reliable internet connection to transmit data quickly and keep the real-time monitoring systems working well. However, many rural areas may need access to high-speed internet, making it different to implement the system in those areas.

Technical Expertise:

Using this kind of complicated system requires a certain level of technical expertise. Farmers may need the training to learn how to use the system effectively. Some may not use the system because they find it complicated without professional help.

II. Generating and Defining a Solution

Solution Requirements

Eco-friendliness:

The solution must be eco-friendly by eliminating harmful materials such as chemical pesticides and using eco-friendly methods for treating pests and fungal activities. It also should aim not to pollute the environment with any pollutants, which saves the environment and human health.

Durability:

The project must be durable since it assures the lifetime and dependability of the project. A substantial project can survive numerous environmental variables, and other challenges, guaranteeing that it will continue to be valuable and practical for a long time. Durability not only saves time and money but also improves farmers' satisfaction with the solution, which allows the solution to spread quickly.

Cost reduction:

The project's total cost must be reductive; in order to allow the solution to have widespread among the farmers; this requirement can be achieved by implementing cost-reductive and available materials in our project, which would decrease the total budget of the solution,

Availability:

The solution's materials must be available locally without the need for imported materials; to help maintain a stable budget price for the final product, which would help the solution be affordable and easily manufactured everywhere.

Design Requirements

The following measurable design requirements must be achieved in the project; to consider its success in solving the implemented problem.

Sustainability:

In order to prove the project's sustainability, The solution must succeed in conserving consumed water resources with a minimum of 50% of water compared to traditional farming methods.

Fast feedback response to pests or fungal activities detection:

For the system to be an efficient solution, it must be fast in detecting and responding to the feedback for the detected pests or fungal activities. The project is estimated to complete the two processes in less than 5 seconds.

High accuracy in detecting environmental variables leads to fungal growth:

The system must be able to detect environmental variables that affect fungi growth, which is the moisture, with a minimum estimated accuracy of 75%, which can help in accurately applying the feedback system to protect the plant from fungal activities.

High efficiency of pests elimination by natural extracted pesticides:

The presented solution should depend on natural extracted pesticide; to eliminate the harms of chemical pesticides. The solution should show a high elimination percentage greater than 70% when it is applied to pests to maintain its removing efficiency.

Selection of Solution

Figure 22: Peat moss and Perlite soilless farming.

Firstly, the farming system will be set to build the whole feedback. The farming system consists of soilless agriculture medium made of peat moss and perlite on the ratios 7:3, respectively, as shown in Figure 22. This farming method was chosen as it has proven to achieve higher crop yields and saving up to 70% of water compared to traditional farming. After setting it lettuce plants were planted in that medium.

Then the feedback system is established on the farming system, which consists mainly of two processes; the first process is capturing three parameters to control the feedback: the detection of pests, moisture, and temperature levels. In this step passive infrared motion sensor is used to detect the motion of pests by detecting the infrared rays emitted from them; temperature sensor (thermistor) and moisture sensors were used, as shown in figure 23. These sensors are all connected to Arduino Uno board, which allows the computer connected to read the output values of these sensors and write the programming conditionals code that will be executed if a pest was detected or out of range moisture and temperature levels that help in the growth of fungi were detected.

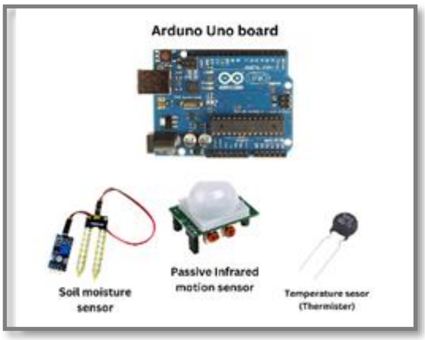


Figure 23: First process (detection) main components.

Once a pest is detected using the motion sensor, or out-of-safe-range moisture levels (from 80% to 100%), or temperature levels (15°C to 20°C), the feedback system will run automatically to protect the plant from pests and fungal activities by automatically spray diluted solution of naturally extracted neem oil, which can act as both pesticide and fungicide to protect the plant with no harms on the environment, soil, or plant health.

The second process of the feedback system consists mainly of a water pump 6V and relay module, which acts as a switch to control the running of the water pump based on specific conditionals, pipes, and 6v battery; to run the pump, and sprayers, as shown in figure 24, These materials of the second process help in spraying the neem oil on the plants and control the water pump running based on established conditions using the relay module.

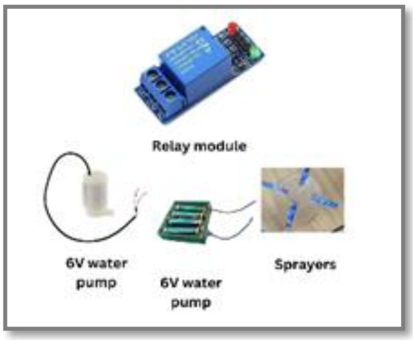


Figure 24: Second process (Feedback response) main components.

The system would automatically run the pump motor to spray neem oil for a specific number of seconds, depending on the estimated value of neem oil that should be sprayed on plant when a pest is detected; after that time, the system will stop pumping neem oil for 2 to 3 hours, until its effects appear and kill pests, at this case no motion will be detected so the mission of the feedback system would be completed.

SELECTION OF THE PROTOTYPE

First, the farming system is implemented using a wide container, and it is filled with peat moss and perlite in a ratio of 7:3, respectively. Then lettuce plants are added, and the container was split into two halves; each half contained four lettuce plants, with a total planted of 8 plants, as shown in the following sketch figure 25.

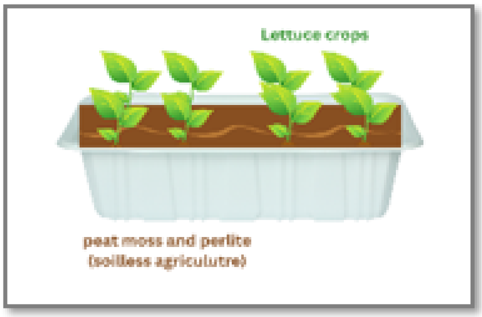


Figure 25: Farming and plants prototype.

Then, motion, temperature, and moisture sensors are added; firstly, 2 Passive Infrared motion sensors are added on the sides of the container held on sticks. Then moisture sensor was added by submerging the sensor in the soil, and it is connected with the soil module to be connected with the Arduino board. Then, a temperature sensor is added (thermistor) by connecting it to the breadboard and managing its wire connections with the Arduino. Figure 26 shows a sketch of all implementations of this step. All materials chosen in this process are characterized by their fast and accurate readings which match the design requirements chosen.

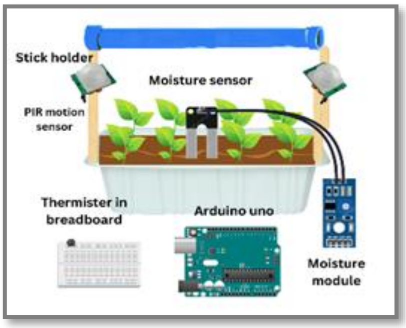


Figure 26: the implementation of detection components.

After that all detection sensors were connected with the Arduino uno board using jumper wires and the breadboard, which can help control all the inputs got and run the suitable feedback automatically.

Then, the feedback system response materials are established. Firstly, the neem oil diluted solution is added in two jars on each side of the container. Then a water pump 6V is put into each pot, connected to the relay module, and battery 6V. Then the relay module is connected to Arduino to connect the running of the water pump once a pest is detected or out of range moisture and temperature levels for fungal growth. Then the thin pipe is connected to a water pump to deliver the neem oil solution to the sprayers, in which neem oil will be sprayed on the plants automatically to protect them from pests

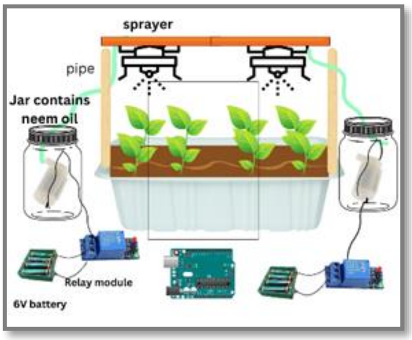


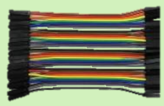
Figure 27: the implementation of feedback response.

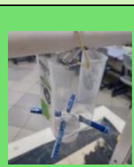
and fungal activities. Figure 27 shows a sketch for all implementations used for this step, which helps in making fast feedback response that matches the design requirements implemented.

The prototype will be tested to confirm that it matches the design requirements by measuring the time it takes from gathering inputs in the first process to generating responses in the last process. Many trials will also be made to test the system's accuracy in detecting environment condones that help in the growth of fungi and the accuracy of generating feedback responses when out-of-range values are recorded, which helps the project achieve the desired design requirements.

III. Constructing and Testing the Prototype

Materials and Methods

Item	Quantity	Description	Usage	Cost	Source	Picture
Rectangular Flowerpot	1 container	It contains drainage holes to allow excess water to drain out and prevent root rot.	It was used to carry the soilless mixture and hold lettuce plants.	110 EGP	Florist	
Sphagnum Peat Moss & Perlite	25,700 cm^3 ± 10 cm^3 of peat moss, 11,000 cm^3 ± 10 cm^3 of perlite	Peat moss is an organic material formed by slow decomposition. Perlite is a lightweight and porous volcanic glass.	They are used to make the soilless mixture for the farming system by the ratio 7:3 respectively.	75 EGP	Florist	 
Neem Oil	2 ml ± 0.2 ml of neem oil / 1 L of water	It is an extracted oil through cold pressing the seeds, to be used in medical conditions.	It was used as a pesticide and fungicide. It is diluted with water before using it.	20 EGP	Herbalist	
Arduino UNO R3	1 board	It is a microcontroller that controls all of the feedback and receive the code to apply it.	It is programmed to read input and give certain actions based on the received data.	350 EGP	Electronics Store	
Jumper wires	2 packets	They are long wires used to connect electronic components and have three kinds: Male-Female, Male-Male, and Female-Female	They are used to connect feedback components with each other or with the Arduino.	35 EGP	Electronics Store	

Soil Moisture Sensor	1 sensor	It is a part of the feedback components. It maintains if there were fungal activities in the plant.	It was installed in the roots to measure its moisture.	75 EGP	Electronics Store	
PIR Sensors	2 PIRs	An electronic device that detects motion by sensing changes in infrared radiations.	It was used to detect pests' motion in the plant's leaves.	45 EGP	Electronics Store	
NTC Thermistor	1 Thermistor	A semiconductor component measures in terms of the change of its resistance.	It was used to measure temperature of the plants' surroundings.	3.5 EGP	Electronics Store	
Relay Module	2 Relays	It is an electric component that control high voltage devices with low voltage devices.	It is used to connect 6V water pump (high voltage) with Arduino (low voltage).	35 EGP	Electronics Store	
6 Volt Pump / pipes	2 pumps 1 meter of pipe	It is a small-scale pump that can lift water to height of 3 meters.	A small-scale pump is used to deliver neem oil to the sprayers through pipe connected with it.	85 EGP 30 EGP	Electronics Store	
Jar	2 Jars	It is a small jar carried on the edges of the recycled stand with volume 350 ml.	It is used to store neem oil, in which the motor pump will be put in; to deliver neem oil to the sprayers.	5 EGP	Small Shop	
Recycled Drip Emitters	2 Sprayers	It is recycled emitters with four nozzles for each four plants.	It was used to drip the neem oil solution on the leaves of the lettuce plant.	5 EGP	Recycled	

Safety Precautions

- Plastic gloves were used during the handling with neem oil and nutrient solution, and to avoid any contact with the pests.
- Wearing safety goggles while constructing the prototype and testing it.
- Wearing a lab coat while constructing the prototype and testing it.
- Anti-electric insulating gloves were used while measuring electricity during the test plan.

TEST PLAN

Design Requirements

The following measurable design requirements must be achieved in the project; to consider its success in solving the implemented problem.

Sustainability:

In order to prove the project's sustainability The solution must succeed in conserving consumed water resources with a minimum of 50% of water compared to traditional farming methods.

Fast feedback response to pests or fungal activities detection:

For the system to be an efficient solution, it must be fast in detecting and responding to the feedback for the detected pests or fungal activities. The project is estimated to complete the two processes in less than 5 seconds.

High accuracy in detecting environmental variables leads to fungal growth:

The system must be able to detect environmental variables that affect fungi growth, which is the moisture, with a minimum estimated accuracy of 75%, which can help in accurately applying the feedback system to protect the plant from fungal activities.

High efficiency of pests elimination by natural extracted pesticides:

The presented solution should depend on natural extracted pesticide; to eliminate the harms of chemical pesticides. The solution should show a high elimination percentage greater than 70% when it is applied to pests to maintain its removing efficiency.

Test Plan

The prototype was subjected to several experiments and tests to ensure it accomplishes the chosen design requirements of Conserving more than 50% of water used, fast running of the feedback detection and response in less than 5 seconds, accurate detection of fungal growth conditions (moisture) greater than 75%, and high efficiency of eliminating pests with natural pesticide greater than 70%. The tests are as follows.

1. First, the amount of water consumed with soilless farming is calculated with a graduated cylinder and compared with traditional farming to estimate the water-saving ratio.

2. Second, a timer was used to measure the speed of detection of pests and fungal conditions in 6 trials. Then the average speed was calculated.

3. Third, four samples of peat moss with different moisture levels were added on each sample. The moisture sensor was submerged on each one to measure its moisture percentage.

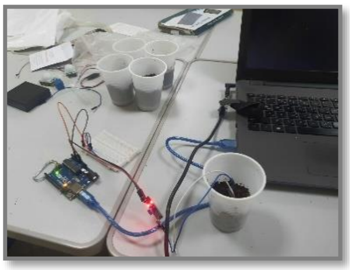


Figure 28: measuring soil moistures in samples.

4. Forth, readings got were compared with more accurate moisture readings from the same samples using the soil moisture equation:

Moisture (percentage) = [(wet sample mass – dry sample mass) / dry sample mass] *100,

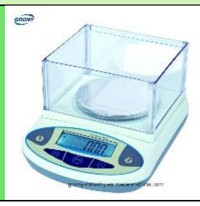
5. Fifth, to estimate the accuracy percentage, the sensor reading is compared with the accurate readings from the equation above.

6. Finally, five trials were made; each trial contains five pests. The number of pests eliminated by the neem oil is measured in each trial, to estimate the elimination pests efficiency in the system.

Figure 29: Jars contain 25 pests from different kinds.

Data Collection and Results

Data Collection

Item	Usage	Measurement unit	Measurement error	Picture
Pipet	Used to dilute the neem oil in order to be in concentration of 2% inside water solution.	µL	± 2 µL	
Graduated cylinder	Measuring water used in the soilless medium, therefore estimate water saving ratio.	mL	± 0.1 mL	
Stopwatch	Measure the time taken to apply the feedback on pests or fungal growth conditions.	Sec	± 0.04 s	
Sensitive balance	Measure the mass of soil samples which can be used to calculate moisture based on mass difference equation.	g	± 1.5 g	

Results

Negative results:

Many negative results appeared while testing the prototype represented in:

- The high sensitivity of the PIR (motion sensor) leads to undesirable detections other than pests. This forced us to adjust its sensitivity and add on the code to make the system run when three continuous motions are detected.
- Using a high voltage power supply of 9V at first to control the 6V water pump led to the burning of the pump, which required us to replace it with another one and change the 9V battery to a 6V one.

- Poor soldering methods used while making the sprayer led to the leakage of neem oil solution of its dedicated path, which required us to strengthen it to prevent unintended pores.

Positive results:

Conserving water resources used:

The system could pass the 50% conserving water in sustainability with conserving reached 64% ±2%. As it could reduce water consumed in each plant from about 500 ml/day in traditional farming to just 180 ± 20 ml /day for each plant.

Fast detection of pests and fungal growth conditions:

The system could successfully perform detection and feedback within fast duration, with an average time taken of 2.3 ± 0.1 and 4.2 ± 0.1 seconds for fungal growth and pest feedback times respectively. The average values were taken from three trials made for each criterion, which is shown in figure 30.

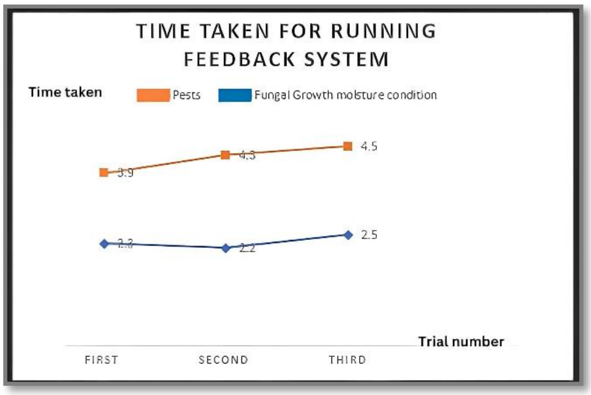


Figure 30: Line chart of time taken to run the feedback in each detection criteria.

High efficiency of eliminating pests using neem oil pesticide:

Five trials were made with a total number of pests of 25 were tested on the neem oil feedback. The system could remove 21 out of the 25, with an estimated removing efficiency of 84%. The result of each trial is recorded in table 1.

Trial	Pests numbers	Eliminated pests
First	5	4
Second	5	3
Third	5	5
Fourth	5	4
Fifth	5	5
Total	25	21

Table 1: Pests eliminated by the neem oil.

High accuracy for detecting fungal growth conditions (moisture):

By comparing the moisture values got from the moisture sensor with the more accurate values got from moisture equation, which is mentioned in the test plan. The accuracy was estimated to be on average 81.12. ± 2% The conducted table is shown in table 2.

Trial	Dry sample mass (g)	Water mass added (g)	Real moisture value	Moisture sensor value	Error	Accuracy
First	40	5	12.5%	17.14%	4.64%	62.88%
Second	40	15	37.5%	30.08%	7.42%	80.21%
Third	40	25	62.5%	69.37%	6.87%	89.01%
Fourth	40	30	75%	80.73%	5.73%	92.36%

Table 2: Accuracy of the detecting fungal growth moisture conditions.

IV. Evaluation, Reflection, Recommendations

Analysis and Discussion

From the conducted tests, it can be deducted that the prototype achieved the design requirements. This proves that the solution can be used to effectively treat pests and fungal activities in Egypt the solution was chosen while depending on a strong scientific basis, which is represented in this section.

Soilless farming with Peat Moss & Perlite

Peat moss is a soilless medium with high porosity and water-holding capacity, formed from the slow decomposition of wetland biomass. It has a low pH and high-water buffering capacity, which can help to buffer soil against pH fluctuations. Perlite, a volcanic glass, is lightweight and porous, improving soil drainage and aeration. It is often mixed with organic substrates like peat moss to maintain them for long periods and prevent compaction.

The 7:3 peat moss to perlite ratio provides a balance of water retention and drainage suitable for many types of plants. Peat moss provides water-holding capacity, while perlite provides pore space for aeration and drainage. The prototype, tested with this ratio, was found to conserve over 50% more water than traditional farming.

Nutrient Solution

The nutrient solution used is a carefully formulated mixture of essential micronutrients, composed of two main solutions, A and B. Solution A contains various fertilizers such as zinc, magnesium, high phosphorus, copper, and magnesium sulfate, while solution B contains iron and calcium nitrates. Also, the solutions contain components like potassium, nitrogen, and phosphorus, which are necessary for plant growth and productivity.

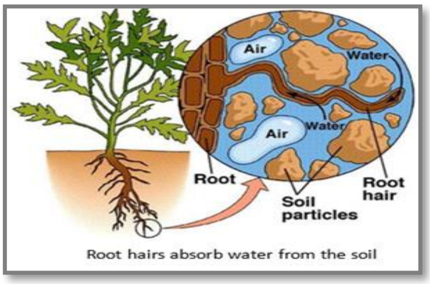


Figure 31: The uptake process by osmosis phenomenon.

Nutrients uptake occurs through the process of osmosis, as shown in figure 31, in this process plants absorb nutrients using their root hairs, this method has shown great efficiency in the fast growth rate of the plants.

Neem Oil

Neem tree is a semi-tropical plant distributed in climate zones like Africa, and South Asia. As it is studied in (BI.2.11), binomial nomenclature is used to specify the ancestry of plants. Neem tree came from (*Azadirachta indica A. Juss*) ancestor. The most common way for extracting neem oil is through cold pressing the seeds of the neem tree. This involves crushing the seed to release oil, which is then filtered and collected.

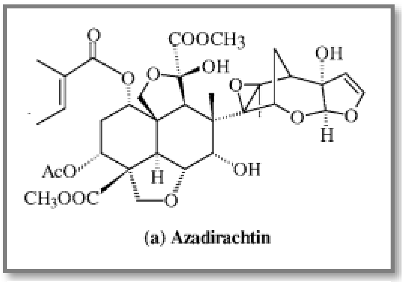


Figure 32: Structural formula of Azardirachtin.

Neem oil contains Azardirachtin compound, as shown in figure 32, which is known for its antifeedant activity on pests and fungi. Azardirachtin works blocking the release of molting hormone (ecdysteroids) from the prothoracic gland, leading to incomplete ecdysis in immature insects. In adult female, a similar mechanism of action leads to sterility. One of the key features of neem oil is being eco-friendly and having no harm to the nature compared to chemical pesticides.

The Feedback system, Arduino microcontroller and IDE

Feedback revealed its importance as a monitoring and controlling system, which helps manage the farming process to improve crop yields and maintain its sustainability. The project's feedback system was created to detect pests and fungal activities, as shown in the following flowchart.

Figure 33: Flowchart for the feedback system process.

Arduino UNO microcontroller is used to manage information given by motion, moisture, and temperature sensors. Thus, managing the flow between inputs and outputs by using certain programming conditionals in the Arduino IDE, as shown in the flowchart. The conditions focus on the detection of motion and fungal growth conditions (moisture > 80%, temperature > 15°C and < 20°C). Based on these conditions, the Arduino automatically runs the feedback process to spray neem oil to protect the plant. A waiting period of three hours is required after neem oil spray to allow it to affect pests and subsequently impede the motion detection controller from reactivating the feedback loop.

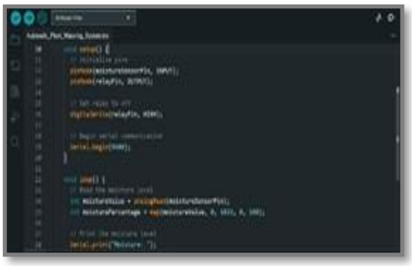


Figure 34: A snipping of the Arduino code used.

Gathering inputs process, Passive infrared motion detection

A passive infrared motion sensor was used to monitor pest motion in the system. It consists mainly of two metals of ceramic substrate surrounded with a filter window to increase the range of detection angles, as shown in Figure 35. The sensor can detect the infrared rays emitted from any living organism passing within the two metallic poles. Once a motion is detected, it sends signals to the Arduino board to confirm pests' presence. The sensor also contains two adjusting screws for controlling the sensitivity of detection and the delay time between each detection. Both values should be well adjusted to prevent motion detection errors.

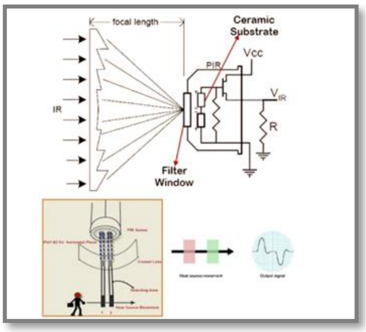


Figure 35: Internal structure of the PIR sensor.

The PIR sensor is connected to the Arduino using the following connections shown in figure 36. The output PIN is connected with PIN number 2 of the Arduino; the results while testing the PIR sensor overpassed the expectations for detection with a wide range can reach 1.5 meter compared to its low price, which matches the design requirements implemented for fast and accurate detection.

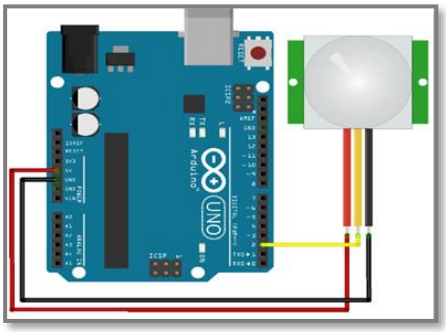


Figure 36: Connection of PIR Sensor with the Arduino.

Measuring soil moisture

Monitoring moisture levels in the soil is a crucial part, which can help in detecting if the plants are at risk of fungal activities. A soil moisture sensor is used to perform this task. It works mainly in two parts. The first one is the pope, which acts as a variable resistor that vary according to soil moisture. The second part is the module, which generates an output voltage based on the resistance of the probe. The voltage value is ranged from 0 (wettest level) to 1023 (driest level). In order to convert it into analog reading and get the moisture percentage, equations 1 and 2 are used.

$$AnalogOutput = \frac{ADCValue}{1023}$$

Equation 1: Calculating analog output from the voltage readings.

$$\text{Moisture in percentage} = 100 - (\text{Analog output} * 100)$$

Equation 2: Calculating moisture percentage with the analog readings.

The sensor is connected to the Arduino using the following connections shown in Figure 37. The output pin that delivers moisture value was connected to the A0 pin of the Arduino. From the test plan results, soil moisture was found to be sufficient for recording moisture levels.

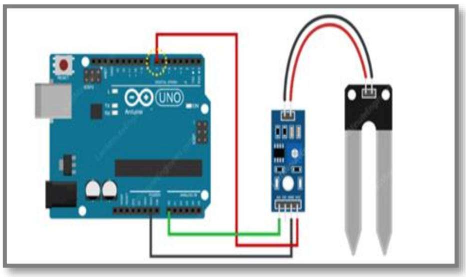


Figure 37: Connection of Moisture Sensor with the Arduino.

Measuring temperature (Thermistors)

A thermistor is an electronic component used to measure temperature in terms of its internal resistance. Relying on applications of semiconductors in DC circuits studied in (PH.2.15), the thermistor is mainly made of semiconductor material in which electrons move from the -N regions to the +P regions. When the temperature increases, electrons' speed increases and therefore, resistance decreases according to Ohm's law (R = V/I), and verse vice, as shown in figure 38. Temperature coefficient of resistance (TCR) can be estimated using equation 3.

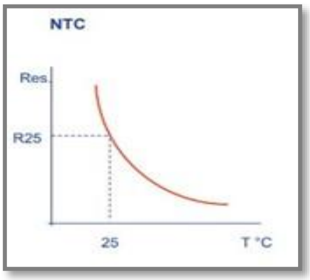


Figure 38: Relationship between temperature and resistance in thermistors.

$$TCR = \frac{(R_2 - R_1)}{R_1(T_2 - T_1)} \times 10^{-6}$$

where R_2 is the value of resistance at operating temperature T_2, and R_1 is the value of resistance at temperature T_1, which is typically room temperature (25°C).

Equation 3: Calculating Temperature coefficient of resistance (TCR).

The thermistor was connected with a 10KΩ resistance, followed by Arduino connections, as shown in Figure 39. The output pin was connected with the A1 pin of the Arduino.

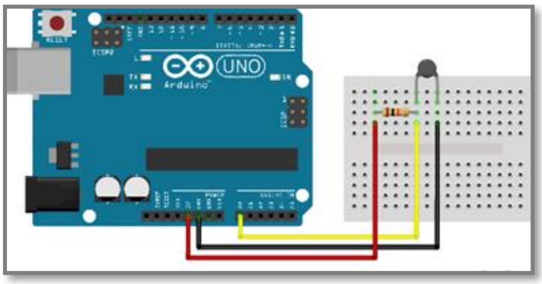


Figure 39: Thermistor connection in Arduino.

Water Pump

According to (PH.2.10) that focuses on how motors work, the structure of the water pump motor depends on the quick rotation of the impeller, which generates a high centrifugal force that pushes the water to the edges of the cavity. This reaction creates a vacuum in the middle of the impeller, which helps in sucking more water from the inlet pipe and passing it out to the outlet pipe, as shown in figure 40. DC pump is a fast solution as it can lift up to 120L/H, which meets the design requirements for generating a quick response system.

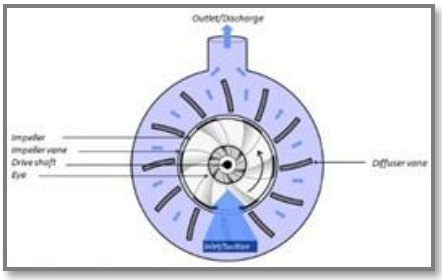


Figure 40: Internal structure of DC mini water pump.

Relay module switching circuit

The relay module's working principle is based on the idea of electromagnetic induction that was taught in (PH.2.08). It consists mainly of a coil, armature, and common channel, which represents the positive pole. When low voltage signals less than 2V is sent to the relay, the relay turns on and runs the water pump by connecting the common pole side with the NC (Normally Closed). If a higher voltage passes, it will turn off the relay by connecting the common side with the Normally opened (NO) side, as shown in Figure 41.

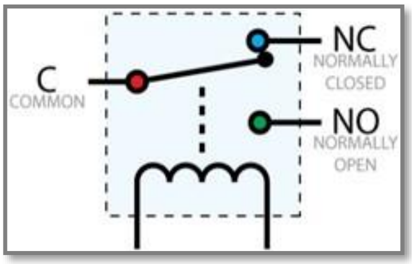


Figure 41: Internal structure of the relay module.

The water pump circuit is built by connecting the positive terminal with the common pin channel, and the positive side of the pump with the Normally Open (NO) channel. Then, the negative pole of the relay with the negative pole of the battery, as shown in figure 42. The Arduino was coded to send high signals when there is no motion of pests or safe moisture and temperature levels, and send low signals to run the pump, and vice versa.

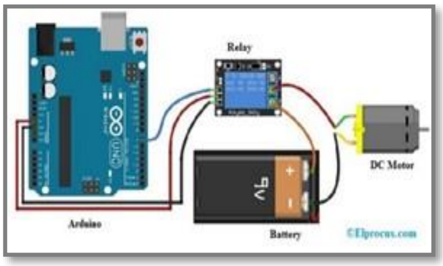


Figure 42: Relay module, water pump, and battery connections with Arduino.

Battery series connection

To get the suitable voltage supply for the pump (6V), four pieces of 1.5V AA battery are connected in series, producing one large 6V battery, which forms a cheap solution and a quick method of running the pump.

The Conclusion

The main pesticides and build a modern agricultural system that focuses on detection and removal of pests and fungal activities, eliminating the use of chemical pesticides, and reducing crop losses. The solution uses a developed feedback system in a soilless farming medium. It uses motion, moisture, and thermistor sensors connected with Arduino that manages these inputs and respond by running the water pump. The solution successfully meets the design requirements for conserving more than 50% of water, fast detection of less than 5 seconds, neem oil efficiency of more 80% and accurate detection of more than 80% of fungal growth conditions (moisture). The project is believed to be an efficient solution for solving pests and fungal activities challenges in Egypt.

Recommendations

Large Scale

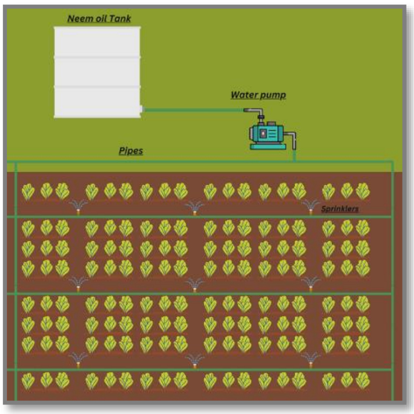


Figure 43: 2d sketch for the large scale.

Figure 44: the Rain Bird PRS-DIAL Pressure Regulator.

For the large-scale implementation, traditional farming methods with peat moss and perlite will be used, and adjacent rows of lettuce crops will be organized with a distance of 0.3 meters between each crop in the same row and each adjacent row. The pesticide distribution system will be similar to sprinkler irrigation systems, with the source container for the system being the mixing tank for the automated neem oil preparation. Rain Bird PRS-DIAL Pressure Regulator sprinkler, shown in figure 44, will be set to cover a circular area with a radius of 1 meter, with sprinklers arranged 2 meters apart, as illustrated in figure 43. This system provides adjustable pressure settings and controls the variable flow rate. It requires 120-volt AC centrifugal pump to provide higher flow rates. Moreover, Hikvision DS-2TD2636B-15/P thermal camera sensors will be installed above each sprinkler at a height of one meter, allowing for real-time monitoring of the crops and quick detection of any issues or presence of pests within the coverage area of each sensor. The data collected from these various sensors will be transmitted to a central control system through a wireless sensor network. Pests will be detected in real-time, which will trigger neem oil sprinklers only in the affected area covered by the detected pest. The spacing between lettuce crops, as well as the arrangement of sprinklers and thermal camera sensors, has been carefully planned to optimize the efficiency of the pest detection and control system in the large-scale implementation.

Automated neem oil preparation

Creating an automated system to prepare a diluted solution of neem oil of percentage 0.3% can ease removal pests. The system requires a tank, agitator, dosing pump, and process pattern for cleaning the tank. First, the large mixing tank relies on an agitator to ensure that the ingredients are well mixed. Second, the neem oil container shall be made of high-density polyethylene (HDPE). As, HDPE tanks are lightweight, durable, and resistant to corrosion and chemicals, making them cost-effective. Then, it relies on the dosing pump like Watson-Marlow 520DuN/RL peristaltic pump as shown in figure 45, which offers high accuracy and adjustable flow rate. Finally, cleaning the mixing tank is a process pattern that shall be set up in the control system. The frequency of cleaning can be set to every 2 weeks.

Figure 45: the Watson-Marlow 520DuN/RL peristaltic pump.

Hikvision DS-2TD2636B-15/P Thermal Camera sensor

The Hikvision DS-2TD2636B-15/P, as shown in figure 46, is a high-performance thermal camera sensor that offers a high temperature sensitivity of 40 mK, so it can detect small temperature differences with high accuracy. Moreover, the camera can advance their image-processing capabilities, including video analytics for advanced motion detection. Compared to the PIR sensor, the Hikvision DS-2TD2636B-15/P offers a higher ability to detect pests based on thermal signatures rather than just motion. It couldn't be implemented in the prototype due to its high cost and scarcity in Egypt. Nevertheless, for future implementations, the Hikvision DS-2TD2636B-15/P could be considered as an option for its advanced features and capabilities in pest detection in crops.

Figure 46: the Hikvision DS-2TD2636B-15/P. Thermal Camera.

The Raspberry Pi 4

Finally, The Raspberry Pi 4, shown in figure 47, is a powerful single-board computer with features such as higher processing power, larger memory capacity, built-in networking capabilities, and the ability to run a full-fledged operating system. These features make it suitable for controlling complex systems, handling multiple tasks simultaneously, storing and processing large amounts of data, and easy communication and integration with other devices in the system. However, it was not implemented in the prototype because the simple tasks could be handled by the Arduino board, which was more than enough for the scale of the project.

Figure 47: the Raspberry Pi 4.

What would we tell another team who wanted to start where we stopped on your solution to help them?

In fact, this project is not that tough to finish, but unfortunately, some wrong decisions have been made concerning time management, judging things, and responsibilities. Regarding time, no balanced time has been given to each task resulting in not completing them in the due time. Another important point to be considered is misjudging things. Using an improper component has led to less voltage. So, choosing the right materials will save a lot of effort and money.

Working on the project helped us in becoming better STEM students in the following ways?

Working on the project improved the ability to deal with challenges by learning from our mistakes and making improvements until we are happy with their work. Working on projects has many benefits such as Problem Solving, Creativity, Self-Confidence, and Critical Thinking. The act of defining a problem, discovering the origin of the problem, and finding, and prioritizing. Chapter IV Evaluation, Reflection, Recommendations selecting alternatives for a solution is known as problem-solving. Creativity is how to recognize new ideas and possibilities. Self-Confidence is a sense of self-assurance that is a belief in one's own skills. It indicates that you have faith in yourself and feel in command of your life. The capacity to think clearly and rationally, comprehending the logical link between concepts, is known as critical thinking.

LEARNING OUTCOMES

Subjects	Learning outcome	Description
Biology	BI.2.09	The learning outcome helps to know the hormonal feedback loop and control in human female that inspired us in the project to make a feedback loop for agriculture system.
Biology	BI.2.11	This learning outcome helps in knowing about phylogenetic diversity and how to relate each organism to a kingdom from their characteristics. That helped in knowing the kingdom of the Neem plant.
Biology	BI.2.14	This learning outcome helps to know about biodiversity and the factors that affect it to decrease or increase. In our project, the number of pests is being removed that is considered as reduction of biodiversity.
Earth science	ES.2.12	This learning outcome helps to know about the evolution of Earth's geosphere and how it developed among billions of years. In our project, the perlite is used which is an igneous glass rock that is evolved from the lava.
Earth science	ES.2.15	This learning outcome helps in knowing about the conditions that living organisms live in and the major changes affect the organisms among the geologic times and why they have evolved. In our project, the conditions that the pests that can live in can be prevented to get rid of the pests.
Physics	PH.2.13	This learning outcome helps in knowing about the filtering characteristics of circuits with inductors or capacitors. In our project, a capacitor is used to regulate the frequency rate of current.
Physics	PH.2.16	This learning outcome helps in knowing about logic gates and binary numbers that is used in the Arduino and the electronic components in our system.

Chemistry	CH.2.09	This learning outcome helps in knowing about solutions that conduct electricity. In our project the water conducts electricity that makes the moisture sensor could measure the moisture by the difference of resistance.
Math	MA.2.08	This learning outcome helps in knowing about rate of change and the derivatives of functions. In our project, a graph was made of the rate of change for the number of pests that affect the plant with respect to the amount of neem oil produced.
Computer science	CS.2.05	This learning outcome helps in knowing how to make applications on the android studio and how can it be used in our system to make an application to get feedbacks from the users who will use our system.
English	EN.2.17	This learning outcome helps in knowing about different types of writings including descriptive and expository that used to write in the poster and portfolio.
Computer science	CS.2.05	This learning outcome helps us understand how a loop can be programmed using different methods. Which helped us with writing the programming code of the feedback system.

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