Sensor Pole: a farming approach to an IOT technology

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Abstract

The following report documents the design and fabrication of an IOT based agricultural pole sensor, the above-mentioned pole sensor was developed to provide real-time, temperature, light, moisture, and location from not only the soil but also from the environment around the sensor pole. The reasoning behind this is to help lower the number of child labours around the world by offering a cheaper more sustainable alternative negating the need for the child labours. The design process consists of the selection of suitable materials and components, such as probes, sensors, and a microcontroller, to ensure the reliability and longevity of said device in challenging agricultural environments. All the chosen components are analysed for cost and ability. This is followed by the programming process that ensures that the data is transmitted correctly and accurately from the devices to the servers and back to the user's input device. The fabrication process that takes places after consisting of 3D printing the necessary casing and components followed by the assembly of the electronics and securing the necessary connections while also making sure that the parts that need to be water resistant are up to spec.

With the goal of validating and troubleshooting the device testing will be conducted in four faces: proof of concept, water resistance testing, weather testing, long term testing, each of these is responsible for validating part of the design and making sure that device operates as intended by the designer.

Based on the data collected from the testing and validation a multitude of improvements will be made to make the device more accessible, easier to use, easier to deploy, and cheaper to manufacture. This is followed by a cost analysis of the overall cost of the pole sensor.

The report will conclude by elaborating on future plans for the technology and possible ways to improve the technology.

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1.0 Introduction

Agriculture being one of the biggest industries in the world, it presents one of the main causes of child labour around the world. In poor areas of the world where people don't have the funds and access to cutting edge technology and proper laborer's they use child laborers as their main source of hand labor as they find it hard to sustain themselves not only in a consistent way but in reliable using any other method. More than 60% of the world's child workers work in the agricultural field, these kids work long hours in gruesome conditions, get a minimum amount of food if any at all. This limits the kid's growth physically and mentally and leads to lifelong injuries. With the goal of developing a technology that limits the need for these child labors, the following report describes the design and implementation of an IoT-based agricultural pole sensor that aims to provide farmers with accurate and reliable information on the moisture content, temperature, humidity levels of the soil and surrounding area, and UV light levels. The proposed system uses a low-cost and energy-efficient sensor network that can be deployed on agricultural poles to collect and transmit data to a server-based platform on an open-source hardware for visualization. The system has the potential to revolutionize the way farmers monitor and manage their crops, leading to increased yields, reduced costs, and improved sustainability. and limit and lower the need for child labor by eliminating the need for them by presenting a cheap, and easy to deploy solution.

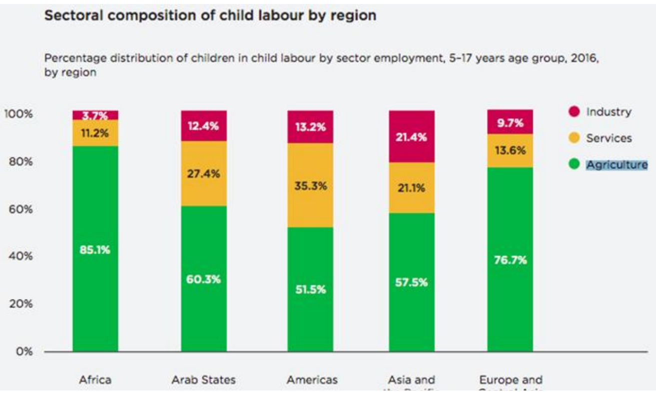

Figure 1 :Figures for child labour.(international-partnerships.ec.europa.eu, n.d,2022).

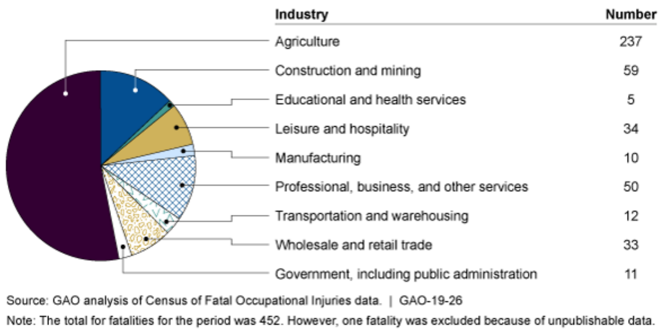

Figure 2: (Office, n.d, 2022))

1.1 Objectives

The objective of the project is to design an IOT based agricultural pole sensor, this pole sensor has to be able to do the following :

- Measure temperature of air and ground
- Measure humidity of air and ground
- Measure of light intensity (UV)
- Share data and position.
- Provide reading every 15-30 minutes.
- Communicate with other sensor poles and propagate alerts to a central station if detected.
- Signal location overall status using a traffic-light metaphor.
- This technology must also be cheap, accessible, and easy to implement in multiple areas.

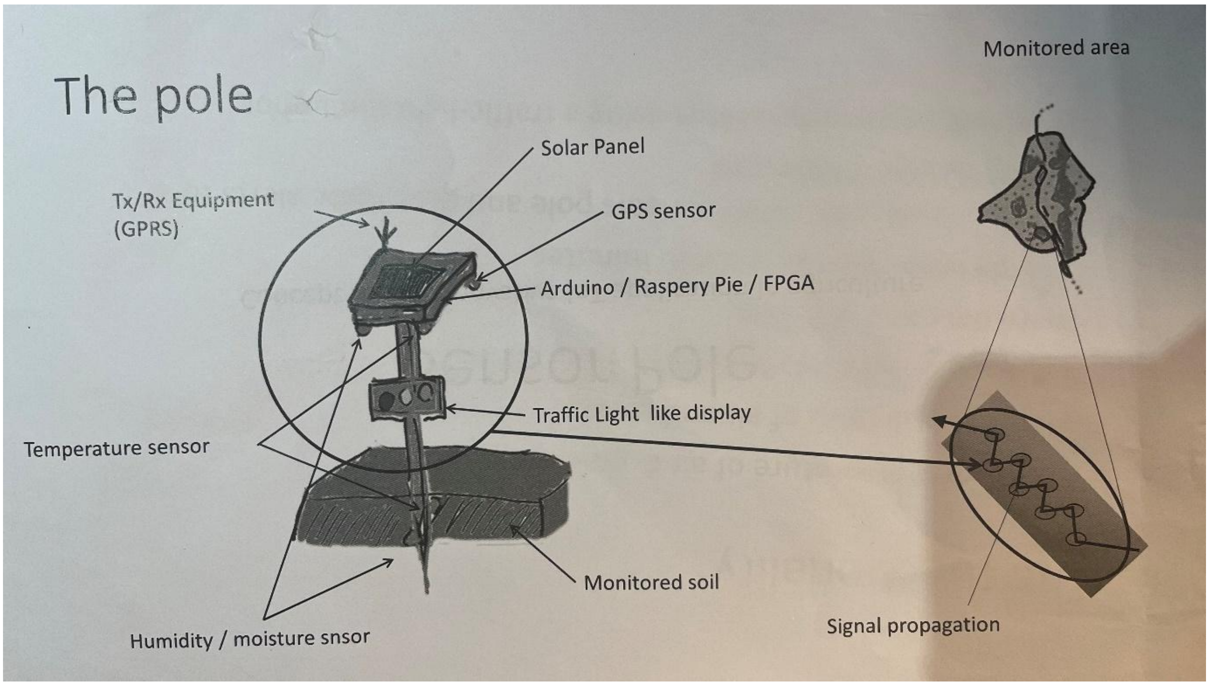

Figure 3 : picture of the pole sensor concept (Omid Razmkhah, 2022)

2.0 Literature Review

2.1 IOT Based Agriculture

To understand the project that is being undertaken first there needs to be an understanding of what IOT agriculture. Internet of things agriculture is agriculture that uses the internet, cameras, sensors, and motherboards among other things to monitor the agricultural field in real time. This technology allows to user to check temperature, humidity, and other data immediately allowing for consistent monitoring of the plants. (Xu et al., 2022)

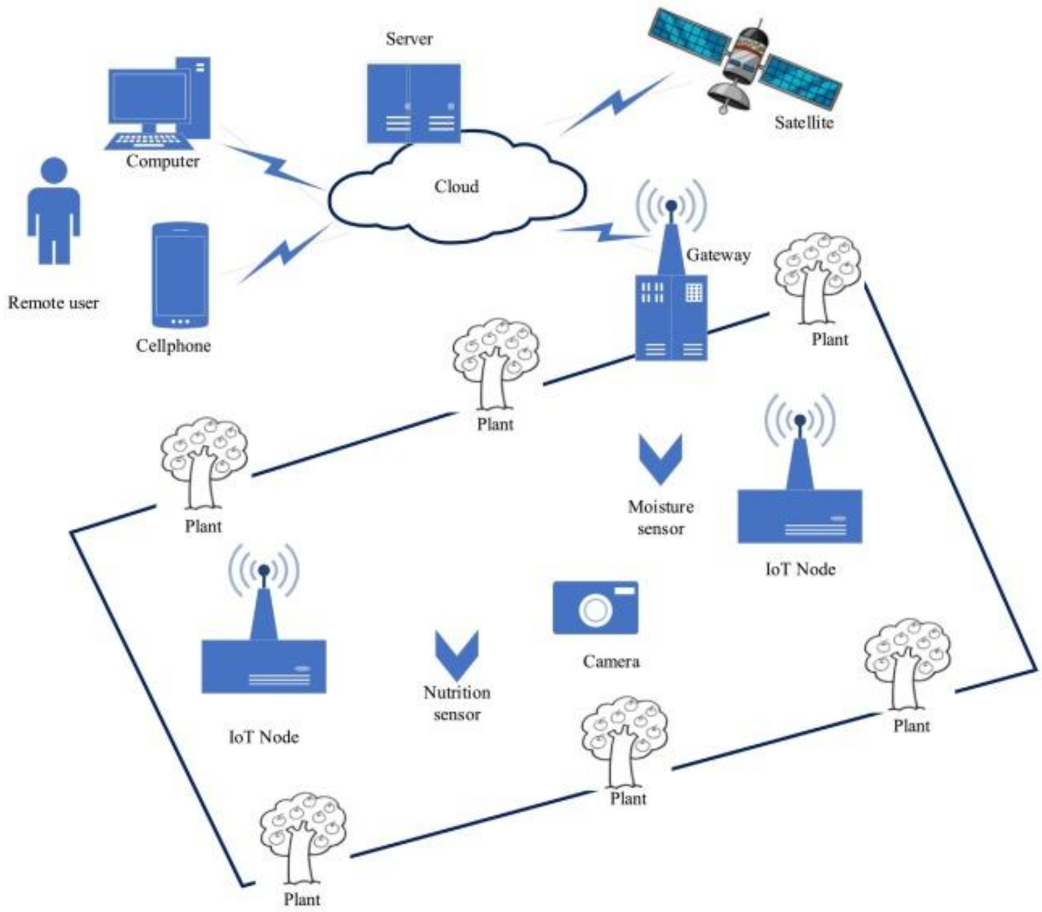

Figure 4: Typical plant life information monitoring system. (Xu et al., 2022)

This technology brought agriculture to a new era, but not only lowering labour cost, increasing farmers income, and overall improving the quality of the products. This technology truly brought agriculture to the modern world. Not only that but overall, this technology increased yield quantity and quality and made the process that much more efficient. (*What Is IoT in Agriculture? Farmers Aren't Quite Sure despite $4bn US Opportunity - Report*, 2018)

Not to mention that iot in agriculture is not only used in plants but also in animals allowing greater control over the heard.

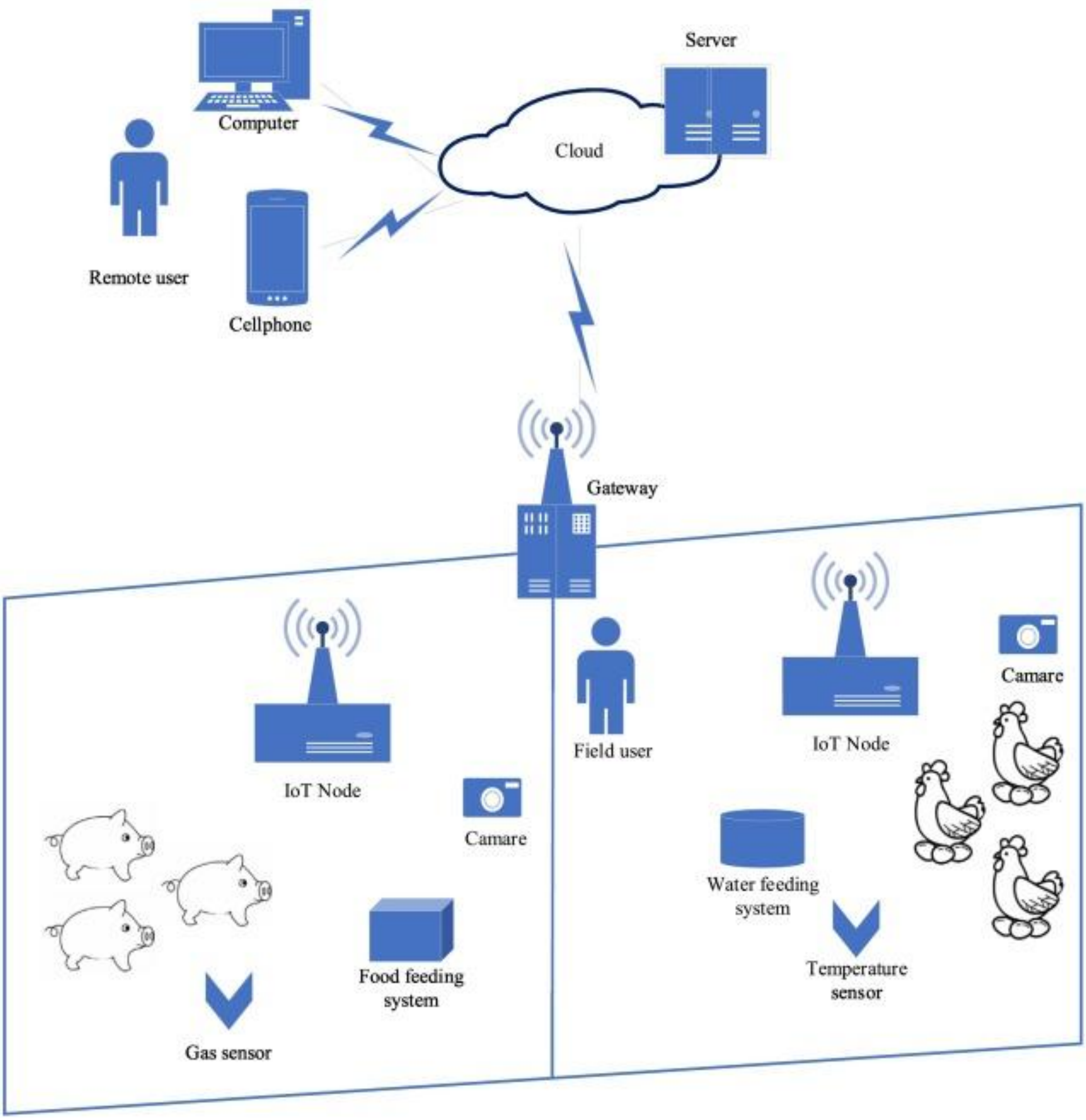

Figure 5: Typical animal information monitoring system. (Xu et al., 2022)

This increase of control presents a great advantage with minimal to non-existent drawbacks.

2.2 Similar products

There is a multitude of projects and products that already exist in the sector. When it comes to actual products here are some examples with their specifications and drawbacks:

The first product is LORAWAN SMART AGRICULTURE IOT SOLUTIONS, this product provides :

- Asset Tracking
- Soil Moisture Sensors
- Smart Irrigation
- Environmental Sensors
- Fluid Level Monitoring

- Waste Management
- Open/Close Sensors
- Vibration Monitoring for Machinery
- Remote Pest Control Monitoring
- rack the location of key machinery and equipment
- Maximise operational efficiencies
- Save on water waste
- Optimisation of environments for improved crop yield
- Performance monitoring of important machinery
- Raise alerts when gates and doors are left open (Alliot technologies, 2022)

This product comes as an add-in system where they allow you in their website to buy what monitoring equipment you need and connect it to their main network. And for connection to the cloud and their network there exists a subscription-based platform allowing for easy access and monitoring.

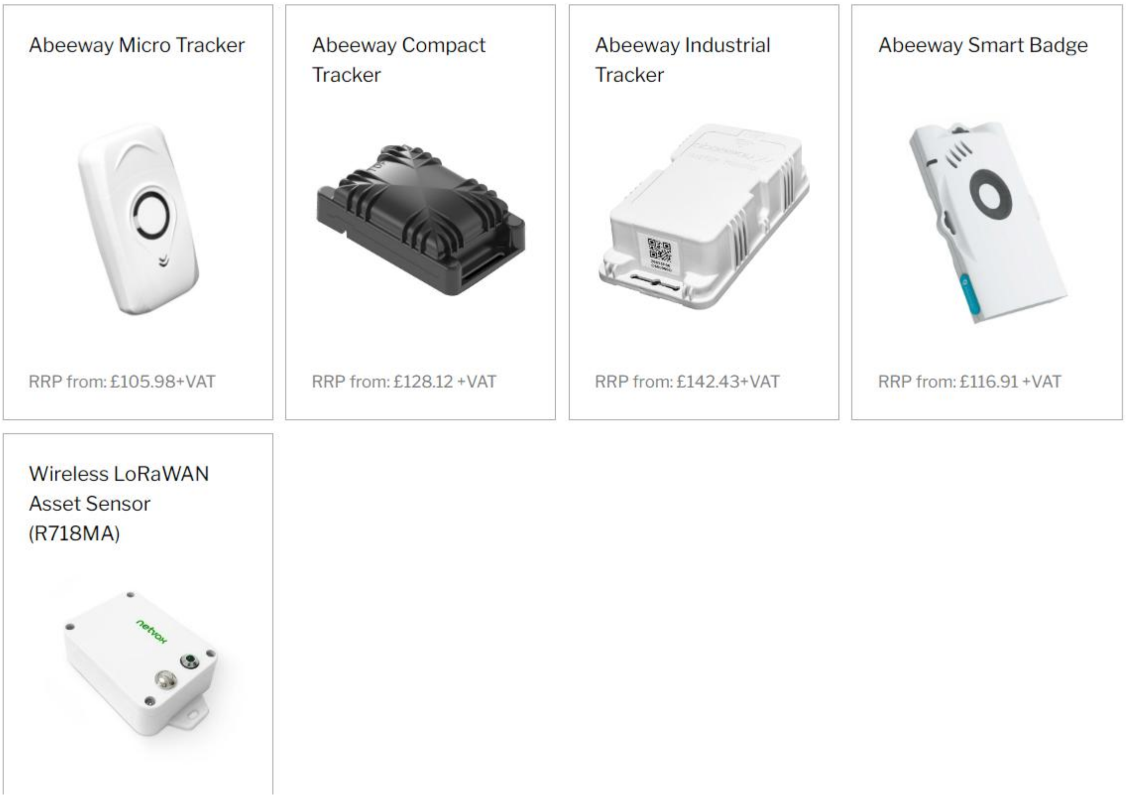

Figure 6: example of the modular products Alliot technologies offers on their website. (Alliot technologies, 2022)

Another company specialize in this sector is Wittra, Wittra is a company that specializes in iot agriculture. The company offers a range of packages most famously its IoT Out Of The Box. The IoT Out Of The Box is a wireless sensor network kit that allows for easy setup it offers the same modularity and features as the LORAWAN.

Figure 7: IoT Out Of The Box. (Wittra, 2022)

The drawbacks of this solution:

- high-cost entry point: all these solutions that stem from proper companies share the fact that the entry point is extremely expensive something that most farmers can't afford. No to mention the cost of installation, addons, subscriptions among other extra costs that drive the price of the technology way high than its original starting point.
- expensive upkeep: due to the exclusive nature of the technology and the closed source software all the maintenance and upkeep must be done by the original company meaning that a farmer that can't afford the high cost of consistent upkeep and maintenance can't fix his broken hardware. This means that even if the farmers were able to afford the original high-cost entry point he might no be able to afford keeping it running.
- low accessibility: due to nature of these companies all existing in the west they do not have representatives in third world countries where they don't believe they have a market to sell their products. Meaning that even if a farmer wanted to adopt the technology due to the lack of nearby representatives, they will be unable to do as there is no way to get the technology unless they import it along with the expertise needed to operate it.

2.3 Similar projects

For the project side there is multiple examples ranging from Arduinos to raspberry pi all with different portability here are a few :

The first project is by RSInnovators and it's based on nodeMCU V1.0 and it detects the soil moisture and waters the plant. It's programmed in the Arduino software making it a simple project.

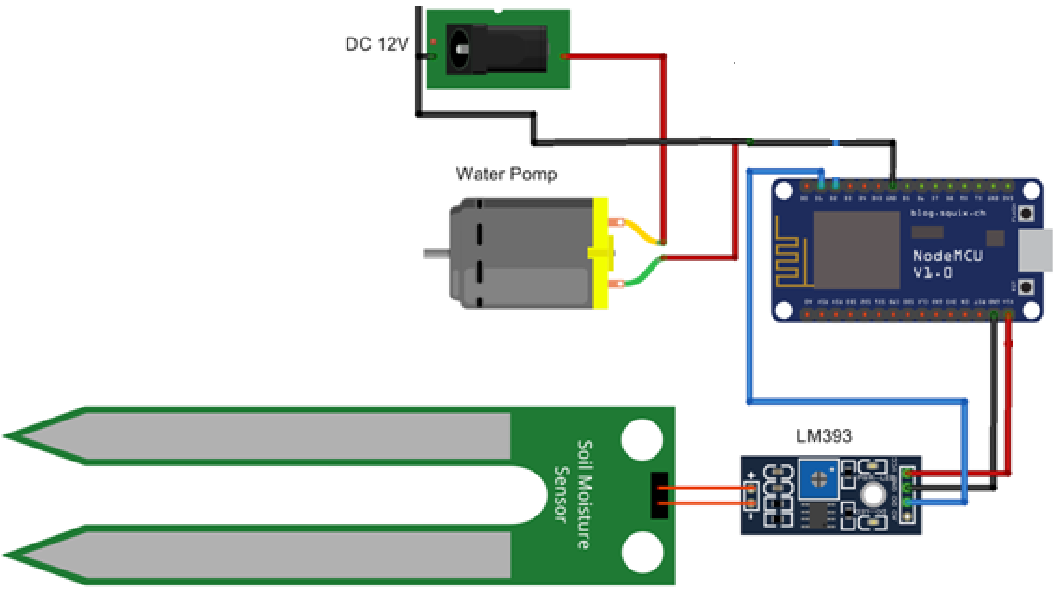

Figure 8: picture of RSInnovators diagram. (RSInnovators, 2022)

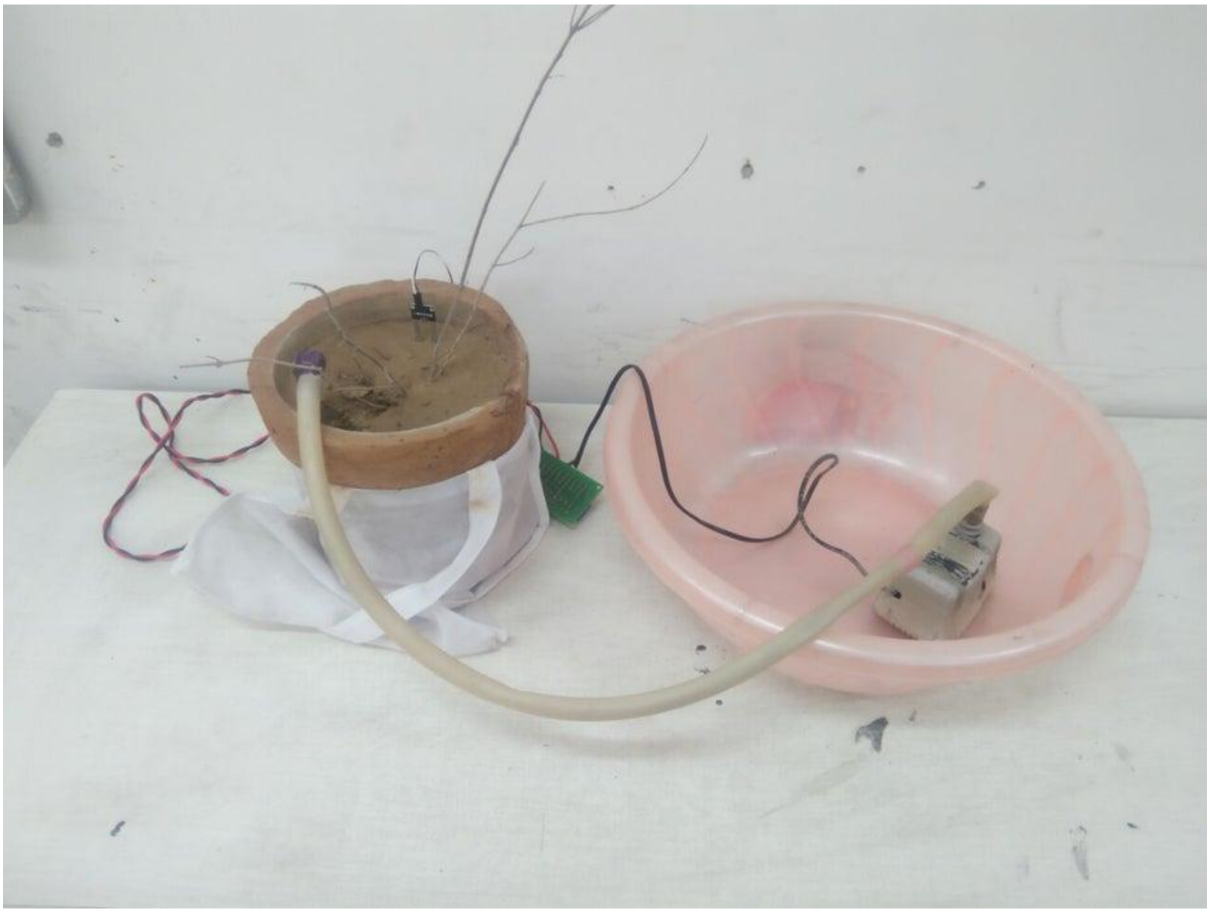

Figure 9: picture of RSInnovators project. (RSInnovators, 2022)

Another project is Low-Cost Smart Agriculture System By Jitendra Jangir and V.K. Shukla it's a complex system that uses multiple mother boards based on the NodeMCU ESP-32 8266 Wi-Fi module. It detects the moisture and waters the plans with low moisture soil.

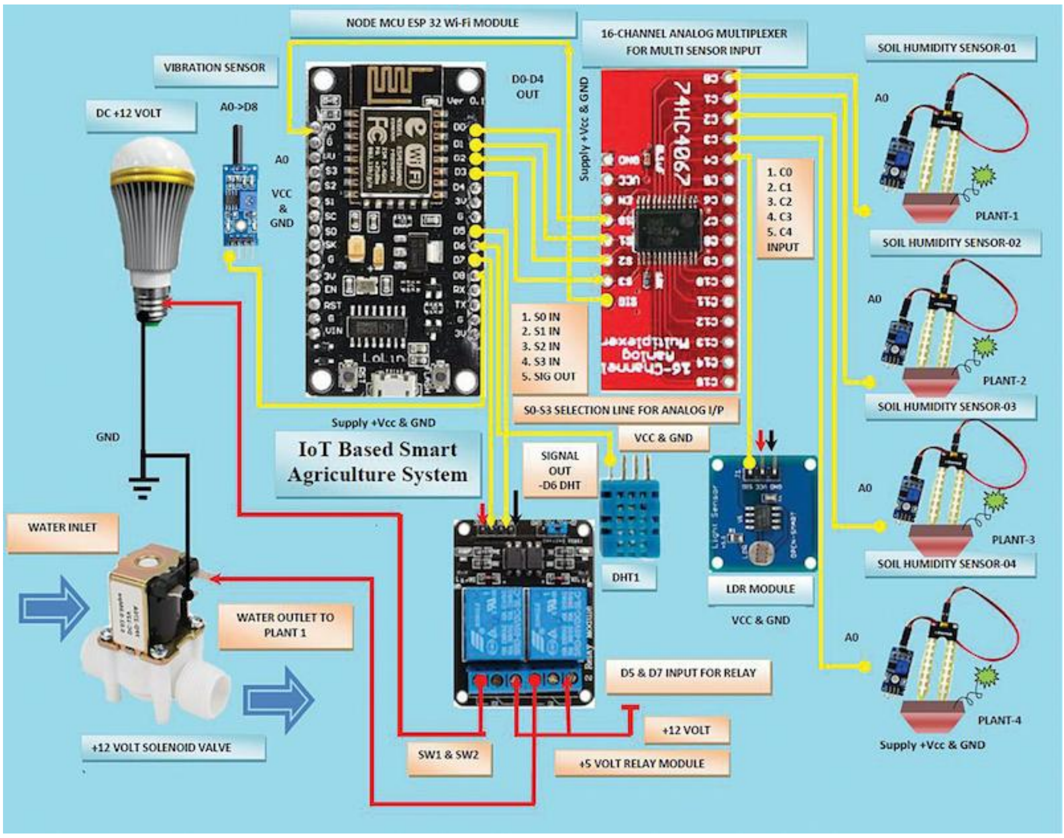

Figure 10: wiring diagram.(Low-Cost Smart Agriculture System By J Jangir and Shukla, 2022)

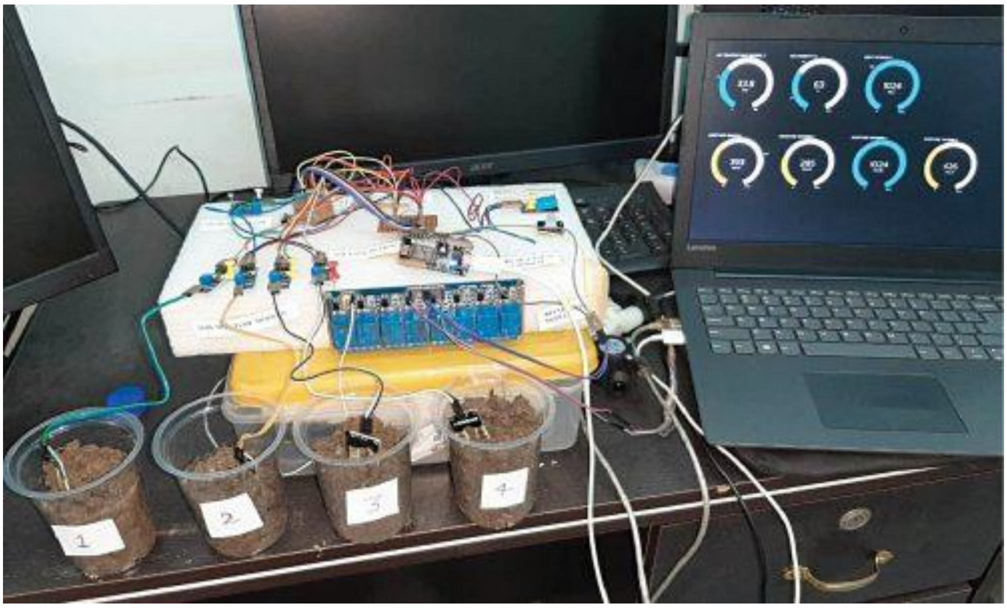

Figure 11:project testing.(Low-Cost Smart Agriculture System By J Jangir and Shukla, 2022)

The drawbacks:

- Lack of refinement: due to the project being homemade they lack the refinement and complexity needed to be deployed in any kind of professional capacity. The lack of refinement in this case is the lack of casing, water resistance, proper assembly, safety considerations among other things that would allow for proper deployment and use, because of this project are unusable in real life applications.

- Lack of proper documentation: none of these projects have proper documentation, reports, instruction, or any of the similar, because of that these projects don't not contain enough details or data to give a general idea of how to deploy, develop and improve this technology. Also, the lack of documentation could cause gaps in explanations, definitions, and instructions.

- Lack of proper testing: besides the early stage of testing just to prove the concept none of these projects have been properly tested for weather testing, condition testing, long term testing among other types of testing that have not been properly conducted by any of the projects. This means that none of these projects have proved their ability in real circumstances and cannot be deployed in any capacity as not data exists for performance, endurance, failure, operating conditions.

2.4 How the Current Project differs

The products represent a complete package that has been properly testes and is proven to be able to work as advertised in agricultural environment, but their price, and inaccessibility doesn't make them an option for almost any farmers in third world countries and poor areas around the world, especially to the farmers who use child labours.

The open-source projects are very cheap in cost and don't need any preparatory technology or software to operate and maintain; the open-source Ness of these projects also allows for constant improvement and editing for special use cases and differences in type of work and environment. But the lack of testing, proper documentation, lack of any kind of environment proofing creates an inability to be used in any kind of proper work or deployment making it also an invalid option to be used in the harsh fields and terrains.

the current project promises to offer the cheap cost and open-source format of the projects while also providing the proper documentation, data, testing and refinement that a proper product offers. This is due to the student's expertise as an engineering and the universities resources. The use of open-source hardware allows for the cost to be driven down, while the use of 3D modelling and 3D printing allows for proper testing and adjusting.

3.0 Design and development

A crucial aspect of this report is the design and development as it outlines the process creating and implementing the solutions to meet the goals that have been set. This section provides an in-depth description of the design and development approach, methodology, tools, and techniques used.

3.1 The hardware

The hardware being used will consist of two main components:

- The server.
- The sensor pole.

The first part being the server will use an open-source microprocessor to act as server collecting the data and sharing it appropriately; the use of an open-source microprocessor is warranted as although open-source motherboards are still relatively niche products, and may not offer the same level of compatibility or performance as mainstream hardware. However, they do offer the ability to tinker and customize hardware to a greater degree than closed-source alternatives and allow for schematics and code to be shared openly allowing for community development of a product. This means that although my development of the project may stop after the end of the project it doesn't mean the end of the development, as it can be continued by other members of the community allowing for consistent improvement and sharing.

The second main component is the sensor pole, the sensor pole will use a similar but less powerful microprocessor to share data collected by the sensors from and to the main server; not only that but it will also be responsible for energy management and connection maintenance. For that reason, a low power wireless chip will be used, this chip will connect to multiple sensors to collect data. The chip will also be connected to a battery and a solar panel responsible for the charging of the battery. The Chip will share its data with the main server through a wireless network leading to a no need for any wired connection or out of component source of energy.

3.11 Why the Raspberry PI as the server's microprocessor

The server is a very important part of the project as it will need to do the following:

- Onboard data storage: data such as temperature, detection of light, battery percentage, moisture and GPS location among others will be collected over a consistent interval and need to be to be directly stored on the server before being shared with other devices.
- High processing power: due to the complexity and number of tasks required to be done with the server a powerful microcontroller is required so microcontrollers suitable for simple repetitive tasks such as the Arduino are not recommended.
- Onboard wireless connectivity: since the sensor pole is planned to be wireless an onboard wireless connection is necessary to transfer data from and to the sensor pole. Another necessity for the wirelesses Ness of the device is the ability to wirelessly connect to the internet allowing for access to the data collected anywhere.
- Easily accessible user interface: since most places where this technology is planned to be deployed won't have a computer on site to get access to the microcontroller, a microcontroller that has its own operating system and output is very important. As it saves from the cost of having to buy another piece of equipment making the technology more appealing.
- Simple and easy to use operating system: since this technology is planned to be deployed without the need of any professional technicians and is the most likely to be deployed by people with no expertise, that are just following instructions, a Simple and easy to use operating system will make it a lot easier for this technology to spread and to be implemented.
- Cost effective: Being affordable and low-cost is another necessity as any expensive option would be out of range for most of the target audience that this technology is aimed at helping.
- Open-source: Having an open-source platform would be a crucial part in the development of the technology, as it means that it has a large and active community that offers support and resources for developing said technology.

Based on the criteria the only viable choice is the Raspberry PI 3, the raspberry pi has an adequate performance, its own onboard storage plus the possibility to add storage using an SD card, good onboard wireless connectivity, its own HDMI output and Linux based operating system allowing it to be programmed without ever needing to be connected to an external device; also the version of Linux used is a basic open source easy to use version that fits the following use case; finally the technology is extremely cheap and open-source making it fit all of the criteria's.

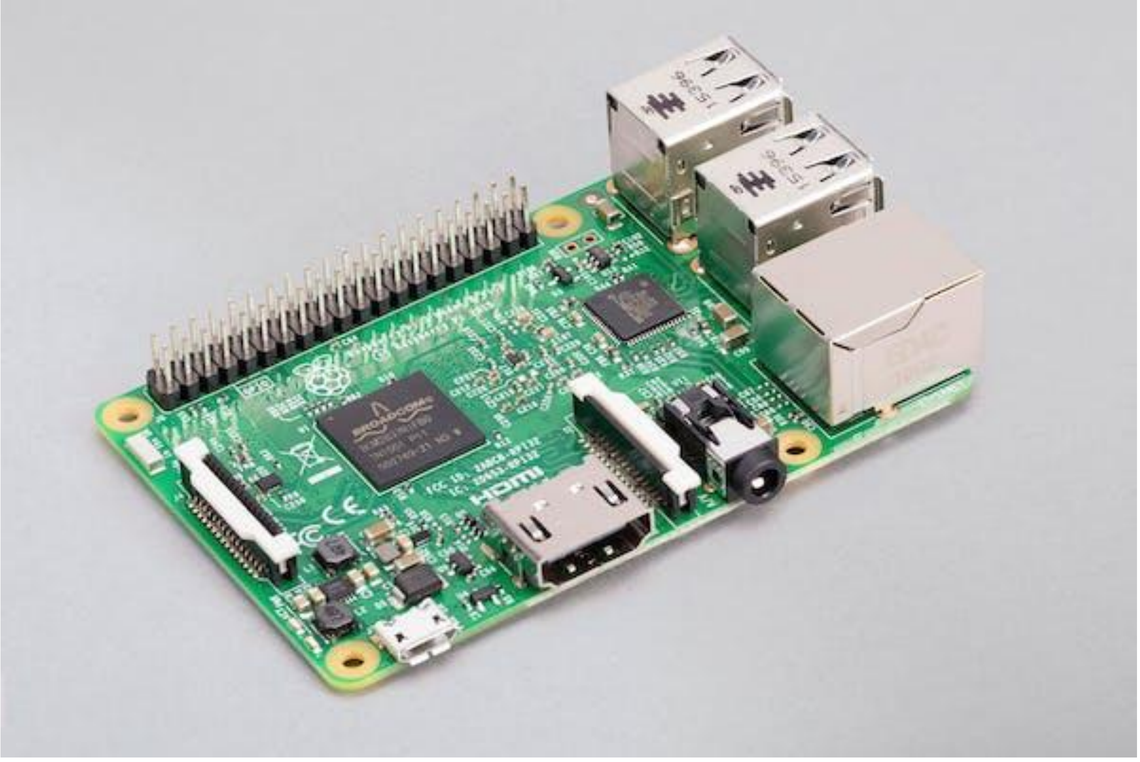

Figure 12: Raspberry PI 3.(Ltd, n.d.).

3.12 The sensors and the reasoning for the choice

In an IoT-based agricultural pole sensor system, the choice of sensors plays a critical role in determining the effectiveness and efficiency of the technology. The Agricultural pole sensor is a device that is meant to monitor environmental parameters such as temperature, humidity, soil moisture, light intensity, and nutrient levels to provide insights into the health and growth of crops. The right choice of sensors ensures that the system collects accurate and reliable data, enabling farmers to make informed decisions about their crops. First all the sensors must share the following:

- Cheap cost: as mentioned multiple times cost is an important part of this project so cheap sensors is a necessity.
- Accurate data capturing: a reliable sensor that gives accurate reliable data is another important thing that must be satisfied.
- Low energy usage: the sensors poles are expected to operate under low energy, in an environment were the supply of energy is based the weather, so they are expected in some cases to last months without recharging so low power sensors are another necessity.

With totality of the sensors the following data should be captured:

- temperature of air and ground
- humidity of air and ground
- light intensity (UV)
- GPS positioning

Table 1: List of possible sensors.

sensor name	sensor responsibility	Cost £	choice	Reason
Adafruit LTR390 UV Light Sensor	Detects the presence of UV light	4.8	Yes	A UV light sensor is required, the following is a low power cost efficient option.
DHT22/11 Humidity and Temperature Sensor	Registers the humidity level and the temperature for the outside environment	4.3	Yes	This sensor is responsible for the humidity and temperature of the outside environment, its relatively cheap and offers accurate consistent readings.
Soil Moisture Sensor	Detects the moisture level in the sail where its planted	4	Yes	This sensor exists in multiple versions all very cheap and very reliable.
Adafruit Ultimate GPS Breakout	Broadcasts the location of the unit based on coordinates	28.5	Yes	Although the price for the GPS sensor is expensive its one of the necessities, so the cheapest most reliable option has been chosen.
LED - RGB Addressable	Shines light in colour based on the signal request	0.5	Yes	LED are cheap reliable ways to output data output data, this LED will flash red, yellow and green based on the strength of the signal.
Photo Transistor Light Sensor	Detects the presence of light on the sensor	1	No	A UV light sensor already detects the presence of light so there is no need for a separate light sensor
mmWave Radar - Human Presence Detection	Detects movement around the sensor	28.2	No	There is no need for a sensor responsible for detecting motion
TMP36 - Analog Temperature sensor (TMP36)	Detects the temperature of the air around the sensor	2.7	No	Since a sensor already exits for detecting the outside air temperature no need for another one, on top of that the already existing one also detects humidity
DHT20 - AHT20 Pin Module - I2C Temperature and Humidity Sensor	Registers the humidity level and the temperature for the outside environment	4.5	No	A similar sensor to the one used but although the one used is a bit more expensive it offers better compatibility with the raspberry PI
Adafruit BME280 I2C or SPI Temperature Humidity Pressure Sensor (STEMMA QT)	Registers the humidity level, pressure of the air and the temperature for the outside environment	14.7	No	The high price of the sensor along with the useless feature in this use of detecting pressure makes it an unviable option
XENSIV™ PAS CO2 sensor	Detects the CO2 levels of the air around the sensor	49.95	No	Although the ability to detect outside AIR CO2 levels would be a great indicator to a farmer the cost is simply way too high for it to be a viable option.
EXO Nitrate Smart Sensor	Detects the nitrate level of the soil where its planted giving an insight into the health of said soil	835.20	No	Nitrate level detection in the soil is a great indicator of the nutrient available in the soil but the combination of high price and high-power requirement don't

				make it a be a viable option.
Fast Vibration Sensor Switch (Easy to trigger)	Detects vibrations	0.8	No	As there will be a lot of vibrations in the pole sensor due to its existence in a relatively rough environment the detection of vibration is relatively useless.

3.13 the function of the parts and the reasoning behind the choices

Understanding the functioning of the parts and the reasoning behind their choice gives great insight to the functioning of this technology and gives insight to one of its greatest strengths, its flexibility.

Table 2: List of parts and their functions

Part	Function	Reason for choice
Adafruit LTR390 UV Light Sensor	Detects the presence of UV light and its levels on the outside the sensor pole	A UV light sensor is required, the following is a low power cost efficient option.
DHT22/11 Humidity and Temperature Sensor	Registers the humidity level and the temperature for outside the pole sensor	This sensor is responsible for the humidity and temperature of the outside environment, its relatively cheap and offers accurate consistent readings.
Soil Moisture Sensor	Detects the moisture level in the soil where the sensor pole is planted	This sensor exists in multiple versions all very cheap and very reliable.
Adafruit Ultimate GPS Breakout	Broadcasts the location of the pole sensor based on coordinates	Although the price for the GPS sensor is expensive it’s one of the necessities, so the cheapest most reliable option has been chosen.
LED - RGB Addressable	Shines light in colour based on the wireless signal strength	LED are cheap reliable ways to output data output data, this LED will flash red, yellow, and green based on the strength of the signal.
ESP32 – DevKitC	Responsible for collecting data from the sensors and transmitting it to the server, also responsible for managing data collection intervals, battery management, and maintenance signal connection.	There exist a multitude of wireless micro controllers but the ESP32 is the most popular one, know for its cheap price, low energy consumption and relatively simple programming.
10K Ohm Resistor	Responsible for regulating the current between one of the sensors and the micro controller.	Very cheap, extremely available.
Lithium Polymer Battery	Responsible for powering the microcontroller.	A lithium polymer battery has been chosen due to its reliability, great safety and low internal resistance.
Lipo Battery Charger	Responsible for managing battery	Cheap and compatible with

Module Flexible solar panel	charge and discharge.	the microcontroller
Raspberry PI 3	Responsible for programming the sensor poles, containing the server, sharing instructions with all the sensor poles, collecting data on board.	Check part 3.11 3.11 Why the Raspberry PI as the server's microprocessor
MERCUSYS 300 Mbps Wireless N Router	Responsible for the connection between the sensor poles and the server.	Cheap and reliable

3.14 Part cost analysis

As the cost is one of the most important parts of the project a cost analysis of the hardware is important:

Table 3: List of parts and their cost.

Part	Cost £
Adafruit LTR390 UV Light Sensor	4.8
DHT22/11 Humidity and Temperature Sensor	4.3
Soil Moisture Sensor	4
Adafruit Ultimate GPS Breakout	28.5
LED - RGB Addressable	0.5
ESP32 – DevKitC	11
10K Ohm Resistor	0.1
Lithium Polymer Battery	5
Lipo Battery Charger Module Flexible solar panel	4.7 0.7
Raspberry PI 3	33.5
MERCUSYS 300 Mbps Wireless N Router	16
total	113.1
Pole sensor	63.9
Pole sensor without GPS sensor	35.1

The cost of the pole sensor can varies based on the necessary sensors and their cost, based on this the cost can be lowered for those who struggle with the already low price.

Unfortunately, the cost of the Raspberry PI cannot be changed as it's a universal Microcontroller and doesn't have any parts.

The wireless connection can be changed based the operators need In this case the wireless router chosen is just a cheap one chosen to satisfy the project's needs.

Based on the data collected the entry and starting price for the server and four pole sensors can be as low as 190£ compared to the other competitors where the hardware can cost up to tens of thousands of pounds the hardware cost presents a very cheap entry cost.

3.2 Casing and Design

A case for both the sensor pole and the PI will need to be made.

The case for the PI is a rather simple design that only must cover the PI.

The case for the sensor pole has many complications. As not only does it have to be water sealed and resistant to element but has to be able to withstand long use.

Both cases will be 3D printed meaning the material chosen must be 3D printable.

3.21 Raspberry Pi casing

The design of the casing of the Raspberry PI is rather simple, it needs to follow the following design requirement:

- It should allow for wireless connection to pass
- It should have space for the output ports and power ports
- It should have mounting spots for the Raspberry PI
- It should be able to close and open
- It should be able to offer basic protection
- It should offer adequate passive cooling for the components

Based on said criteria the following design has been generated. The holes not only allow for outputs to have an opening but also allows for passive cooling to cool the components. The mounting equipment's on the inside uses 3.5 mm diameter screw holes in positions in accordance with the mounting holes in the raspberry PI. Finally, the closing mechanism uses friction to keep the whole design closed.

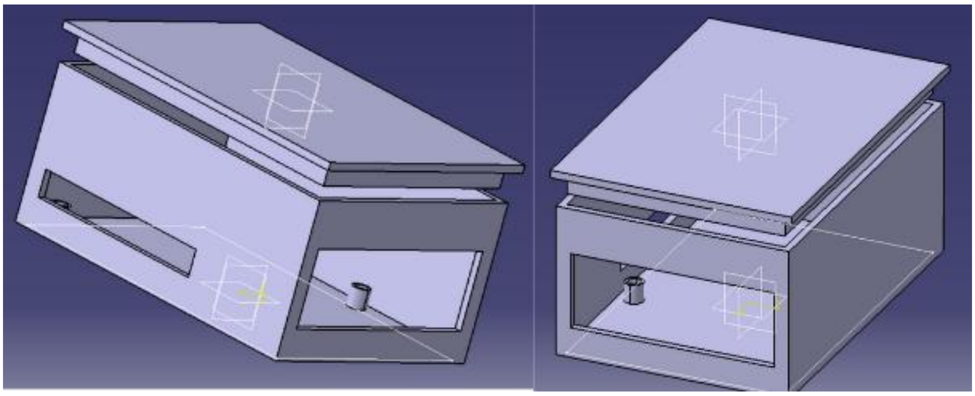

Figure 13: Raspberry PI casing CAD model.

3.211 Material choice

The material used for the Raspberry PI casing needs to follow the following criteria:

- The material needs to be easily available
- The material needs to be 3D printable
- The material needs to have relatively durable properties
- The material needs to be able to withstand relatively high temperature (up to 100 Celsius)

Table 4: list of possible materials for the casing of the Raspberry PI.

Material	strength	flexibility	Durability	Pros	Cons	Price £ per KG
polylactic acid (PLA)	Medium	low	medium	Easy to print, cheap, easy to print	Brittle, lacks any good mechanical properties	21
Acrylonitrile butadiene styrene (ABS)	High	Medium	high	Very durable and strong, withstand high temperature	Hard to print, toxic	30

Polyethylene terephthalate (PET)	High	Medium	high	Flexible, durable, easy to print	Weak to moisture, soft	25
thermoplastic elastomers (TPE)	medium	Very high	Very high	Flexible and easily compressible	Hard to print and takes time to print	54
Polyamide (PA)	Very high	high	high	Very durable, flexible, and strong	Weak to moisture, Hard to print and takes time to print	62
Polycarbonate (PC)	Very high	Medium	Very high	Very strong, resistant to heat and physical impact	Weak to moisture, Hard to print	40
Poly-vinyl chloride (PVC)	Very high	Medium	Very high	Very strong, resistant to heat and physical impact, resistant to chemicals	Expensive, hard to print	51

Based on the criteria and the different properties of the different materials ABS plastic (Acrylonitrile butadiene styrene) has been chosen. ABS is available everywhere as it is one the most used type of plastics in the world, it offers high strength, high temperature resistance and high durability while being relatively cheap making it the perfect material for the casing of the Raspberry PI.

The cost of the material can be calculated using the following formula:

Volume of part* density of material * price per weight = cost of material

6.9058e-5m^3 * 1,050KG/m^3 *30£/KG= 2.17533£

Based on that the estimate for 3D printing the part is 5£

3.22 Sensor pole Casing

The pole sensor case design is much more complex and has the following requirements:

- It should allow for wireless connection to pass
- It should have holes for the wires to pass
- It should have mounting spots for ESP32
- It should be able to close and open
- It should be able to offer protection against the environment
- It should have mounting holes for the soil moisture sensor
- It should have plat surfaces where the different sensor can be sticked

Based on the requirements the following design has been designed. Since the material is plastic it allows for wireless waves transmission, holes in the bottom allow for the wires to pass, the inside has mounting holes for screws with a diameter of 3.5 mm and the holes are positioned based on the ESP32 mounting hole's location. The friction system allows for closing. The combination of the O-ring around the lid and the lip on the bottom provide adequate weather protection. The bottom of the casing has similar mounting holes based on the location on the soil moisture sensor. The flat surfaces around the case give multiple locations where the sensors can be glued.

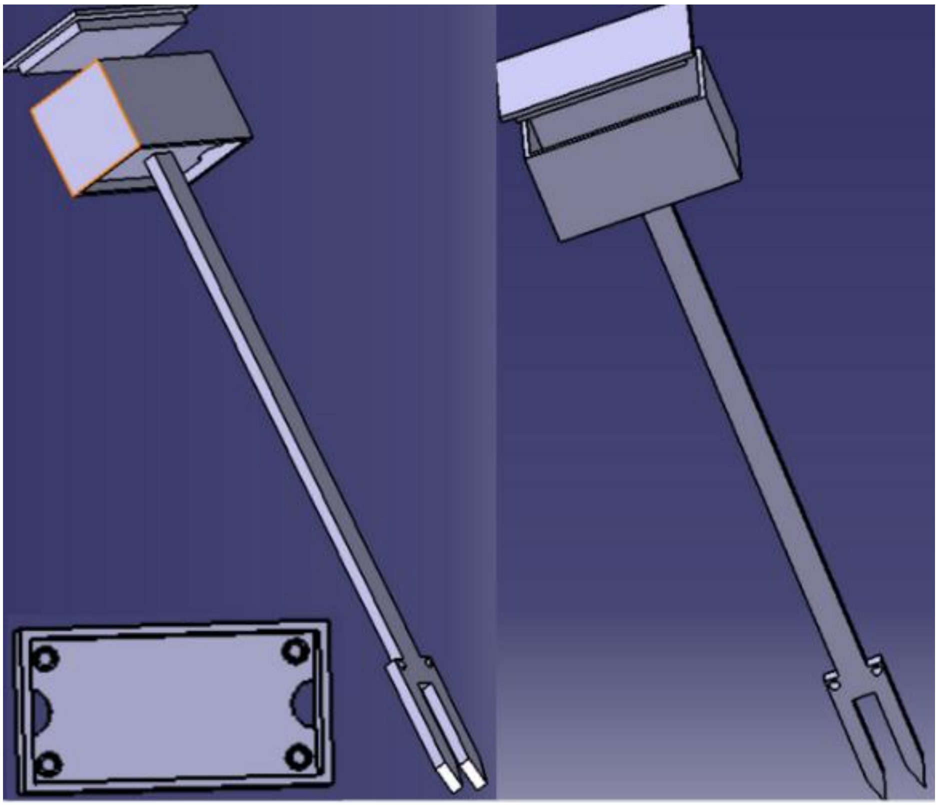

Figure 14: Pole Sensor casing CAD model.

3.221 Material choice

The material used for the Sensor Pole casing needs to follow the following criteria:

- The material needs to be easily available
- The material needs to be 3D printable
- The material needs to have relatively durable properties
- The material needs to be able to withstand relatively high temperature (up to 100 Celsius)
- The material needs to able to handle the consistent UV light exposure
- The material needs to able to handle the moisture of the environment
- The material needs to able to be able to resistant to acidic rain

Table 5: list of possible materials for the casing of the Pole sensor.

Material	strength	flexibility	Durability	Pros	Cons	Price £ per KG
polylactic acid (PLA)	Medium	low	medium	Easy to print, cheap, easy to print	Brittle, lacks any good mechanical properties	21
Acrylonitrile butadiene styrene (ABS)	High	Medium	high	Very durable and strong, withstand high temperature	Hard to print, toxic	30
Polyethylene	High	Medium	high	Flexible,	Weak to	25

terephthalate (PET)				durable, easy to print	moisture, soft	
thermoplastic elastomers (TPE)	medium	Very high	Very high	Flexible and easily compressible	Hard to print and takes time to print	54
Polyamide (PA)	Very high	high	high	Very durable, flexible, and strong	Weak to moisture, Hard to print and takes time to print	62
Polycarbonate (PC)	Very high	Medium	Very high	Very strong, resistant to heat and physical impact	Weak to moisture, Hard to print	40
Poly-vinyl chloride (PVC)	Very high	Medium	Very high	Very strong, resistant to heat and physical impact, resistant to chemicals	Expensive, hard to print	51

Based on the criteria and the different properties of the different materials PVC (Poly-vinyl chloride) has been choose as it satisfies all of the above mentioned. PVC plastic is available everywhere, it's extremely though, it's extremely resistant to high temperature, moisture, and UV radiation. Finally, its able to resist acid rain and toxic environments.

The cost of the material can be calculated using the following formula:

Volume of part* density of material * price per weight = cost of material

4.1938e-5m^3 *1330KG/m^3*51£/KG= 2.84465£

Based on that the estimate for 3D printing the part is 7£

3.222 Weatherproofing

The weather proofing of the Sensor pole is split into two main parts:

- sealing the top part of the casing: using an O-ring the part between the case lid and the top case will be weather sealed.
- Protecting electronics from corrosion and moisture: using an Acrylic Conformal Coating Anti Corrosion spray all the electronics will be covered and protected from moisture and corrosion.

3.3 Assembly

The assembly is another extreme part of the project as giving the proper instruction could allow anyone even without prior experience to assemble both the sensor pole and the server.

3.31 Tools needed for assembly

The following are the tools needed to assemble the sensor pole and the server:

Table 6: list of tools needed for assembly and their cost.

tool	Cost £
Screwdriver	1
No.8 (4mm) x 12mm Fully Threaded Pozi Countersunk Chipboard Screws	2.5
Soldering iron	10
solder	2
65 Breadboard Jumper Wire	2.5
Acrylic Conformal Coating Anti Corrosion PCB's	10
Zhanlida T-7000 Adhesive Glue With Precision Applicator Tip	2
total	30

3.32 Wiring diagram

The following table describes all the connection and their type:

Table 7: table of parts and other parts its connected to.

Part	Other parts its connected to	Type of connection
Adafruit LTR390 UV Light Sensor	ESP32 – DevKitC	wired
DHT22/11 Humidity and Temperature Sensor	ESP32 – DevKitC	wired
Soil Moisture Sensor	ESP32 – DevKitC	wired
Adafruit Ultimate GPS Breakout	ESP32 – DevKitC	wired
LED - RGB Addressable	ESP32 – DevKitC	wired
ESP32 – DevKitC	Adafruit LTR390 UV Light Sensor, DHT22/11 Humidity and Temperature Sensor, Soil Moisture Sensor, Adafruit Ultimate GPS Breakout, 10K Ohm Resistor, Flexible solar panel, Lithium Polymer Battery, Lipo Battery Charger Module	wired
ESP32 – DevKitC	MERCUSYS 300 Mbps Wireless N Router	wireless
10K Ohm Resistor	ESP32 – DevKitC, DHT22/11 Humidity and Temperature Sensor	wired
Lithium Polymer Battery	ESP32 – DevKitC	wired
Lipo Battery Charger Module	ESP32 – DevKitC	wired
Flexible solar panel	ESP32 – DevKitC	wired
Raspberry PI 3	MERCUSYS 300 Mbps Wireless N Router	wireless
MERCUSYS 300 Mbps Wireless N Router	Raspberry PI 3, ESP32 – DevKitC	wireless

The following is the wiring diagram for the sensor pole:

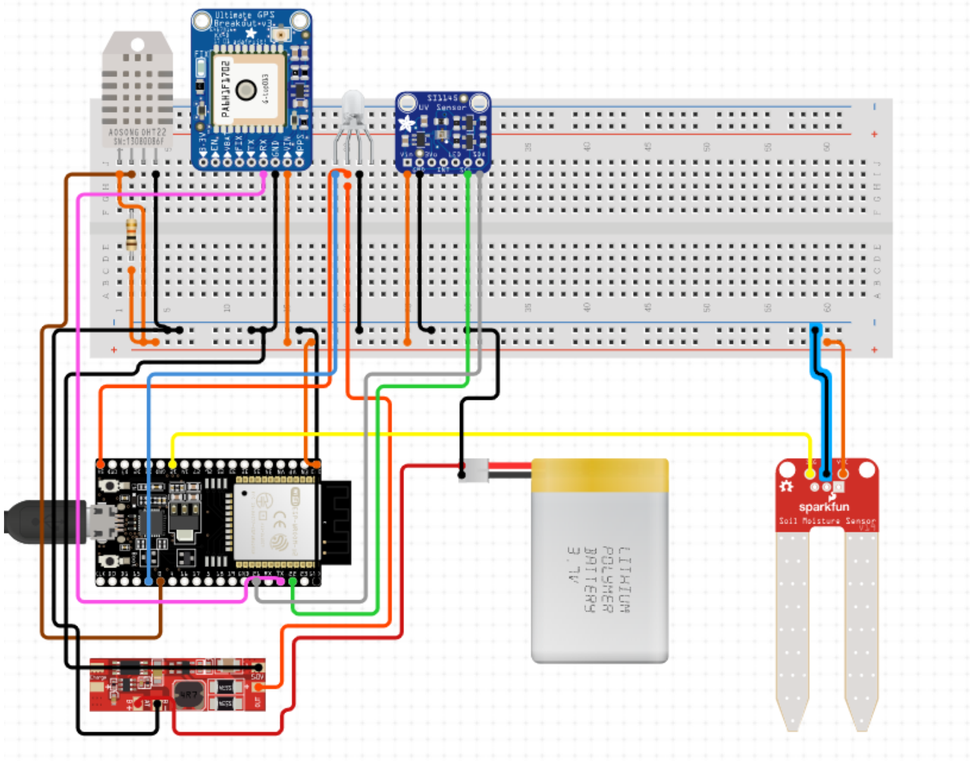

Figure 15:wiring diagram for pole sensor.

3.33 Electronics placement in casing

The electronics placement in the case is mainly split into the placement of the Raspberry PI in the case And the placement of the sensor pole in the case.

The Raspberry PI must simply be placed in its casing and crewed down correctly without exerting too much force.

To assemble the sensor, pole the following steps must be followed:

1. based on the wiring Diagram all the cables must be soldered to the ESP32 and connected to the battery controller and the battery leaving enough leeway to be moved. NOTHING ELSE SHOULD BE SOTERED BY THIS POINT.
2. All the components so far must be sprayed with multiple layers with the anti-corrosion spray except for the ends of the cables that are not connected
3. All the rest of the cables must be pulled down and out of the hole in the bottom of the casing.
4. The ESP32 chip be screwed down in its correct positioning based on matching the screw holes, all four screws must be screwed down without the use of too much force.
5. The battery controller and the battery must be secured to the sides of the case using the glue, wait for the glue to dry before doing anything else.
6. The rest of the components of the sensor pole must be soldered according to the wiring diagram.
7. Everything that hasn't been already sprayed by the anti-corrosion spray must now be sprayed with at least three layers.
8. The moisture sensor must be now screwed in its designated area at the bottom of the sensor pole using two screws and without using excessive torque.
9. Finally using the glue the rest of the parts must be glued in positions where its believed they will perform best, this is based on the environment where they are planned to be deployed.

3.4 Software and programming

Using the Arduino IDE, the raspberry pi connected to the same network as the pole sensors will use an MQTT protocol to send and receive data from the sensor pole. The data includes humidity, charge, temperature, UV light, GPS location, among others. This data will then be uploaded to a server that can be checked anywhere in the world.

The programming will also allow the pole sensors using an LED to display the signal strength allowing for easier deployment not to mention periodic reading every 10 to 15 minutes to conserve the battery of the sensor pole to the max.

3.41 The algorithm logic

The algorithm will work as shown is the diagram bellow:

In this algorithm the main brain is the Raspberry PI.

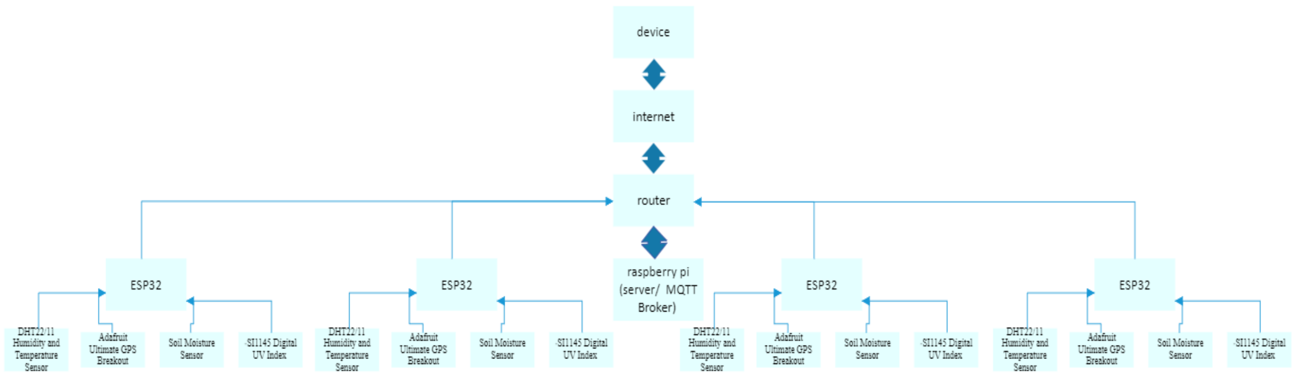

Figure 16: Data path based on the algorithm.

3.42 The MQTT Protocol

MQTT or Message Queuing Telemetry Transport is a lightweight messaging protocol designed for constrained devices and low-bandwidth, high-latency, or unreliable networks. It is commonly used in Internet of Things (IoT) and Machine-to-Machine (M2M) communication scenarios similar to this use case where the Raspberry PI communicates with the ESP32.

MQTT works on a publish-subscribe model, where clients connect to a broker in this case the Raspberry PI and subscriber in this case the ESP32. The broker then receives messages published by other clients and forwards them to the subscribed clients. The protocol allows for efficient and reliable communication between devices, with minimal overhead and low power consumption.

This make the MQTT perfect for the following use case.

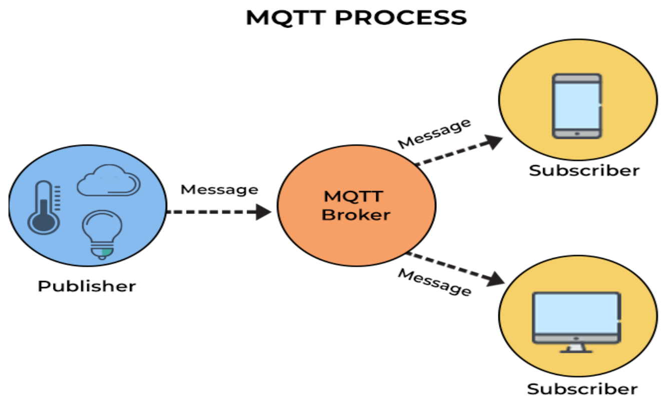

Figure 17: (BasuMallick, 2022)

3.5 Testing and trouble shooting

The testing will consist of four main parts:

- The proof of concept
- Water resistance testing
- Weather testing
- Long term testing

Each of these tests is meant to satisfy a different part of the validation process of the sensor pole

3.51 Proof of concept

The proof-of-concept testing is the initial part of testing, it will consist of testing the equipment features and if they all work as intended. This testing is rather simple and quick as its basic checks of all the systems and if they operate correctly. If any parts don't operate as intended, they will be fixed and retested.

3.52 Water resistance testing

The water resistance testing will consist of testing for rain like situations and moisture intrusion. Water in different intensities and densities will be sprayed constantly on the device overall different intervals, after each test, the sensor pole will go through the proof-of-concept and if any function doesn't work the issue will be fixed and sensor pole will be tested again. For the moisture testing the sensor pole will be left in moist environment for different periods of time, after each test, the sensor pole will go through the proof-of-concept and if any function doesn't work the issue will be fixed and sensor pole will be tested again

3.53 Weather testing

The weather testing will consist of putting sensor pole through different possible weather situations (Fast winds, earthquakes, acid rain, UV radiation exposure, or a mix of all of some of the already mentioned) , after each test, the sensor pole will go through the proof-of-concept and if any function doesn't work the issue will be fixed and sensor pole will be tested again.

3.54 Long term testing

The long-term testing is the most complicated as it consists of actually deploying the pole sensor in an environment where it's expected to operate. This testing could take months as data gets collected and as the device gets improved.

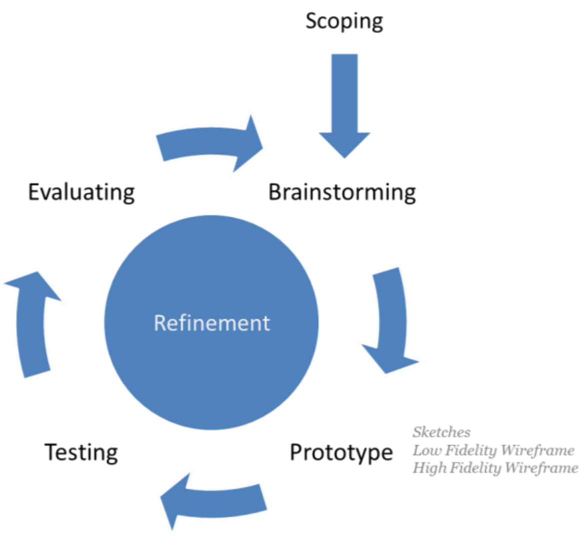

Figure 18: (edgarator, 2013)

3.6 Improvement and optimization

The testing phase will more than likely show multiple areas of improvement for the equipment. Using the data collected the equipment can be improved on and optimized.

Areas where it is expected to be optimized are:

- Battery life
- Signal connection
- Range
- Accuracy
- Cost
- Types of data collected.

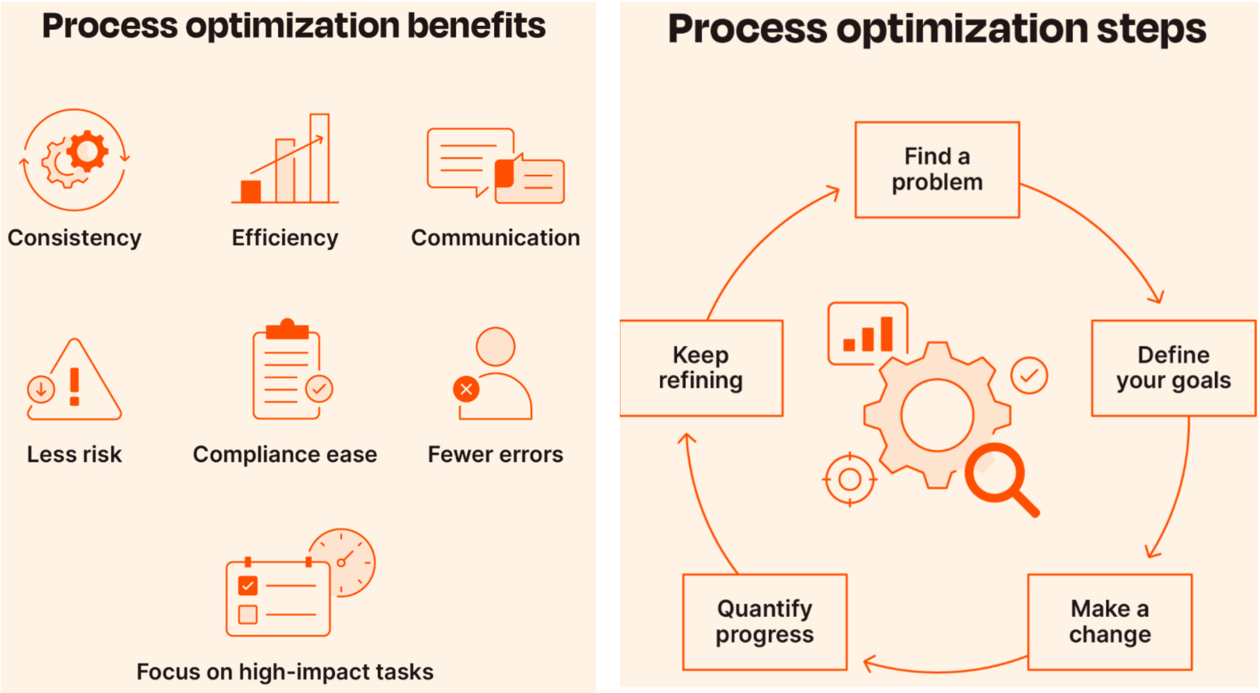

Figure 19 : (Emley, 2022)

3.61 Capabilities improvement
Based on the environment where the sensor pole can be deployed, and the needs of the farmer different sensors can be deployed and used. Not only that but code improvements could help battery life, data accuracy and efficiency.

3.62 Accessibility and cost improvement
Based on more research and data collected cheaper more affordable and more accessible parts can be used. Not only that but the use of moulds for the manufacturing of casings could lead to a much cheaper product

3.7 Cost analysis
The total cost for the project to be deployed is as follows:

- Cost of each pole sensor with GPS: 63.9£
- Cost of each pole sensor without GPS: 35.1£
- Cost of the server and wireless network: 49.5£
- Cost of the Raspberry PI Case: 7.17533£
- Cost of the server case: 9.84465£
- Cost of the tools: 30£
- Cost of labour: 3*10.18= 30.54£
- Cost of development: 0 as the Development was done by me

The cost of deployment of 4 sensor poles comes up to 382.65998£ which a lot cheaper than anything else in market costing thousands of pounds less while being a lot more flexible and adaptable.

4.0 Conclusion
In conclusion, designing an IoT-based agricultural pole sensor can significantly improve the efficiency and productivity of agricultural practices while eliminating the need a noticeable number of child labours. By utilizing the power of IoT and wireless communication technology, farmers can

remotely monitor their crops' health, soil moisture levels, and other important parameters in real-time. This enables them to make informed decisions about irrigation, fertilization, and pest control, resulting in reduced water usage, increased yields, and ultimately higher profits. Not only that but with this technology no farmer will need to use a child ever again to watch the fields, or water the plants constantly. The agricultural pole sensor we designed provides a scalable and cost-effective solution that can be easily deployed in both small and large-scale farming operations. With further improvements and advancements in IoT technology, the potential for IoT-based agriculture to revolutionize the industry is immense, and positive impact it could do to the world is limitless.

4.1 Future plans

In the future it is planned to publish this research in an open-source website allowing for consistent development and use by plenty of people around the world. Contacting suppliers and manufacturers around the world is also one of the plans as it can lead to cheaper mor available final product. And finally, the positive impact that is hoped the project can achieve will monitored anxietly.

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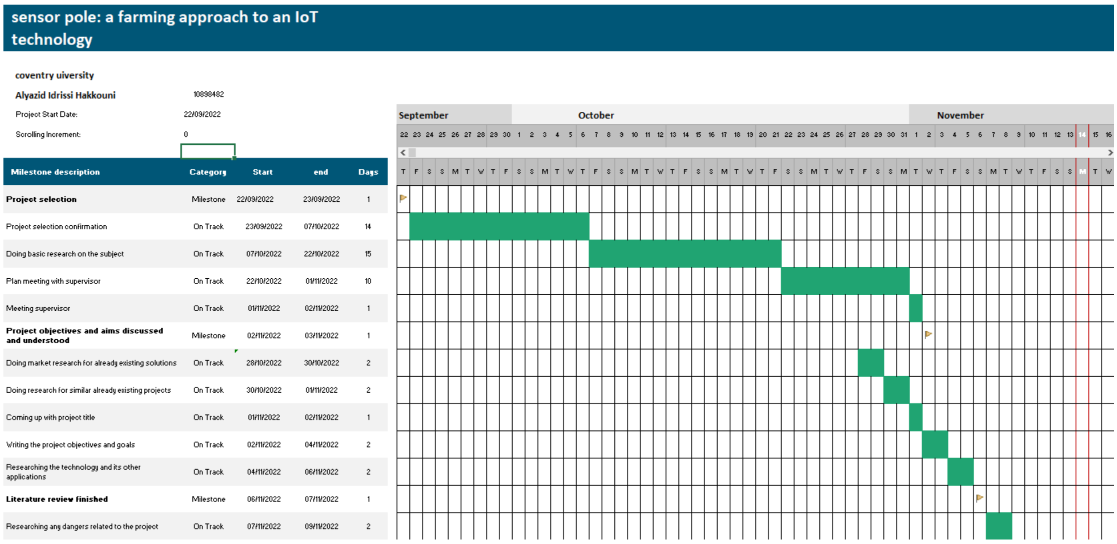
6.0 Appendix

6.1 Appendix A

1.1. Gantt Chart/Project Plan & Timescales

The following Gantt chart has general introduction to the plan of action to undertake the project.



sensor pole: a farming approach to an IoT technology

coventry uiversity

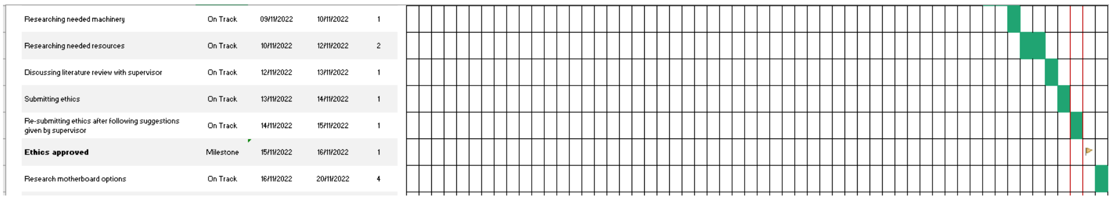
Alyazid Idrissi Hakkouni 10898482

Project Start Date: 22/09/2022

Scrolling Increment: 0

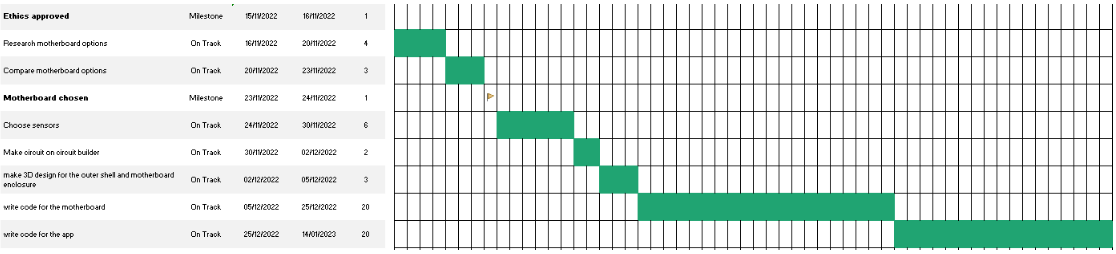
Milestone description	Category	Start	end	Days
Project selection	Milestone	22/09/2022	23/09/2022	1
Project selection confirmation	On Track	23/09/2022	07/10/2022	14
Doing basic research on the subject	On Track	07/10/2022	22/10/2022	15
Plan meeting with supervisor	On Track	22/10/2022	01/11/2022	10
Meeting supervisor	On Track	01/11/2022	02/11/2022	1
Project objectives and aims discussed and understood	Milestone	02/11/2022	03/11/2022	1
Doing market research for already existing solutions	On Track	28/10/2022	30/10/2022	2
Doing research for similar already existing projects	On Track	30/10/2022	01/11/2022	2
Coming up with project title	On Track	01/11/2022	02/11/2022	1
Writing the project objectives and goals	On Track	02/11/2022	04/11/2022	2
Researching the technology and its other applications	On Track	04/11/2022	06/11/2022	2
Literature review finished	Milestone	06/11/2022	07/11/2022	1
Researching any dangers related to the project	On Track	07/11/2022	09/11/2022	2

Figure 20: 1st part of the Gantt chart.



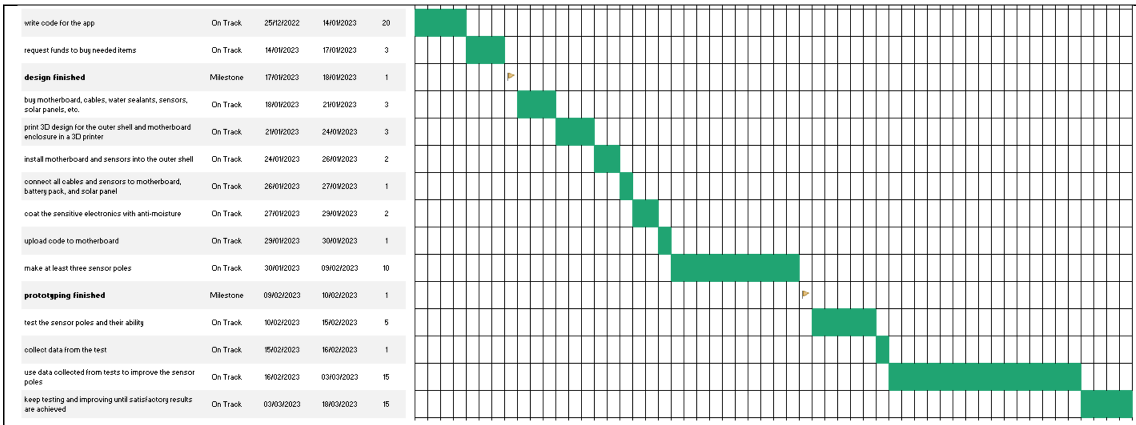
Researching needed machinery	On Track	09/11/2022	10/11/2022	1
Researching needed resources	On Track	10/11/2022	12/11/2022	2
Discussing literature review with supervisor	On Track	12/11/2022	13/11/2022	1
Submitting ethics	On Track	13/11/2022	14/11/2022	1
Re-submitting ethics after following suggestions given by supervisor	On Track	14/11/2022	15/11/2022	1
Ethics approved	Milestone	15/11/2022	16/11/2022	1
Research motherboard options	On Track	16/11/2022	20/11/2022	4

Figure 21: 2nd part of the Gantt chart.



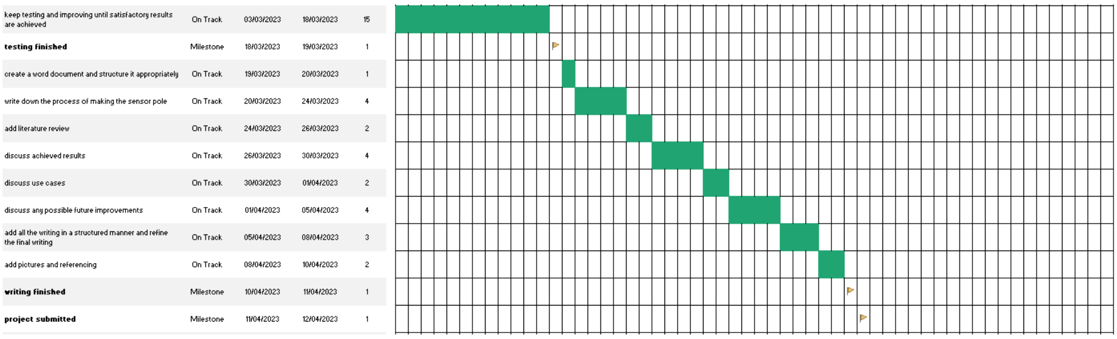
Ethics approved	Milestone	15/11/2022	16/11/2022	1
Research motherboard options	On Track	16/11/2022	20/11/2022	4
Compare motherboard options	On Track	20/11/2022	23/11/2022	3
Motherboard chosen	Milestone	23/11/2022	24/11/2022	1
Choose sensors	On Track	24/11/2022	30/11/2022	6
Make circuit on circuit builder	On Track	30/11/2022	02/12/2022	2
make 3D design for the outer shell and motherboard enclosure	On Track	02/12/2022	05/12/2022	3
write code for the motherboard	On Track	05/12/2022	25/12/2022	20
write code for the app	On Track	25/12/2022	14/01/2023	20

Figure 22: 3d part of the Gantt chart.



write code for the app	On Track	25/12/2022	14/01/2023	20
request funds to buy needed items	On Track	14/01/2023	17/01/2023	3
design finished	Milestone	17/01/2023	18/01/2023	1
buy motherboard, cables, water sealants, sensors, solar panels, etc.	On Track	18/01/2023	21/01/2023	3
print 3D design for the outer shell and motherboard enclosure in a 3D printer	On Track	21/01/2023	24/01/2023	3
install motherboard and sensors into the outer shell	On Track	24/01/2023	26/01/2023	2
connect all cables and sensors to motherboard, battery pack, and solar panel	On Track	26/01/2023	27/01/2023	1
coat the sensitive electronics with anti-moisture	On Track	27/01/2023	29/01/2023	2
upload code to motherboard	On Track	29/01/2023	30/01/2023	1
make at least three sensor poles	On Track	30/01/2023	09/02/2023	10
prototyping finished	Milestone	09/02/2023	10/02/2023	1
test the sensor poles and their ability	On Track	10/02/2023	15/02/2023	5
collect data from the test	On Track	15/02/2023	16/02/2023	1
use data collected from tests to improve the sensor poles	On Track	16/02/2023	03/03/2023	15
keep testing and improving until satisfactory results are achieved	On Track	03/03/2023	18/03/2023	15

Figure 23: 4th part of the Gantt chart.



keep testing and improving until satisfactory results are achieved	On Track	03/03/2023	18/03/2023	15
testing finished	Milestone	18/03/2023	19/03/2023	1
create a word document and structure it appropriately	On Track	19/03/2023	20/03/2023	1
write down the process of making the sensor pole	On Track	20/03/2023	24/03/2023	4
add literature review	On Track	24/03/2023	26/03/2023	2
discuss achieved results	On Track	26/03/2023	30/03/2023	4
discuss use cases	On Track	30/03/2023	01/04/2023	2
discuss any possible future improvements	On Track	01/04/2023	05/04/2023	4
add all the writing in a structured manner and refine the final writing	On Track	05/04/2023	08/04/2023	3
add pictures and referencing	On Track	08/04/2023	10/04/2023	2
writing finished	Milestone	10/04/2023	11/04/2023	1
project submitted	Milestone	11/04/2023	12/04/2023	1

Figure 24: 5th part of the Gantt chart.