GROUP 40

Implementing Smart Farming using IoT and AI

Project Management Report

School of Information Technologies
Faculty of Engineering & IT

ASSIGNMENT / PROJECT COVERSHEET - GROUP ASSESSMENT

Unit of Study : INFO6007: Information Technology Project Management
Group Number : **40**
Project name : Implementing Smart Farming using IoT and AI
Tutorial Time : Wednesday – 8 PM to 9 PM
Tutor's Name : Dr. Rabiul Hasan and Ajit Pillai

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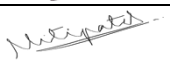
We realise that we may be asked to identify those portions of the work contributed by each of us and required to demonstrate our individual knowledge of the relevant material by answering oral questions or by undertaking supplementary work, either written or in the laboratory, in order to arrive at the final assessment mark.

Student ID	Unikey	Student name	Participated	Agree to share	Signature
500261879	LPAS4239	Lakshmi Bhargavi Pasupuleti	Yes	Yes	
500351402	AANG4191	Andre Ang	Yes	Yes	
480421861	TTRA7259	Tung Nhan Tran	Yes	Yes	
500245053	NPAT6703	Niti Virendra Patel	Yes	Yes	
500388660	AASH6904	Arief Rachman Ashar	Yes	Yes	

SIT Building, J12
The University of Sydney,
NSW 2006 Australia

T: +61 2 9351 3423
F: +61 2 9351 3838
E: sit.info@sydney.edu.au
W: sydney.edu.au/it

ABN 15 211 513 464
CRICOS 00026A

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1 | Project Charter

Background

Research estimates that the world population would reach 10 billion in 2050 and the demand for food would increase by more than 70%, pressurizing farmers to meet the demand despite the decreasing area of arable land. A practical solution to meet this demand is to bring about technological innovation in farming. It has started to revolutionize farming practices throughout the world. Some examples include:

- Internet of Things (IoTs) and drones are used to monitor crops from a distance and non-invasively.
- Big data has improved the decision-making processes in farming.
- Robots harvest crops at a faster pace and in a higher volume than humans.
- Artificial intelligence (AI) is used to predict the impact of environment stimuli on agricultural products.

However, one of the significant problems facing farmers in farming is degraded farmland. This is a result of improper crop rotation. Extensive planting of the same crop type leads to the exhaustion of nutrients and minerals in the soil. The exhaustion is because each crop has different nutrient interactions with the soil, i.e., they each release and absorb different nutrients and minerals. If the same crop is planted after every harvest, the soil will become devoid of nutrients and minerals required for its yield, and the quality and quantity of the harvest might be inferior to its previous batch. Hence, crop rotation is crucial to balance and restore soil nutrients and minerals.

Crop selection is a crucial component of crop rotation. It is the process of choosing a suitable crop to be planted based on several conditions such as humidity, soil pH level, soil nutrient composition, weather, season, market price, and farmer specialisation crop. By choosing suitable crops, farmers can increase the crop's productivity and their profits from farming. Farmers need to analyse various factors manually to determine which crop is the best choice to be planted next. Understandably, these practices also involve some risk. Crop yield is not guaranteed due to unknown factors, and farmers can end up incurring loss of harvest.

However, these practices are yet to see the light of technological innovation. This project aims to develop an AI that recommends suitable crops for the crop selection and crop rotation processes by implementing IoTs to gather the required data on the field.

Opportunity

Smart Farming Technology is a newly emerging field that is predicted to be valued around $(USD)12.8 billion by 2025.

Goal and Objective Statement

Goal

Provide useful farm information to improve farmers efficiency and provide suitable crop recommendations to increase farmers profitability.

Objective

- Increase AquaSpy revenue by adding value to current company technology in the market.
- Assist farmers in selecting suitable crops to be planted.
- Help farmers get actual field conditions in soil pH, soil nutrients, temperature and humidity.

Success Criteria

1. The project was completed all the scope requirements.
2. The project was completed within two years.
3. The project was completed under $2,750,000 (±10% of estimated cost).
4. The final project deliverables were ,completed within the deadlines.
5. The final project milestones were achieved within the deadlines.
6. All project deliverables defined in the planning phase of the project were completed (i.e., there is no change in the list of deliverables between the planning phase and control phase).
7. All project milestones defined in the planning phase were achieved (i.e., there is no change in the list of milestones between the planning phase and control phase).
8. All defects (bugs) are resolved within the planned time.
9. The project had less than 10 per cent of defects (bugs).

Project Description

There is a real need for an integrated system to assist farmers in deciding which crop suits their condition, by leveraging environment and market data. The first part of the system is to gather environment data by using the Internet of Things (IoT) devices, market data by using web crawlers/Application Programming Interface (API) and farmers' data via a mobile application. This data will be fed to cloud computing for storage and analysis. The second part of the system is to analyse which crop is suitable for each farmer using Artificial Intelligence (AI). The third part is making this information available to farmers through AquaSpy mobile application to help them make informed decisions.

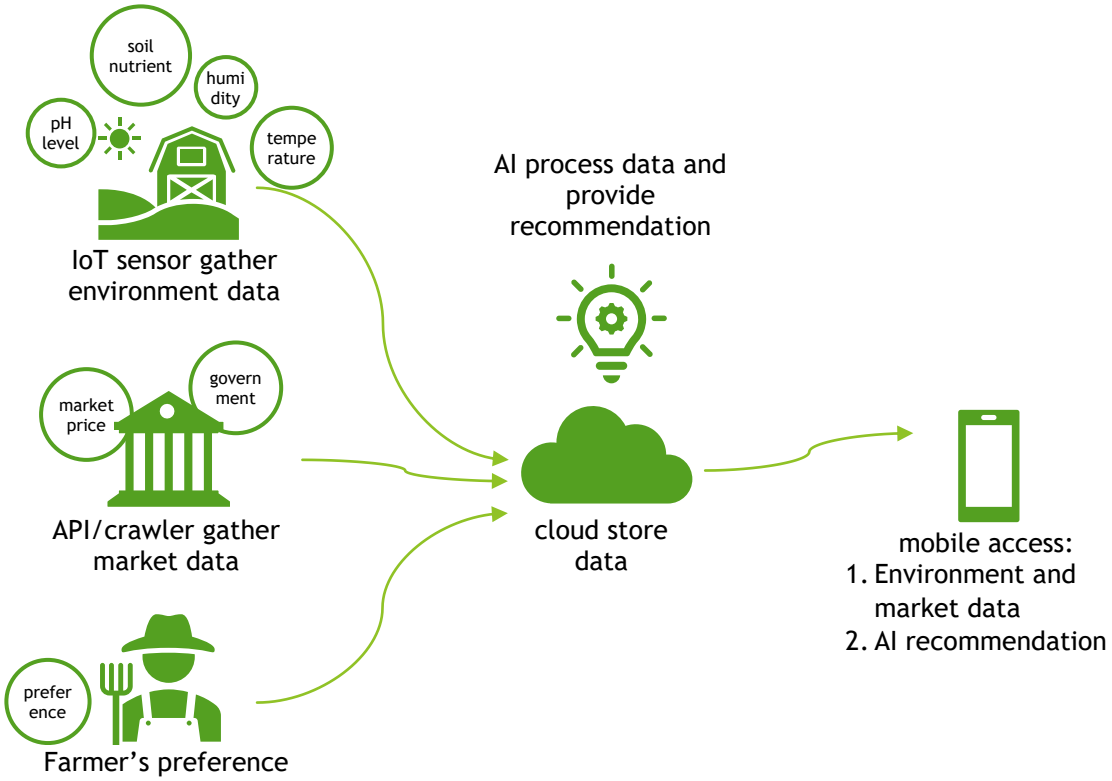

Figure 1 Product Illustration

The project approach of product development is Waterfall because a greater emphasis on planning and designing stage. However, as the first to introduce a solution to market, we are exposed to a certain degree of uncertainty. To counter this, we involve our potential customers in market research and Agronomist through several iterations.

Project Structure

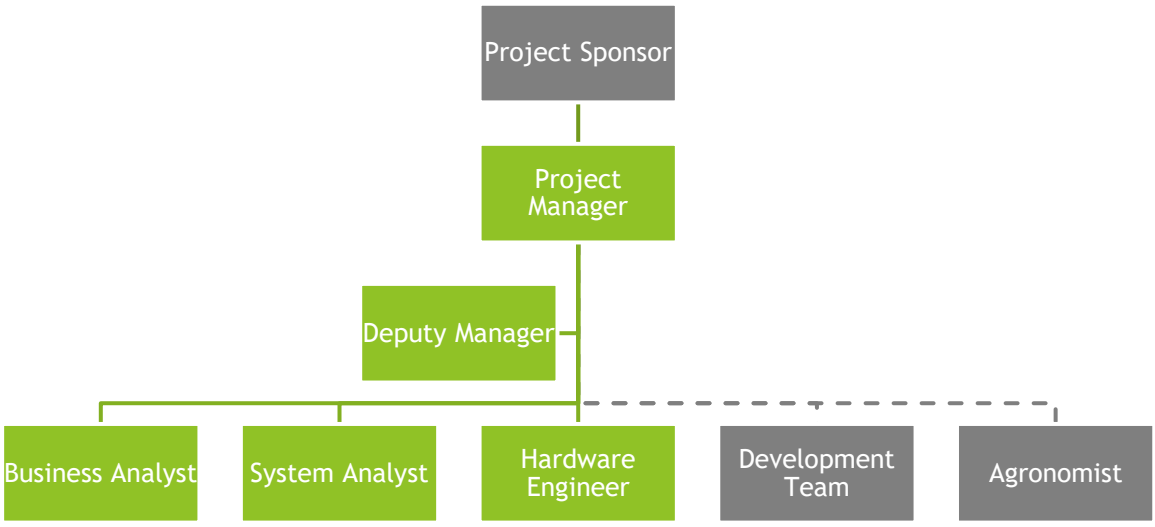

Figure 2 Project Structure

Core Team Member

- **Project Manager : Niti Patel**
  - Monitoring the progress of the project
  - Resolving internal conflicts
  - Ensuring that all team members contribute to the project
  - Communicate with stakeholders
  - Change requests
  - Hiring decisions
  - Control and monitoring the project process
  - Development of work Breakdown structure
  - Project scheduling and timeline (including Gantt chart)
  - Creating the project plan
  - Quality assurance and control
  - Risk monitoring and mitigation
  - Review project
- **Deputy Manager : Lakshmi Bhargavi Pasupuleti**
  - Contribute to the project
  - Helping Project Manager
  - Data collection and analysis
  - Cost modelling
  - Budget proposal
  - Quality assurance and control
  - Risk monitoring and mitigation
  - Review project
- **Hardware Engineer: Nhan Tran**
  - Contribute to the project
  - Communication plan
  - Team communication
  - Quality control
  - Review project
- **System Analyst : Arief Ashar**
  - Contribute to the project
  - Scope statement
  - Risk Management
  - Quality control
  - Interview with farmers via email
  - Review project
- **Business Analyst : Andre Ang**
  - Contribute to the project
  - Project charter
  - Quality Management planning
  - Quality assurance and control
  - Review project

Stakeholder

- **Company : AquaSpy**
  - Provide funds for the project
- **Project Sponsor : CEO of AquaSpy – Bruce Moeller**
  - Point of communication with Aquaspy.
  - Provide direction and guidance for the project
  - Negotiate funding for the company
- **Customer : Farmers**
  - Provide inputs on current farming practices and project's requirement
  - Provide inputs on the device
- **Subject Matter Expert : Agronomist**
  - Perform Soil nutrient analysis
  - Provide suggestions on best crops for crop rotation and crop selection
  - Assist in testing progress.
- **Development Team : Contractors**
  - Executing the project
  - Provide their expertise in developing the product
  - Provide recommendations for improvement

Summary Project Status	
Project Start Date	20/03/2020
Estimated Completion	20/03/2022
Project Time	2 years
Project Impacted	Helps farmers in crop selection
Cost Estimation	$AUD 2,750,000
Sponsor Approval	Bruce Moeller
Date	20/03/2020

2| Scope

Product Requirement

- *IoT devices to gather environment data*, such as temperature, humidity, soil pH level, soil moisture and sunlight. These devices should be connected to the Internet to communicate with cloud servers; however, the connection does not need to be constant or real-time.
- *APIs to gather market data*, such as current price of commodities in specific locations, export tariffs and government incentives.
- *Cloud-based server to store, compute and analyse data*, such as data warehouse, business intelligence, machine learning engine, mobile app engine.
- *AI model to provide crop recommendations*. The AI will be trained with primary data from environment and market as well as secondary data from research on crop interaction with soil nutrients.
- *iOS and Android mobile applications* with the following functions:
    - Display current and past environment and market data, including trend analysis.
    - Display soil information retrieved from sensors.
    - Receive additional inputs from farmers, then provide crop recommendations.

Project Management Deliverables

1. Project Initiating
    a. Project charter
    b. Scope statement
2. Project Planning
    a. Project proposal
    b. Project estimation and budgeting
    c. Work breakdown structure
    d. Gantt Chart/schedule
    e. Risk management plan
3. Project Execution
    a. Quality control (software and hardware testing)
    b. Field testing (market acceptance)
4. Monitoring and Controlling
    a. Project status update (fortnightly)
5. Project Closing
    a. Final report

Product Deliverables

1. IoT devices as sensors to gather environmental data.
2. Cloud-based server to store, compute and analyse data.

3. Mobile application for users as a front-end interface to receive farmers input and display environment data, market data, and AI-based suggestions.
4. App engine as the backend to improve AI suggestion and manage front-end.

Out of Scope

- The systems operate on the assumption of the availability of electricity and Internet connection.
- The project does not cover user's training, system maintenance, product support after deployment, which will be provided by AquaSpy operational team.
- The project does not cover product manufacturing expenses, the funds for the same will be provided by Aquaspy upon product development.
- The project does not cover product implementation in the client's location. The exception is during field testing, in which project team member will assist installation and support.

Project Milestones

- Project Manager Selected
- Project Team Formed
- Market Research and Data Collection Completed
- Product Requirement Finalised
- Project Initiated
- Project Scope Finalised
- WBS and Scheduling Finalised
- Product Design Finalised
- Cost Modelling Finalised
- Budget Approved
- Communication Plan Finalised
- Quality Management Plan Finalised
- Risk Management Plan Finalised
- Resources Procured
- Hardware and Software Prototype Completed
- Product and Field Testing Completed
- Operational Team Trained
- Product Released and Launched
- Market Feedback Gathered
- Final Report Submitted

3 | Literature Review

Introduction

Agriculture has evolved from a simple practice of cultivating soil to grow crops since its inception in the hunters-and-gatherers era. Today, it is a technology-intensive practice of maximising crops yields [1]. In its early years, which is referred to as Agriculture 1.0, agriculture was subsistence farming (also referred to as peasant farming) that used traditional farming practices that are labour and knowledge-intensive [2]. It required about a third of the population to feed the whole population. These farming practices prevailed for many centuries.

However, the advent of mechanization and green revolution with genetic modification of seeds became the basis for Agriculture 2.0. It is characterized as industrial agriculture and began with the advent of agriculture tools (such as supplemental fertilizer and tractors) in the late 1950s that dramatically increased crop yield.

However, the current research in agriculture focuses on the use of information and communications technology (ICT) to improve crop yields and to empower the automation of farming practices. At the same time, the area of arable land decreases and the population continues to grow.

Need for Information Technology (IT) in Farming

The world population is increasing at a rapid rate, which results in an increased demand for food. Research estimates that by 2050, the population is expected to reach 10 billion (from the current population of 7.7 billion) [3]. Based on this estimate, farmers would need to increase their food production by 70 per cent to meet the population's demand. Traditional farming methods cannot meet the increasing demand. Hence, farmers employ certain practices, such as the use of harmful pesticides, to meet the increasing demand that impacts the soil quality, resulting in a barren land with no fertility. Therefore, there is a critical need to analyse the impact of using harmful pesticides, controlled irrigation, pollution, and the environment in farming today.

In addition, some problems in farming today include crop diseases, lack of storage management, pesticide control, weed management, lack of irrigation, and water management. The Food and Agriculture Organization of the United Nations (UN) estimates that approximately one-third of all food produced (i.e., 1.3 billion tonnes) is wasted annually.

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[1] Schrire, C. (Ed.). (2009). *Past and present in hunter gatherer studies*.
[2] Creutzberg, G.M. K. (2015). *Agriculture 3.0: A New Paradigm for Agriculture.* 10.13140/RG.2.1.4218.5205.
[3] Courtois, J., 2019. *Harnessing The Power Of AI To Transform Agriculture - The Official Microsoft Blog*. [online] The Official Microsoft Blog. Available at: <https://blogs.microsoft.com/blog/2019/08/07/harnessing-the-power-of-ai-to-transform-agriculture/> [Accessed 23 April 2020].

Use of IT in Farming Today

Modern agriculture has become an intrinsic part of farming over the past few centuries. It is a progressive approach to using agricultural innovations to help farmers increase the efficiency of farming practices while reducing the number of natural resources required [4]. Modern agriculture revolution has significantly transformed the way farming is performed over the world today.

The first wave involved mechanization (refers to the use of machinery to improve farming practices and the quantity and quality of agricultural produce). This wave saw the invention of machinery, such as ploughing machines, threshing machines, and seed drills [5].

The second wave focused on a green revolution with its genetic modification. It focused on three elements: continuous expansion of farming land, increase in crop seasons per year (from one crop season to two crop seasons), and the use of genetically modified seeds to increase crop yield [6].

The third wave, which is currently in effect, is precision agriculture (which is the use of technology to help farmers perform their farming practices accurately). Advancements in the use of technology in the agriculture sector have fuelled the efficiency of farming processes, reduced human labour, enhanced the quality and quantity of agricultural products, and resulted in higher soil gains and fertility.

Agriculture 4.0

An evolving set of practices in precision agriculture involves the utilization of information and communications technology in farming practices and using the data derived from them to make better-informed decisions. This paradigm is often referred to as *data-driven agriculture*, *smart farming*, *digital farming*, and *agriculture 4.0*. *Agriculture 4.0* refers to the upcoming trends in the agriculture industry based on precision agriculture with a significant emphasis on the use of Internet of Things (IoT) and big data that results in superior efficiencies in the farming practices and farming products, despite the growing population and climate change [7].

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[4] "What is Modern Agriculture?", *ModernAg*, 2020. [Online]. Available: https://modernag.org/modern-agriculture/. [Accessed: 29- Apr- 2020].
[5] "The Agricultural Revolution | Boundless World History", *Courses.lumenlearning.com*, 2020. [Online]. Available: https://courses.lumenlearning.com/boundless-worldhistory/chapter/the-agricultural-revolution/. [Accessed: 01- May- 2020].
[6] "The Green Revolution", *EduGreen*, 2020. [Online]. Available: http://edugreen.teri.res.in/explore/bio/green.htm. [Accessed: 01- May- 2020].
[7] "What is Agriculture 4.0?", *Proagrica*, 2020. [Online]. Available: https://proagrica.com/news/what-is-agriculture-4-0/. [Accessed: 29- Apr- 2020].

Internet of Things (IoT)

Internet of Things (IoT) is a set of interconnected computing devices with unique identifiers that can record and transfer data over a network without requiring human-to-human or human-to-computer interaction. IoTs include cameras and sensors.

IoT in farming is used to gather data and transfer it over a network and obtain objective information from monitoring crops. Advancements in IoT for farming include:

- The significant strides in the development of multispectral or hyperspectral imaging technologies to capture data non-invasively and at a distance from the target.

The platforms for supporting IoTs include satellites, aircraft systems, and proximal sensing using ground autonomous systems [8]. Some satellites that provide agricultural information are:

- The American Landsat satellites – A group of eight satellites that collects spectral data from the Earth every 16 to 18 days.
- The European Sentinel 2 satellite system – It captures multispectral data at 10 m pixel resolution for Normalized Difference Vegetation Index (NDVI) imagery, soil, and water cover every ten days.
- The RapidEye constellation – A group of five satellites that capture multispectral RGB imagery as well as red-edge and NIR bands at 5 m pixel resolution.
- The GeoEye-1 system – It captures multispectral RGB data and NIR data at a 1.84 m pixel resolution.
- The WorldView-3 – It collects multispectral data from the RGB bands including the red-edge, two NIR bands, and 8 SWIR bands with a pixel resolution of 1.24 m at nadir.

Aircraft systems supporting IoT include Unmanned Aerial Vehicles (UAVs) and Remotely Piloted Aircraft (RPAs). Proximal sensing using autonomous ground systems include unmanned ground vehicles and ground robots.

[8] F. Rovira-Más and V. Saiz-Rubio, "From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management.", *Agronomy*, vol. 10, 2020. Available: https://www.researchgate.net/publication/338991757_From_Smart_Farming_towards_Agriculture_50_A_Review_on_Crop_Data_Management. [Accessed 2 May 2020].

Drones

Drones, also known as unmanned aerial vehicles (UAVs), are considered to have the potential for solving significant challenges in agriculture. Today, drones are used in farming to: [9]

- Perform soil and field analysis.
- Plant crops.
- Spray fertilizers, pesticides and chemicals on crops.
- Monitor crops.
- Irrigate crops.
- Assess crops' health.

Big Data

Big data analytics plays an intrinsic role in smart farming. It is currently transforming the farming practices in the following ways [10]:

- It boosts productivity and innovation – Data from IoTs such as soil sensors, GPS-equipped tractors, and weather websites enables better utilization of critical resources, like fertilizers, water, pesticides, and seeds.
- It helps combat environmental changes – Data on climate, weather and weather forecasting help farmers be better prepared and make their farms better equipped to deal with the future climate. For example, Predictions of high temperatures in weather forecasts can help farmers be better prepared by providing more water for the crops.
- It minimizes costs and increases business opportunities – Big data analytics help farmers be better equipped to manage risks and cushion themselves for changes in the domestic and global markets.
- It improves supply chain management – Big data analytics helps farmers easily track their products throughout the supply chain. It also helps retailers, distributors, and other key stakeholders to provide customized products or services that meet farmers' needs.

Agriculture 5.0

Agriculture 5.0 refers to the advancements in agriculture 4.0 with a greater focus on using automated robotic systems and artificial intelligence to enhance the efficiency of farming practices [5]. It involves using equipment

[9] M. Mazur, "Six Ways Drones Are Revolutionizing Agriculture", *MIT Technology Review*, 2016. [Online]. Available: https://www.technologyreview.com/2016/07/20/158748/six-ways-drones-are-revolutionizing-agriculture/. [Accessed: 02- May- 2020].

[10] O. Schlam, "4 ways big data analytics are transforming agriculture", *Future Farming*, 2020. [Online]. Available: https://www.futurefarming.com/Tools-data/Articles/2019/7/4-ways-big-data-analytics-are-transforming-agriculture-450440E/. [Accessed: 01- May- 2020].

that performs crewless operations and promotes autonomous decision support systems in farming while conforming with the precision agriculture principles.

Robots

In traditional farming practices, farmers used to hire workers to keep their farms productive and harvest crops. Today, most farmers face a shortage of workers because of the increasing population shift from rural areas to urban areas.

With the growing advancements in technology, agricultural robots were developed to help farmers overcome this challenge. Examples of robots used in farming are as follows:

- Farm robots are used to harvest crops at a higher volume and faster pace than human workers [11].
  - These include robots that [12]:
    - prune crops
    - perform weeding [9] and cultivate crops.
- Scouting robots monitor crops for diseases and infestations.
- Robots spray fertilizers, pesticides, and chemicals on crops [9].

The challenge facing most farmers is that robots are too expensive, and they would instead employ human workers because they are cost-effective and more affordable.

Artificial Intelligence

Artificial intelligence (AI) is used to monitor crops and soil quality and predict the impact of environmental stimuli on agricultural products. Current implementations of AI in farming include [13]:

- *Plantix*, a deep learning platform, identifies potential defects and nutrient deficiencies in the soil.
- *Trace Genomics*, a California-based company, provides soil analysis to farmers.
- *SkySquirrel Technologies Inc.* analyses images captured from drones and use algorithms to analyse data and provide a detailed report on a vineyard's health.

[11] Walch, K. How AI Is Transforming Agriculture. Available online: https://www.forbes.com/sites/cognitiveworld/2019/07/05/how-ai-is-transforming-agriculture/ (accessed on 1 January 2020).
[12] J. Harris, "'We'll have space bots with lasers, killing plants': the rise of the robot farmer", *The Guardian*, 2020. [Online]. Available: https://www.theguardian.com/environment/2018/oct/20/space-robots-lasers-rise-robot-farmer. [Accessed: 02- May- 2020].
[13] K. Sennaar, "AI in Agriculture – Present Applications and Impact ", *Emerj*, 2020. [Online]. Available: https://emerj.com/ai-sector-overviews/ai-agriculture-present-applications-impact/. [Accessed: 02- May- 2020].

- *aWhere*, a Colorado-based company provides weather forecasts and analyses crop sustainability and examines farms for pests and diseases using machine learning programs and satellites.
- *AI Sowing App* – Microsoft, in collaboration with the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), leveraging the power of AI to help farmers improve the harvest of peanuts in Andhra Pradesh, India.

Since 2014, there has been a gradual increase in the number of startups that are focused on solving agricultural challenges using robotics and machine learning, along with a rising interest in AI [14]. There has been a 450% increase in venture capital funding in AI over the past five years [15].

Problem: Why is Crop Rotation and Selection the Need of the Hour?

Today, one of the direct causes of degraded farmland is ***improper crop rotation*** [16]. Such farmlands have increasing carbon emissions (such as CH4 and GHGs emissions in irrigated rice fields) and declining soil fertility due to short rotation and monocropping [17]. In addition, they are also at risk of plant diseases and pest infestations, environmental pollution, depletion of natural nutrients and minerals in the soil. Degraded farmlands could also be a victim to soil erosion and excessive use of agrochemicals. As a result, they may become harmful to organisms and compromising ecosystems [6].

Crop rotation, an indigenous farming practice, is the practice of planting different crops on the same land after every successive season such that no same crop is planted twice consecutively. It promotes nutrient cycling, increases the Soil Organic Carbon (SOC) concentration (which is suitable for crops) and reduces the use of chemicals, pesticides, and fertilizers. It also helps to build a better soil structure and preserves the productive capacity of the soil. A successful practice of crop

[14] D. Varadharajan, "AI, Robotics, And the Future of Precision Agriculture", *CBI Insights*, 2017. [Online]. Available: https://www.cbinsights.com/research/ai-robotics-agriculture-tech-startups-future/ [Accessed: 02- May- 2020].
[15] R. Murugesan, N. Venkataraman, S. Saha, R. Bajaj, A. Miral, M. Venkataraghavan, et. al., "Artificial Intelligence and Agriculture 5.0.", International Journal of Recent Technology and Engineering, Vol. 8., 2019, p. 1870–1877.
[16] M. D. Clercq, A. Vats and A. Biel, "Agriculture 4.0: The Future of Farming Technology", *Worldgovernmentsummit.org*, 2020. [Online]. Available: https://www.worldgovernmentsummit.org/api/publications/document?id=95df8ac4-e97c-6578-b2f8-ff0000a7ddb6. [Accessed: 30- Apr- 2020].
[17] R. Singh and G. Singh, "Traditional agriculture: a climate-smart approach for sustainable food production", *Springer Link*, 2020. [Online]. Available: https://link.springer.com/article/10.1007/s40974-017-0074-7. [Accessed: 26- Apr- 2020].

rotation results in high crop yield, improved soil fertility, and reduced pest problems. [18]

Crop rotation plays a vital role in increasing annual crops' yields while also ensuring sustainable and responsible use of natural resources. Successful crop rotation practice increases yields by 15% to 20% [19]. Crop rotation also helps maintain soil sustainability by improving physical (e.g., soil structure and bulk density), chemical (e.g., pH level and electrical conductivity), and biological (e.g., organic content and microbial biomass) soil properties.

Current Role of IT in Crop Rotation and Selection

Current Research

Crop rotation is often based on expert knowledge of using different crop sequence representations [20]. Castellazzi et al. [21] explain three types of flexible crop rotations for farmers:

- Cyclical crop rotation with a fixed duration of crop rotation
- Cyclical crop rotation with variable duration of crop rotation
- Less structured cyclical crop rotation with highly variable duration of crop rotation

Bruneli et al. [22] offer a solution using multiobjective evolutionary algorithms (MOEA) in crop selection for each parcel of land in a farm. However, Osman et al. [23] propose a prediction model for crop rotations based on expert knowledge. They specify that the following needs for forecasting of crop type mapping are not covered in any existing modelling approaches:

- The type of crop for crop rotation must be predicted for each field. Aggregate data and regional trends are insufficient to predict this information.
- Each farming landscape has a different climatic condition, leading to diverse farming practices. Hence, it is vital to combine regional information with field-level history for developing the crop sequences in crop rotation.

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[18] "Five Indigenous Farming Practices Enhancing Food Security", *Food Tank – The Think Tank for Food*, 2017. [Online]. Available: https://foodtank.com/news/2017/08/celebrating-international-day-of-the-worlds-indigenous-peoples/. [Accessed: 02- May- 2020].

[19] Ouda, S., Zohry, A., & Noreldin, T. (2018). Crop Rotation An Approach to Secure Future Food . https://doi.org/10.1007/978-3-030-05351-2

[20] J. Dury, N. Schaller, F. Garcia, A. Reynaud and J. Bergez, "Models to support cropping plan and crop rotation decisions. A review", *Springer Link*, 2012. [Online]. Available: https://link.springer.com/article/10.1007%2Fs13593-011-0037-x. [Accessed: 02- May- 2020].

[21] M.S. Castellazzi, G.A. Wood, P. Burgess, Jl Morris, K.F. Conrad, and J.N. Perry. (2008). "A systematic representation of crop rotations," *Agricultural Systems.* vol. 97. 26–33. 10.1016/j.agsy.2007.10.006.

[22] R. Brunelli and C. von Lücken, "Optimal Crop Selection Using Multiobjective Evolutionary Algorithms," *AI Magazine,* vol. 30, *(2),* pp. 96-105, 2009. Available: http://ezproxy.library.usyd.edu.au/login?url=https://search-proquest-com.ezproxy1.library.usyd.edu.au/docview/208124719?accountid=14757.

[23] J. Osman, J. Inglada and J. Dejoux, "Assessment of a Markov logic model of crop rotations for early crop mapping", *Computers and Electronics in Agriculture*, vol. 113, Issue April, pp. 234–243, 2015. Available: https://www.sciencedirect.com/science/article/pii/S0168169915000575. [Accessed 2 May 2020].

- There should be a universal approach for crop sequences in crop rotation. It should be assignable to various countries and regions of the world with minimum changes. The model should be able to learn from historical data and to utilise knowledge shared by subject matter experts.
- The approach of developing the crop sequences in crop rotations should not rely solely on field surveys because they are time-consuming and require a considerable workforce to cover vast areas.
- The model should evolve with changing conditions that influence farming practices, like climate change and regulatory constraints.

Proposed Solution

The best sequence of crop rotation depends on several factors:

- The type of crops from the previous cycle – The next crops should not compete for the same soil nutrients and attract similar pest. Instead, it should a complement type by furnishing a different kind of nutrients and naturally break the pest cycle [24].
- The current season – Certain crops are more suitable to be cultivated in specific season or weather condition. In some cases, cultivate the right crops could improve soil mineral level by around 33% to 41% [9]. This factor is closely related to altitude and geographic location, which often dictate common annual seasons.
- The economic value – Farmers are greatly incentivised to plant high-value crops. Therefore, it is essential to consider the current economic value of the next crops. [25]

Considering the needs specified by Osman et al. and the above factors as input parameters, the goal of our project is to design an Artificial Intelligence (AI) model with the purpose to maximise annual crops yields, maximise crops economic value, maintain soil sustainability, and be responsible for natural resource usage. In [26], machine learning algorithms are used to process agricultural data and predict crops are suitable for a piece of land.

[24] Stewart, Rovert E. (2018). "Agricultural Technology: Factors In Cropping" in Encyclopedia Britannica.
[25] Altieri, M.A. & C.I. Nicholls. (2004). "An agroecological basis for designing diversified cropping systems in the tropics" in Dimensions in Agroecology.
[26] Savla, A., Bhadada, H., Dhawan, P., & Joshi, V. (2015). Application of machine learning techniques for yield prediction on delineated zones in precision agriculture.(Report). International Journal of New Computer Architectures and Their Applications, 5(2).

4 | Work Breakdown Structure

The Work Breakdown Structure (WBS) is a deliverable-oriented grouping of the work involved in the project that defines the scope of the project. It is the cornerstone of effective project planning, execution, controlling, monitoring, and reporting. We have designed a 3 level WBS for this project as shown below; this breakdown helps us provide definition and detail to each task in these levels:

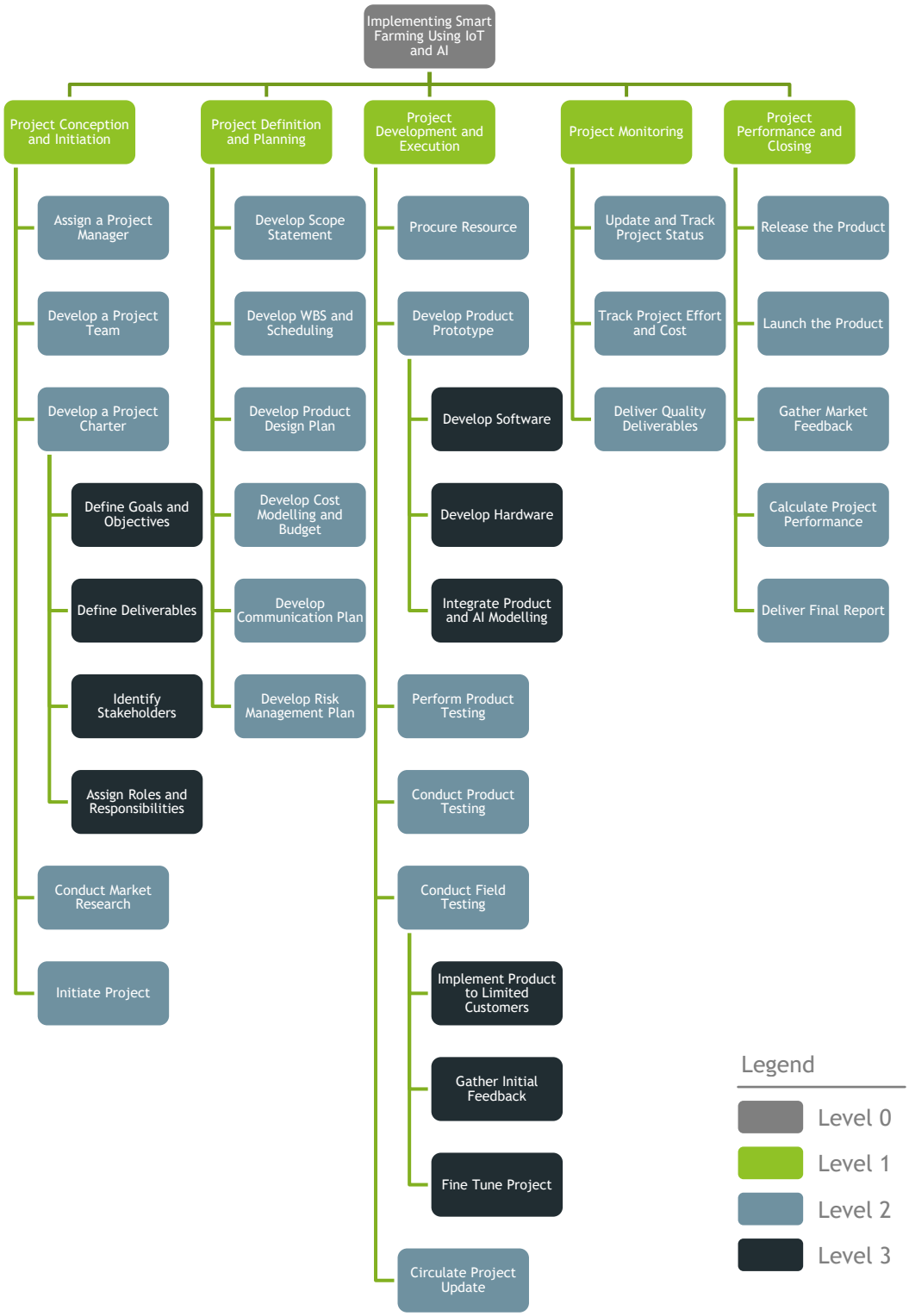

Figure 3 Work Breakdown Structure (WBS)

WBS Dictionary

The WBS dictionary here helps us describe each component of the WBS with detail and understand the working of each element better. The approach that we have undertaken to develop our WBS is a **top-down approach** meaning: We start with the first most significant task and work our way down by breaking it down based on excruciate details to smaller tasks.

Table 1 Work Breakdown Structure (WBS) Vocabulary

WBS NUMBER	TASK TITLE	WBS DESCRIPTION
1	**Project Conception and Initiation**	
1.1	Select a Project Manager	Select a project manager who understands the project thoroughly and can select a good project team based on the project's requirements.
1.2	Select the Project Team	Develop a project team that can work well with the given project and has the skill set required for this project.
1.3	Develop a Project Charter	This document helps us develop an outline for the entire project and sets prospective to the entire project planning.
1.3.1	Define Goals and Objectives	Define the goal and objectives of the project. They also help to justify the need for this product in the market.
1.3.2	Define Deliverables	Help us understand the outcome of the project, project expectation and set an outline for the result.
1.3.3	Identify Stakeholders	Identify the stakeholders of the project.
1.3.4	Assign Roles and Responsibilities	Define the roles and responsibilities of all stakeholders involved in the project.
1.4	Conduct Market Research	Understand the product demand by conducting surveys, interviews and other such research techniques from the end-users of the product or from people who are experts in the domain of the project. In this case, we circulated a questionnaire to one of the experts in the field of agriculture.
1.5	Gather Requirement (Functional and Technical)	Define how the solution can solve the problem statement, i.e. what functionality is needed. Then gather technical capabilities that able to deliver the solutions. Consider the implementation environment and target market; for example, connection requirement, electricity supply, water resistance.
1.6	Initiate Project	Initiate the project by conducting meetings and accumulating the gathered information.
2	**Project Definition and Planning**	
2.1	Develop Scope Statement	It will define the scope of the project, and it will involve the hardware and software development, and initial deployment to finalise the product
2.2	Develop WBS and Scheduling	Develop the WBS that contains the project attributes their dependencies on each other and their scheduling. The WBS helps to keep a track on the project helps set deliverables and

		milestones and helps us understand the structure of the entire procedure that the project undertakes. The tasks assigned in the WBS are in alignment with the WBS no. 1.3.3-Assigning roles and responsibilities. We organise the WBS based on the Gantt chart; which displays the start date, end date, the person responsible for completing the task and the overall the type of task. The visual tool will help us understand the scheduling of the project better and even help us understand the time and resource allocation.
2.3	Develop Product Design Plan	Develop the product design that covers all the aspects of the product, meaning hardware, software and also the user experience that the product is expected to provide.
2.4	Develop Cost Modelling and Budget	Cost Modelling will help us estimate the cost based on resource allocation in the WBS phase of the project plan. It will help us set a total budget for the project and even help us manage our finances throughout the project.
2.5	Develop a Communication Plan	Create a communication plan that can ensure communication with internal team and external stakeholders. It should also explain the purpose and approach undertaken for communication. It also lists down the roles of that the project resources undertake and the means/tools that they use to communicate. This plan ensures that there are no communication gaps between the project team and every member of the team knows whom they should communicate with, using which tool.
2.6	Develop a Quality Management Plan	The Quality Management Plan is to ensure the quality of project deliverables and project process is up to standard. Quality Assurance and Quality Control are the factors that ensure that these quality standards are met.
2.7	Develop a Risk Management Plan	Develop a plan to manage the identified risk; either by risk acceptance, avoidance, transference, mitigation, or exploitation. Provide a risk matrix and risk register to develop a risk management plan. The risk register will provide a better insight into the likelihood and impact of the risks covering the financial, time and reputational aspects on the impact, ensuring an early understanding and assessment of the risks involved.
3	**Project Development and Execution**	
3.1	Procure Resource	Procure the resources based on the plan. They include procurement of both materials required and even the experts/human resources required to work on the project.
3.2	Develop Product Prototype	Develop a basic prototype of the product in order to understand the shortcoming of the current design plan and makes changes in the design based on the prototype to obtain the final product.
3.2.1	Develop Hardware	Develop the hardware based on the product design using sensors and other hardware components.
3.2.2	Develop Software	Develop a software program that collects data from these sensors process them and produces the desired outputs requested by the end-user.
3.2.3	Integrate Product and AI Modelling	Integrate the hardware and software system. Make sure the AI model is functioning in sync with this integration.

3.3	Perform Product Testing	Test the product after a sufficient amount of training data is provided to the product.
3.4	Conduct Product Training	Train the product in order to feed data to the AI model to ensure better result and enhanced decision making.
3.5	Conduct Field Testing	Conduct a field testing before releasing the final product to customers.
3.5.1	Implement Product to Limited Customers	Implement initial product to limited customers as a pilot project. The primary purpose is to gather their initial feedback and fine-tune our product to meet their feedback.
3.5.2	Gather Initial Feedback	Work with our Agronomist as Subject Matter Expert (SME) to gather our early customers of their experience using our product. Identify any difficulties they may encounter and propose changes. Make sure there are no hardware and software defects during implementation.
3.5.3	Fine Tune Product	Fine-tune our product based on early customer feedback. The fine-tune might involve another cycle of software development and hardware engineering. The changes should not be significant, and the primary purpose is to ensure a working product which is acceptable to customers.
3.6	Circulate Project Update	Update the charts based on the project updates.
4	**Project Monitoring**	
4.1	Update and Track Project Status	Track the status of the work done based on the WBS.
4.2	Track Project Effort and Cost	Check and keep a track on the cost and effort incurred by each resource and see if that is going on following the cost management plan.
4.3	Deliver Quality Deliverables	Ensure that the quality of the deliverables is maintained based on the quality management plan.
5	**Project Performance and Closing**	
5.1	Release the Product	Release the product in the market to ensure the target audience is aware of the features of the product before its launch and thereby try to create product demand.
5.2	Launch the Product	Launch the product to its end-user and the market.
5.3	Gather Market Feedback	Gather feedback from the market regarding the product to make further changes to the existing model.
5.4	Calculate Project Performance	Evaluate project performance based on the project plan that was devised and the actual work done based on the devised plan.
5.5	Deliver Final Report	Create the final project report that covers all the aspects of the project. It should explain the project with precision and detail.

5 | Project Schedule

The project schedule helps us understand the timeline for the entire project and each component of the WBS. Here we have used pert analysis to come up with a schedule for the project and determine a time frame for the same. PERT uses probabilistic time estimates OR duration estimates based on using optimistic, most likely, and pessimistic estimates of activity durations, or a three-point estimate.

$$PERT\ weighted\ average\ =\ (optimistic\ time\ +(4*most\ likely\ time)\ +\ pessimistic\ time)/6$$

Short form of the formula: $Expected\ E\ =\ (O+4M+P)/6$

The tasks are classified the tasks into three types as shown, and the estimated amount of days to be added to get the pessimist time based on the classification:

- LOW <=10
- MODERATE <=15
- HIGH <=30

We have also shown the number of resources required for each task and the predecessor task/tasks that need to be accomplished before a given task begins.

Table 2 Project PERT Calculation

Task	Title	Resources	Predecessor	Optimistic	Most Likely	Pessimistic	Type	PERT Average
1	Project Conception and Initiation							
1.1	Assign a Project Manager			1	3	11	L	4
1.2	Develop a Project Team		1.1	3	5	13	L	6
1.3	**Develop a Project Charter**							**25**
1.3.1	Define Goals and Objectives		1.2	5	7	20	M	9
1.3.2	Define Deliverables		1.3.1	3	5	13	L	8
1.3.3	Identify Stakeholders		1.3.1	1	3	11	L	4

1.3.4	Assign Roles and Responsibilities		1.3.1	1	3	11	L	4
1.4	Conduct Market Research	Agronomist (1) Business Analyst (1)	1.3.1, 1.3.2	6	10	21	M	11
1.5	Gather Requirement	Business Analyst (1) System Analyst (1)	1.3.1, 1.3.2, 1.4	5	10	20	M	11
1.6	Initiate Project		1.5	1	3	11	L	4
2	**Project Definition and Planning**							
2.1	Develop Scope Statement		1.6	3	6	13	L	7
2.2	Develop WBS and Scheduling		2.1	7	12	22	M	13
2.3	Develop Product Design Plan	Agronomist (1) Hardware Engineer (2) Software Developers (2)	2.2	20	30	45	H	31
2.4	Develop Cost Modelling and Budget		2.2	5	10	20	M	11
2.5	Develop Communication Plan		2.2	3	6	13	L	7
2.6	Develop Quality Management Plan	Business Analyst (1) System Analyst (1)	2.2	5	10	20	M	11
2.7	Develop Risk Management Plan		2.3, 2.4, 2.5, 2.6	5	10	20	M	11
3	**Project Development and Execution**							
3.1	Procure Resource		2.3, 2,6, 2.7	15	20	45	H	23
3.2	**Develop Product Prototype**							**136**
3.2.1	Develop Hardware	System Analyst (1) Hardware Engineer (3)	3.1	40	50	70	H	52
3.2.2	Develop Software	System Analyst (1) Software Developer (3)	3.1	40	50	70	H	52
3.2.3	Integrate Product and AI Modelling	Business Analyst (1) System Analyst (1) Software Developer (3)	3.2.1, 3.2.2	20	30	50	H	32
3.3	Perform Product Testing	Quality Control (2) Hardware Engineer (2)	3.2	20	30	50	H	32

		Software Developer (2)						
3.4	Conduct Product Training		3.3	15	20	45	H	23
3.5	**Conduct Field Testing**							**100**
3.5.1	Implement Product to Limited Customers	Hardware Engineer (2) Software Developer (2)	3.4	20	30	50	H	32
3.5.2	Gather Initial Feedback	Agronomist (1) Business Analyst (1)	3.5.1	10	15	25	M	16
3.5.3	Fine Tune Product	System Analyst (1) Hardware Engineer (3) Software Developer (3)	3.5.2	40	50	70	H	52
3.6	Circulate Project Update		3.5.3	3	5	13	L	6
4	**Project Monitoring***							
4.1	Update and Track Project Status	System Analyst (1) Business Analyst (1) Quality Control(1)		2	4	12	L	5
4.2	Track Project Effort and Cost			2	4	12	L	5
4.3	Deliver Quality Deliverables			2	4	12	L	5
5	**Project Performance and Closing**							
5.1	Release the Product		3.5,4.3	3	5	13	L	6
5.2	Launch the Product		5.1	5	7	15	L	8
5.3	Gather Market Feedback	Agronomist (1) Business Analyst (1)	3.3,3.5.1,3.5.2, 5.1	10	12	25	L	14
5.4	Calculate Project Performance		5.3	3	5	13	L	6
5.5	Deliver Final Report		5.4	5	7	15	L	8

*Project monitoring is conducted simultaneously with the WBS Unit 2 and 3 therefore here we have shown the estimated duration of 5 days/month. However, this does not add extra days to the entire project schedule.

Gantt Chart

The WBS based Gantt Chart is a timeline that is used as a project management tool to illustrate how the project will run. Here we can view individual tasks, their durations and the sequencing of these tasks. View the overall timeline of the project and the expected completion date. We have added the duration (in days) and a start date to each task. We have also linked the tasks together, so they are in a logical order.

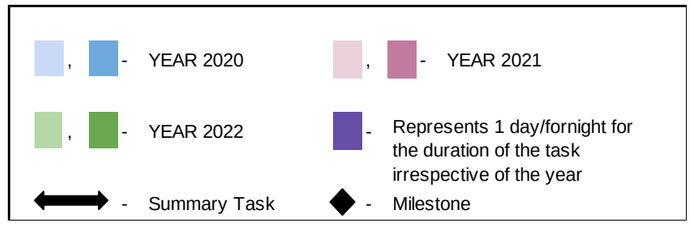

Figure 4 Gantt Chart

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
1	**Project Conception and Initiation**				
1.1	Assign a Project Manager	-	20/03/20	26/03/20	4
1.2	Develop a Project Team	Niti	26/03/20	03/04/20	6
1.3	**Develop a Project Charter**		**03/04/20**	**08/05/20**	**25**
1.3.1	Define Goals and Objectives	Andre	03/04/20	16/04/20	9
1.3.2	Define Deliverables	Andre	16/04/20	28/04/20	8
1.3.3	Assign Roles and Responsibilities	Niti	28/04/20	04/05/20	4
1.3.4	Identify Stakeholders	Andre	04/05/20	08/05/20	4
1.4	Conduct Market Research	Arief	08/05/20	25/05/20	11
1.5	Gather Requirement	Lakshmi	25/05/20	09/06/20	11
1.6	Initiate Project	Dan	09/06/20	15/06/20	4
2	**Project Definition and Planning**				91
2.1	Develop Scope Statement	Arief	15/06/20	24/06/20	7
2.2	Develop WBS and Scheduling	Niti	24/06/20	13/07/20	13
2.3	Develop Product Design Plan	Team	13/07/20	25/08/20	31
2.4	Develop Cost Modelling and Budget	Lakshmi	25/08/20	09/09/20	11
2.5	Develop Communication Plan	Dan	09/09/20	18/09/20	7
2.6	Develop Quality Management Plan	Andre	18/09/20	05/10/20	11
2.7	Develop Risk Management Plan	Arief	05/10/20	20/10/20	11
3	**Project Development and Execution**				320
3.1	Procure Resource	Lakshmi	20/10/20	20/11/20	23
3.2	**Develop Product Prototype**		**20/11/20**	**31/05/21**	**136**
3.2.1	Develop Hardware	Dan	20/11/20	02/02/21	52
3.2.2	Develop Software	Arief	02/02/21	15/04/21	52
3.2.3	Integrate Product and AI Modelling	Andre	15/04/21	31/05/21	32
3.3	Perform Product Testing	Dan	31/05/21	14/07/21	32
3.4	Conduct Product Training	Lakshmi	14/07/21	16/08/21	23
3.5	**Conduct Field Testing**		**16/08/21**	**03/01/22**	**100**
3.5.1	Implement Product to Limited Customers	Dan	16/08/21	29/09/21	32
3.5.2	Gather Initial Feedback	Arief	29/09/21	21/10/21	16
3.5.3	Fine Tune Product	Andre	21/10/21	03/01/22	52
3.6	Circulate Project Update	Niti	03/01/22	11/01/22	6
4	**Project Monitoring**				9
4.1	Update and Track Project Status	Niti	15/06/20	11/01/22	82
4.2	Track Project Effort and Cost	Lakshmi	15/06/20	11/01/22	82
4.3	Deliver Quality Deliverables	Niti	20/10/20	11/01/22	64
5	**Project Performance and Closing**				
5.1	Release The Product	Andre	11/01/22	19/01/22	6
5.2	Launch The Product	Dan	19/01/22	31/01/22	8
5.3	Gather Market Feedback	Andre	31/01/22	18/02/22	14
5.4	Calculate Project Perfomance	Lakshmi	18/02/22	28/02/22	6
5.5	Deliver Final Report	Niti	28/02/22	10/03/22	8

6 | Cost Modelling

The project cost modelling is calculated based on labour cost for the team member, raw material for hardware, and cloud computing cost. Operational costs are assumed to be part of AquaSpy, such as office space, utilities, personal desktop/laptop.

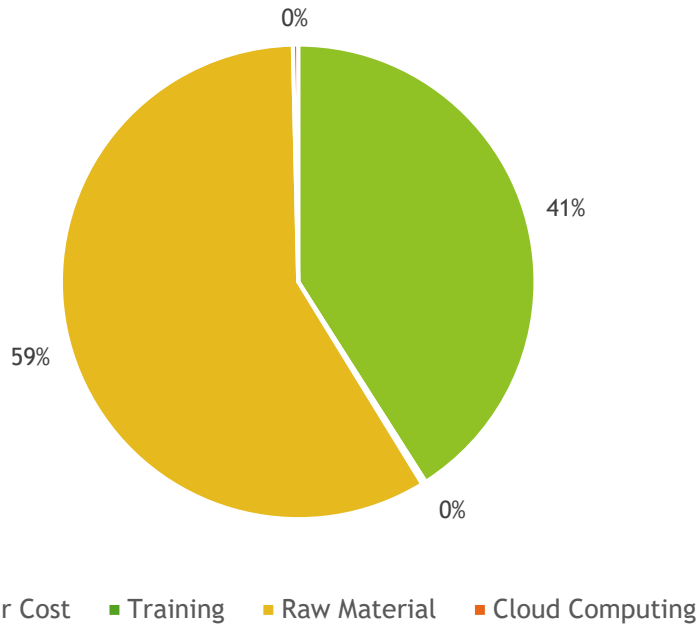

Figure 5 Project Cost Composition

The following cost structure combines all the cost aspects and is broken down into each project phase. The total cost is estimated **$2,628,274.56**, already consists of the contingency reserve of 5% and the management reserve of 10%. The cost assumptions are:

- Duration includes buffer; i.e., it accounts for holidays, resource unavailability, and any delays.
- Salaries are rounded-off estimates sourced from PayScale and Indeed.
- Salary increment of 3% at the beginning of every financial year.
- Facilities, laptops (or PCs), Internet, electricity, and Insurance are part of AquaSpy operational expenses.
- Cloud computing cost has 4% annual increment.
- Project monitoring (tasks 4.1, 4.2, and 4.3) require one day per workweek.
- The production cost estimation(Table 6:Hardware Production cost) for 40,000 units is assumed to be an expenditure on the end of Aquaspy and is excluded in the total cost estimation.

Table 3 Cost Structure Model

WBS Components	Subtotals	WBS Level 2 Totals	Percentage of Totals
1. Project conception and initiation		**$216,500.00**	**3.43%**
1.1. Select the project manager	$4,000.00		
1.2. Select the project team	$3,000.00		
1.3. Develop the project charter	$102,100.00		
1.4. Conduct market research	$46,420.00		
1.5. Gather requirements	$54,340.00		
1.6. Initiate the project	$6,640.00		
2. Project definition and planning		**$413,593.40**	**6.56%**
2.1. Develop scope statement	$33,355.60		
2.2. Develop WBS and project schedule	$48,897.10		
2.3. Develop product design plan	$144,169.10		
2.4. Develop cost modelling and budget	$51,736.90		
2.5. Develop a communication plan	$33,212.35		
2.6. Develop a quality management plan	$50,485.45		
2.7. Develop a risk management plan	$51,736.90		
3. Project development and execution		**$1,445,425.44**	**22.91%**
3.1. Procure resource	$69,164.78		
3.2. Develop product prototype	$605,078.65		
3.3. Perform product testing	$142,418.41		
3.4. Conduct product training	$113,261.68		
3.5. Conduct field testing	$487,695.73		
3.6. Circulate project update	$27,806.19		
4. Project monitoring		**$136,989.82**	**2.17%**
4.1. Update and track project status	$62,669.92		
4.2. Track project effort and cost	$40,927.30		
4.3. Deliver quality deliverables	$33,392.60		
5. Project performance and closing		**$72,947.48**	**2.78%**
5.1. Release the product	$10,566.56		
5.2. Launch the product	$14,088.75		
5.3. Gather market feedback	$17,526.07		
5.4. Calculate project performance	$10,566.56		
5.5. Deliver final report	$20,199.54		
Reserves		**$342,818.42**	**13.04%**
Contingency Reserve (5% of total)	$114,272.81		
Management Reserve (10% of total)	$228,545.61		
	Total Cost	**$2,628,274.56**	

Labour Cost

Table 4 Resource Utilisation based on WBS

WBS Item		Start Date	End Date	Duration	Project Sponsor	Project Manager	Deputy Manager	System Analyst	Business Analyst	Software Developer	Hardware Engineers	Quality Control	Agronomist	Total
Financial Year 2019-2020		20/3/20	30/6/20	73.00	4.00	69.00	63.00	63.00	63.00	49.00	49.00	38.00	44.00	**$258,980.00**
1	**Project Conception and Initiation**	20/3/20	15/6/20	61.00	4.00	57.00	51.00	51.00	51.00	42.00	42.00	26.00	37.00	**$212,500.00**
1.1	Assign a Project Manager	20/3/20	26/3/20	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**$4,000.00**
1.2	Develop a Project Team	26/3/20	3/4/20	6.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**$3,000.00**
1.3	Develop a Project Charter	3/4/20	8/5/20	25.00	0.00	25.00	25.00	25.00	25.00	20.00	20.00	15.00	15.00	**$102,100.00**
1.4	Conduct Market Research	8/5/20	25/5/20	11.00	0.00	11.00	11.00	11.00	11.00	11.00	11.00	0.00	11.00	**$46,420.00**
1.5	Gather Requirement	25/5/20	9/6/20	11.00	0.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	**$54,340.00**
1.6	Initiate Project	9/6/20	15/6/20	4.00	0.00	4.00	4.00	4.00	4.00	0.00	0.00	0.00	0.00	**$6,640.00**
2	**Project Definition and Planning**	15/6/20	20/10/20	12.00	0.00	10.00	9.75	11.75	11.75	7.00	7.00	11.75	7.00	**$44,050.00**
2.1	Develop Scope Statement	15/6/20	24/6/20	7.00	0.00	6.00	5.87	6.87	6.87	7.00	7.00	6.87	7.00	**$33,355.60**
2.2	Develop WBS and Scheduling	24/6/20	13/7/20	5.00	0.00	4.00	3.88	4.88	4.88	0.00	0.00	4.88	0.00	**$10,694.40**
4	Project Monitoring	15/6/20	11/1/22	4.00	0.00	2.00	2.25	0.25	0.25	0.00	0.00	0.25	0.00	**$2,430.00**
4.1	Update and Track Project Status	15/6/20	11/1/22	2.00	0.00	2.00	0.25	0.25	0.25	0.00	0.00	0.25	0.00	**$1,470.00**
4.2	Track Project Effort and Cost	15/6/20	11/1/22	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	**$960.00**
Financial Year 2020-2021		1/7/20	30/6/21	261.00	0.00	261.00	261.00	261.00	261.00	238.00	238.00	261.00	36.00	**$1,209,117.00**
2	**Project Definition and Planning**	15/6/20	20/10/20	79.00	0.00	63.00	61.00	77.00	77.00	79.00	79.00	77.00	36.00	**$369,543.40**
2.2	Develop WBS and Scheduling	24/6/20	13/7/20	8.00	0.00	6.00	5.75	7.75	7.75	8.00	8.00	7.75	8.00	**$38,202.70**
2.3	Develop Product Design Plan	13/7/20	25/8/20	31.00	0.00	25.00	24.25	30.25	30.25	31.00	31.00	30.25	10.00	**$144,169.10**
2.4	Develop Cost Modelling and Budget	25/8/20	9/9/20	11.00	0.00	9.00	8.75	10.75	10.75	11.00	11.00	10.75	5.00	**$51,736.90**
2.5	Develop Communication Plan	9/9/20	18/9/20	7.00	0.00	6.00	5.88	6.88	6.88	7.00	7.00	6.88	3.00	**$33,212.35**
2.6	Develop Quality Management Plan	18/9/20	5/10/20	11.00	0.00	8.00	7.63	10.63	10.63	11.00	11.00	10.63	5.00	**$50,485.45**
2.7	Develop Risk Management Plan	5/10/20	20/10/20	11.00	0.00	9.00	8.75	10.75	10.75	11.00	11.00	10.75	5.00	**$51,736.90**
3	**Project Development and Execution**	20/10/20	11/1/21	182.00	0.00	110.00	141.50	177.50	177.50	159.00	159.00	177.50	0.00	**$755,958.20**
3.1	Procure Resource	20/10/20	20/11/20	23.00	0.00	15.00	18.50	22.50	22.50	0.00	0.00	22.50	0.00	**$49,316.40**
3.2	Develop Product Prototype	20/11/20	31/5/21	136.00	0.00	82.00	105.63	132.63	132.63	136.00	136.00	132.63	0.00	**$605,078.65**
3.3	Perform Product Testing	31/5/21	14/7/21	23.00	0.00	13.00	17.38	22.38	22.38	23.00	23.00	22.38	0.00	**$101,563.15**
4	**Project Monitoring**	15/6/20	11/1/22	140.00	0.00	88.00	58.50	6.50	6.50	0.00	0.00	6.50	0.00	**$83,615.40**
4.1	Update and Track Project Status	15/6/20	11/1/22	52.00	0.00	52.00	6.50	6.50	6.50	0.00	0.00	6.50	0.00	**$39,366.60**
4.2	Track Project Effort and Cost	15/6/20	11/1/22	52.00	0.00	0.00	52.00	0.00	0.00	0.00	0.00	0.00	0.00	**$25,708.80**
4.3	Deliver Quality Deliverables	20/10/20	11/1/22	36.00	0.00	36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**$18,540.00**
Financial Year 2021-2022		1/7/21	10/3/22	180.00	0.00	180.00	180.00	166.00	166.00	138.00	138.00	146.00	139.00	**$793,510.76**
3	**Project Development and Execution**	20/10/20	11/1/21	138.00	0.00	82.00	106.50	134.50	134.50	138.00	138.00	134.50	129.00	**$669,618.86**
3.3	Perform Product Testing	31/5/21	14/7/21	9.00	0.00	5.00	6.75	8.75	8.75	9.00	9.00	8.75	0.00	**$40,855.26**
3.4	Conduct Product Training	14/7/21	16/8/21	23.00	0.00	15.00	18.50	22.50	22.50	23.00	23.00	22.50	23.00	**$113,261.68**
3.5	Conduct Field Testing	16/8/21	3/1/22	100.00	0.00	60.00	77.50	97.50	97.50	100.00	100.00	97.50	100.00	**$487,695.73**
3.6	Circulate Project Update	3/1/22	11/1/22	6.00	0.00	2.00	3.75	5.75	5.75	6.00	6.00	5.75	6.00	**$27,806.19**
4	**Project Monitoring**	15/6/20	11/1/22	84.00	0.00	56.00	31.50	3.50	3.50	0.00	0.00	3.50	0.00	**$50,944.42**
4.1	Update and Track Project Status	15/6/20	11/1/22	28.00	0.00	28.00	3.50	3.50	3.50	0.00	0.00	3.50	0.00	**$21,833.32**
4.2	Track Project Effort and Cost	15/6/20	11/1/22	28.00	0.00	0.00	28.00	0.00	0.00	0.00	0.00	0.00	0.00	**$14,258.50**
4.3	Deliver Quality Deliverables	20/10/20	11/1/22	28.00	0.00	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**$14,852.60**

5	**Project Performance and Closing**	11/1/22	8/2/22	42.00	0.00	42.00	42.00	28.00	28.00	0.00	0.00	8.00	10.00	**$72,947.48**
5.1	Release the Product	11/1/22	19/1/22	6.00	0.00	6.00	6.00	6.00	6.00	0.00	0.00	0.00	0.00	**$10,566.56**
5.2	Launch the Product	19/1/22	31/1/22	8.00	0.00	8.00	8.00	8.00	8.00	0.00	0.00	0.00	0.00	**$14,088.75**
5.3	Gather Market Feedback	31/1/22	18/2/22	14.00	0.00	14.00	14.00	0.00	0.00	0.00	0.00	0.00	10.00	**$17,526.07**
5.4	Calculate Project Performance	18/2/22	28/2/22	6.00	0.00	6.00	6.00	6.00	6.00	0.00	0.00	0.00	0.00	**$10,566.56**
5.5	Deliver Final Report	28/2/22	10/3/22	8.00	0.00	8.00	8.00	8.00	8.00	0.00	0.00	8.00	0.00	**$20,199.54**
	Total	**20/3/20**	**10/3/22**	**514**	**$4,000**	**$264,396**	**$250,940**	**$142,223**	**$203,175**	**$475,787**	**$528,653**	**$332,439**	**$63,992**	**$2,261,607.76**

Raw Material

Table 5 Raw Material Price

Material Name	Price / Piece
Humidity and temperature sensor	$45.00
Soil moisture sensor	$15.00
UV sensor	$20.00
Total per unit	**$80.00**

Table 6 Hardware Production Cost

Production	Quantity	Total
Product Development	100	8,000.00
Field Testing	200	$16,000.00
Production	40,000	$3,200,000.00
Total		**$3,224,000.00**

Cloud Computing

Table 7 Cloud Computing Cost

Environment	Machine	Specification	Price / Month
Production	Mobile Application Front-End	Virtual machine regular, 2 vCPU, RAM 8GB 2 instances, load balance 1-year commitment 1 ephemeral public IP address	$214.13
	Back-End Engine	Virtual machine regular, 2 vCPU, RAM 8GB 2 instances, load balance 1-year commitment	$204.50
	Database	High availability 2 instances, load balance SSD Storage 100GB, Backup 50GB	$608.70
	Machine Learning / AI	Job run time 1200 minutes Batch processing	$105.49
Staging	General Purpose	Virtual machine regular, 1 vCPU, RAM 4GB 1 instance Non-preemptible	$56.79
Development	General Purpose	Virtual machine regular, 1 vCPU, RAM 4GB 1 instance Non-preemptible	$56.79
		Total (round off)	**$1,250.00**

7 | Communication Plan

The communication plan helps facilitate effectively, efficient communication among different parties that are involved in this project (CEO of AquaSpy as project sponsor, the project team, farmers as customers and Agronomists as subject matter experts). It sets a communication policy that the project team should follow and improves the project's visibility and transparency for all stakeholders.

Our approach is to define the communication role of each party and use a table that records essential elements. The table consists of communication tool (documents, presentations), the communication method/channel used (email, meetings, shared docs), frequency, the general goal of each tool, the host/owner of this tool, the person to be contacted when problems arise and the audience.

Communication Roles

- **Project Sponsor:** CEO of AquaSpy, who will provide sponsorship and fundings to the whole project. He will also be the one who frequently demands to know the project's progress and transparency.
- **Project Team** which consists of:
    - **Project Manager** is responsible for most communication tools/methods and acts as a bridge between the Project Team and the Project Sponsor, Customers and Subject Matter Experts.
    - **Development Team** is in charge of developing the project (sensor kit and mobile application). Each member of the Project Team should strictly follow the policies in the communication plan.
    - **Contractors** include subject-matter experts (Agronomist, who will analyse plants/soil condition and recommend the best practices based on it during the project's testing phase) and contract team members (Quality Manager, Tester) brought on board to meet the project's requirements.
- **Customers:** farmers provide information and insights into the project requirements.

Tools and Methods

Table 8 Communication Plan's Tools and Methods

Tool	Method/ Channel	Frequency	Goal	Host/ Owner	Contact Person	Audience
Requirement specifications	Questionnaires via Email	At the beginning of the project	Gather inputs from customers (farmers) to help specify requirements.	Project Manager	Project Manager	Customers
Meeting minutes	Google Drive	At every major meeting	Records everything (decision made, future strategies) that's happened in the meeting. Used to inform absent team members or to revisit individual decisions and plans.	Project Manager	Project Manager	Project Team
Team report	Meetings - Quick Presentations	Weekly	Each member reports the status of their assigned tasks (what has been achieved, what to do next).	Project Manager	Project Manager	Project Team
Project status update	Meetings - Formal Presentations	Fortnightly	Reports the current status of the project. Very low and low risks will be assessed here. This document is also used to discuss and discover potential issues within the Project Team. **Project Sponsor is not involved**.	Project Manager	Project Manager	Project Team
Project status report	Meetings - Formal Presentations	Monthly	Reports the current status of the project to Project Sponsor, including completed tasks and issues/risks. Moderate and high risks will be assessed here.	Project Manager	Project Manager	Project Sponsor
Testing report	Google Drive	At the end of each test phase	Reports the status of the current testing process, handles defects and applies fixes in conformance with the Quality Control plan.	Quality Manager	Quality Manager	Project Team

Project review	Meetings - Formal Presentations	At every milestone	Presents the current set of deliverables, gains feedback from Project Sponsor and plans for next steps/deliverables.	Project Manager	Project Manager	Project Sponsor
Analysis report	Email	At the development phase that involves the recommendation system	Retrieve correlation data between plants and soils from Agronomists for training/testing sets of the recommendation system.	Project Manager	Project Manager	Subject Matter Experts
Project final presentation	Meetings - Formal Presentations	At the end of the project	Presents the final version of the project and declares the project as finished. Discusses what has been achieved and what not compared with the success criteria. Discusses actions to be taken.	Project Manager	Project Manager	Project Sponsor

8 | Quality Management Plan

The purpose of Project Quality Management Plan is to ensure that the quality of project deliverables and project process meet the expectation of stakeholder. The Project Quality Management Plan focuses on Quality Assurance and Quality Control undertaken in the project. Quality Management Plan records the information required to assess the quality of the project and aims to ensure team members follow the quality standards in performing the project and ensure the quality of project meets the expectation of stakeholders. Quality Management Plan focuses on:

- Quality Planning: Determine the critical standard to the project and approach to
- Quality Assurance: Ensure the quality of the project process.
- Quality Control: Ensure the quality of the final product.

Various monitoring activities are performed to ensure the standards of the project, such as audit and team review. The stakeholders will also participate to ensure the project quality through meetings. Furthermore, the Quality Management Plan includes details of different standards and approaches used to monitor the quality of the project and to measure project quality success

Quality Planning

Quality planning identifies, defines and manages the quality of the project. It manages the quality of the final product and also the process of the project. Quality Control approach such as Testing is used to ensure the quality of the final product, and Quality Assurance approach such as audit is used to ensure the quality of the project process.

The quality standard used to determine the quality project success are defined below:

- ISO 9001:2015 : An International standard to certify products or services that conform to user and regulatory requirements.
- ISO/IEC 25010:2011 : An International standard to certify system and software engineering products.
- ISO 21500:2012 : An international standard to certify Project Management of a project.
- AS/NZS3820 : An Australia and New Zealand standard for electronic device.

Table 9 Quality Metrics to Measure Project Quality

Measure	Unit	Frequency	Target	Methods	Source of Data	Tools
Customer Satisfaction Index	%	Pre-Project and Post Project	90% with 10% tolerance	Compare the index pre and post-project	Customer Feedback, Survey	Use Formula:1 - (Number of complaints/Total Feedbacks) x 100.
Schedule Performance Index	%	Monthly	100% with 20% tolerance	Compare the project process with the Project Schedule Plan	Project Schedule	Use Formula: (Earned Value /Planned Value) x 100.
Cost Performance Index	%	Monthly	100% with 20% tolerance	Compare the actual project cost to budget planning	Project Budget	Use Formula: (Earned Value /Actual Cost) x 100.
Defect Removal Efficiency	%	Once per completion of every building iteration	95% with 5% tolerance	Investigate the cause of deviation by analysing the defect severity, origin and effort spent	Product Test Report Defect Log	Use the formula of: (Defect remove/Defect found) x 100.
Major Defects Per Business Process	#	Monthly	0 with 20 tolerance	Inspected by Quality Manager	Defect Log	Count the total number of defects found in Defect Log.
Requirement Volatility Index	%	Monthly	90% with 10% tolerance	Compare the number of change requests and total requirements	Change Request Log Project Scope Statement	Use Formula: (Number of Change Requests/Total Requirements) x 100

The following table shows the approach used in the project to ensure the quality of project documentation. The following table identifies the following points:

- Product Document shows the document produced as part of the project report.
- Quality Standard indicates the standard the Product Document will follow.
- Quality Activity Control shows the approach used to ensure the quality standard of the Product Document.
- Frequency indicates how often the Quality Activity Control is conducted.

Table 10 Quality Planning's Approach

Project Document	Quality Standard	Quality Activity Control	Frequency
Project Charter	Conform to guidelines provided by experts and company standards.	Core Team Review Expert Review	Once per project stage
Project Scope Statement	Conform to guidelines provided by experts and company standards.	Core Team Review Expert Review	Once per project stage
Project Time Modelling	Conform to guidelines provided by experts and standards of Gantt chart and Work Breakdown Structure (WBS) Standard.	Core Team Review Expert Review	Once per project phase
Cost Modelling	Conform to guidelines provided by experts and company standards.	Core Team Review Expert Review	Once per project phase
Communication Plan	Conform to guidelines provided by experts and company standards.	Core Team Review Expert Review	Once per project phase
Quality Management Plan	Conform to guidelines provided by experts and industry standards.	Core Team Review Expert Review	Once per project phase
Risk Management Plan	Conform to guidelines provided by experts and industry standards.	Core Team Review Expert Review	Once per project phase

Quality Tools

The following table listed the tools and its function that are used in Quality Assurance and Quality Control.

Table 11 Tools for Quality Assurance and Quality Control

Tools	Function
Benchmarking	Compare similar projects with the current project.
Cause and Effect Diagram	Trace issue of quality complaints to the roots of cause.
Cost-Benefit Analysis	Compare the cost and benefits of performing quality management.
Control Chart	Assist determining whether the project is under control.
Statistical sampling	Select a group of users to be interviewed about system usage for quality control.

Quality Assurance

The purpose of Quality Assurance is to catch defects before the final product. Quality Assurance focuses on the process of the project. The following table lists the approach taken to ensure Quality Assurance. The table identifies these following points:

- Project Process: The stage of the project
- Standard: The passing criteria for project process
- Quality Activity Control: The approach to ensure the quality of the process

- Frequency: How often the Quality Activity Control is conducted.
- Goals: The aim of the project process.

Table 12 Quality Assurance

Project Process	Standard	Quality Activity Control	Frequency	Goals
Develop a project charter	100% compliance with the framework	Audit chapter update by phase	Once per project phase	Gathers the project summary for stakeholders
Develop a project scope	100% compliance with the framework	Audit scope update by phase	Once per project phase	Gather the scope of the project.
Develop a project plan	100% compliance with the framework	Audit plan content and updates, project priorities and task estimation	Once per project phase	Illustrate the project task and timeline and divide activities to team members
Develop a cost Modelling	100% compliance with the framework	Audit cost modelling	Once per project phase	Indicate the project expenditure based on different categories.
Develop a communication Plan	100% compliance with the framework	Audit communication plan	Once per project phase	Show the communication approach used in the project.
Develop a Quality Management Plan	100% compliance with the framework	Audit quality management plan	Once per project phase	Indicate the team approach to ensure the project quality assurance and quality control.
Develop a Risk Management Plan	100% compliance with the framework	Audit quality management plan	Once per project phase	Indicate the team approach in managing risk related to the project.
Execute and control project per project plan	95% compliance with the framework	Audit the following project activities: Quality Communications Progress	 Fortnightly Fortnightly Fortnightly	Monitor and control the process of developing the final product of the project.
Project stage approval	100% compliance with the framework	Audit stage checkpoint	Once per project stage/phase	Approving the milestone for the project.
Close Project with project report and post review	100% compliance with the framework	Audit project review by phase	Once per project phase	Reflect towards shortcomings found during the project and solution to improve it in the future.

Improvement/Suggestion

There are several approaches to improve the Quality Assurance of the project. First is to conduct testing/review as early as possible to detect defects earlier. By detecting defects earlier, it can reduce the cost and time used to fix the defects found. Second, improve the project based on complaints found in the pre-project feedback to improve Quality Assurance. Last but not least, used Project Management Automated Tools to increase time efficiency.

Quality Control

Quality control focuses on the quality of the final product. In this project, the end product focus will be on the sensor kit and the recommendation system. The following table below is the quality control approaches used in the project to ensure the quality of the final product. The table identifies these following points:

- The Phase of Testing shows that the level of the test is conducted to the final product.
- Type of Testing shows the type of test conducted for the final product.
- Criteria show the passing standard the final product needs to pass in the test.

Table 13 Quality Control

Phase of Testing	Type of Testing	Criteria
Phase 1	Unit Testing (Hardware)	1. The kit sensors should be able to function in all weather conditions. 2. The kit sensors should be able to gather data 24/7.
Phase 2	Integration Testing	1. The IoT and software are working in collaboration.
Phase 3	System Testing	1. The kit sensors should be able to gather data properly 2. The data gathered by sensors should be store by the system 3. Recommendation System should recommend all suitable crops based on data gathered and farmers input. 4. Auditing the system for data integrity, confidentiality, and recoverability 5. Data analytics dashboard shows the correct information gathered from the sensors
Phase 4	User Acceptance Testing	1. User inputs are appropriate to the system requirements. 2. Determine if all the requirements of the product have been met. 3. The application is easy to understand and use by the farmers. 4. The data visualization is easy to understand.

The following table identifies all project deliverables and standards and methods used in quality control.

Table 14 Deliverable Quality Control

Deliverables	Deliverables Quality Standard	Quality Control Activities	Time Interval	Person Responsible
Final Product - Sensor Kit with Software Application	A Sensor Kit and Application that passes the testing and downloadable software application.	- Unit Testing (Hardware) - Integration Testing - System Testing - User Acceptance Testing	Testing Period	Project Manager
User Document	Documentation that explains and describes to users how to operate the final product.	Documentation Testing	Before product release	Project Manager

9 | Risk Management Plan

The risk management plan is developed based on ISO 31000:2009 framework. The project considers the risk context within AquaSpy, therefore focusing on Risk Identification, Risk Analysis, and Risk Evaluation. Instead of the usual asset-based approach, Risk Identification is conducted in process-based to cover all project phases. Identified risks are analysed to determine the suitable controls, then evaluated to determine control's effectiveness. An independent third party should monitor the whole process, but internally Project Manager and Deputy Manager performs the monitoring and review.

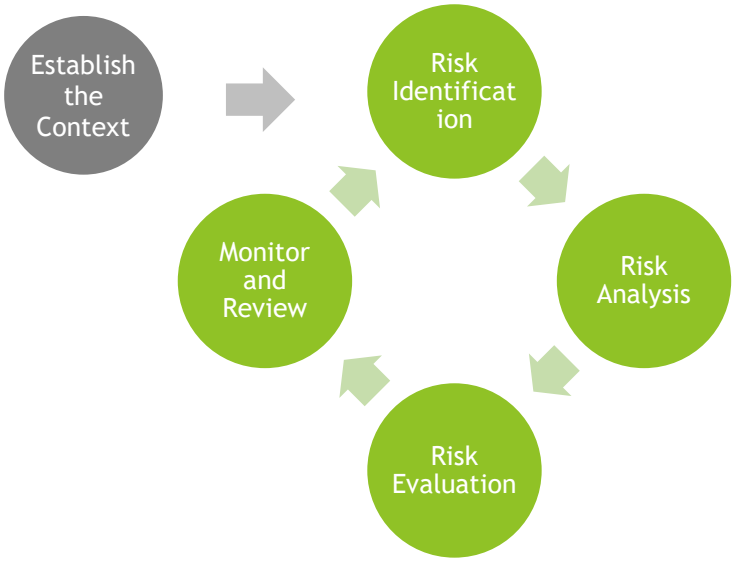

Figure 6 Risk Management Process

Risk Analysis

Table 15 Risk Matrix

Risk Rating		Impact				
		Negligible	Minor	Moderate	Significant	Severe
Likelihood	Very Unlikely	Very Low	Very Low	Low	Moderate	High
	Unlikely	Very Low	Low	Low	Moderate	High
	Possible	Very Low	Low	Moderate	High	High
	Likely	Very Low	Low	Moderate	High	Critical
	Very Likely	Low	Moderate	High	Critical	Critical

Risk likelihood is the chance a risk will occur. The likelihood does not have to be exact as long as the assumptions to justify are used consistently.

1. Very Unlikely : less than 10% of occurrence
2. Unlikely : occurrence between 10% and 40%
3. Possible : occurrence between 40% and 60% or about half the time
4. Likely : occurrence between 60% and 90%
5. Very Likely : more than 90% of occurrence

Risk impact is the quantitative estimate of possible loss in case of risk occurrence. Risk impact is analysed in the following aspect; financial, time, and reputational. In case of risk has multiple impacts, the final impact is the highest aspect.

Financial Aspect

1. Negligible : loss of less than $100
2. Minor : loss between $100 and $1,000
3. Moderate : loss between $1,000 and $5,000 or about 10% of buffer
4. Significant : loss between $5,000 and $10,000 or about 25% of buffer
5. Severe : loss of more than $10,000 or more than 50% of buffer

Time Aspect

1. Negligible : no impact on the overall project timeline
2. Minor : will be delayed for less than and up to a week
3. Moderate : will be delayed for between a week and up to a month
4. Significant : will be delayed for between a month and up to three months
5. Severe : will be delayed for more than three months

Reputational Aspect

1. Negligible : no media coverage
2. Minor : local media coverage
3. Moderate : national media coverage on short term (less than two weeks)
4. Significant : national media coverage on long term (more than two weeks)
5. Severe : international media coverage

The final result of the risk rating will determine the risk escalation and mitigation strategy.

1. Very Low : The risk will be reported in the fortnightly project status update and only require the internal project team to resolve.
2. Low : The risk will be reported in the fortnightly project status update and require the project manager's sign off to resolve.
3. Moderate : The risk will be reported to the project sponsor during the monthly project status meeting and require the project manager's sign off to resolve.
4. High : The risk will be reported to the project sponsor during the monthly project status meeting and require the project sponsor sign off to resolve.
5. Critical : The risk will be reported to the project sponsor as soon as it occurs and requires the project sponsor close monitoring to resolve.

Risk Register

Risk is identified from process-based approached, to cover all phase of project management lifecycle.

- Risk Name : A brief description of the identified risk.
- Risk Description : An elaborate explanation of the identified risk.
- Risk Owner : The first party who has the most knowledge of the risk.

Risk analysis is performed based on its likelihood and possible impact (refer to Risk Matrix), while risk rating is automatically calculated based on input.

- Likelihood : The likelihood of occurrence of the risk.
- Impact : The possible loss of the risk-based on financial, time, and reputational aspects.
- Risk Rating : Automatically calculated based on Risk Matrix.

Risk Control is the necessary control to manage the risk.

- Mitigation Plan : Key activities to manage (avoid, mitigate, transfer, or accept) the risk.
- Contingency Plan : Key activities to ensure the control is adequate to manage the risk. If not, other complementary or alternate control should be introduced.
- Control Owner : The primary responsible party to perform the necessary control.

Escalation is the first accountable party to report in the event the risk occurs.

Table 16 Risk Register

#	Risk Identification			Risk Analysis				Risk Control			Escalation
	Risk Name	Risk Description	Risk Category	Risk Owner	Likelihood	Impact	Risk Rating	Mitigation Plan	Contingency Plan	Control Owner	
1	Sensors reading does not meet the accuracy target.	As part of hardware development, the sensors do not produce readings that are acceptable for our product, or the results are not consistent enough to produce a reliable prediction.	Technology	Hardware Engineer	Possible	Significant	High	Hardware will be carefully procured from reputable vendors. Whenever possible, we should source from our existing partners, unless we need additional requirements, or it is out of price range. During the procurement process, vendors will be required to perform proof of concept to ensure the sensors can produce the required accuracy target.	Hardware Engineers will follow sound procedure along the procurement process. The sensors reading will be validated during hardware quality control after prototyping and during integration with software development.	System Analyst	Project Sponsor
2	AI recommendations are not suitable for actual implementation.	During the integration of software and hardware development, the AI modelling we designed does not produce recommendations that are suitable for actual implementation. The issue could also arise from the lack of primary data for training.	Technology	Software Developer	Possible	Severe	High	AI modelling will involve market research and collaboration with the Agronomist. Business Analyst and System Analyst has to make sure all the required data are available to make an acceptable recommendation. This requirement should be documented as functional and technical requirements. If all the data is available, the AI recommendation can be gradually improved to meet actual implementation.	Multiple iterations are required to meet an acceptable recommendation. We will work closely with our potential customers and Agronomist for their feedback.	- Business Analyst - System Analyst	Project Sponsor
3	Hardware/software development does not meet quality control after the second iterations.	Hardware and software development are going through quality control to fix major defects and vulnerabilities. However, there is a possibility the quality control does not significantly improve to meet our quality standard after second iterations.	Technology / Process	- Hardware Engineer - Software Developer	Unlikely	Moderate	Low	Hardware and software development should focus on quality within the lead timeframe.	For each quality control phase, quality control should record the overall defect score. If the quality score is trending downward, or the latest score is below the threshold, the development process will be reviewed.	Quality Control	Project Manager
4	Security breach impacted the confidentiality, integrity, or availability of data.	A security breach happens and impacted either confidentiality (access by an unauthorised entity), integrity (modification by an unauthorised entity), or availability (authorised entity could not access) of data or its combination.	Technology	Software Developer	Unlikely	Significant	Moderate	The system will be developed in three-tier architecture, with the mobile front-end is the only publicly accessible server (DMZ). While database and processing engine on a private network. Data integrity will also be protected with business rules in the database. Data at rest are encrypted with least privilege access to protect confidentiality. Network communication is also encrypted on the network and application layer. Data Loss Prevention (DLP) is implemented to prevent unauthorised data extraction. All system is hosted on public clouds which offer multi-region redundancy and availability. The system will also be protected by the Intrusion Prevention System (IPS), firewall, and load balancer to ensure availability.	Security aspect will be evaluated during system testing. If applicable, we should utilise an independent third party to try breach system security actively. System vulnerabilities should be remediated before moving to the next phase.	System Analyst	Project Manager
5	Product development team fails to handover product support to the operational team.	Product development fails to handover product support to the actual operational team. The issue will force the development team	Process	- Hardware Engineer	Possible	Moderate	Moderate	The project team should involve operational team during planning to ensure a smooth handover. For each milestone and deliverable, the operational team will	Any concern about operational readiness should be raised as soon as possible. Project Manager should actively seek feedback after	System Analyst	Project Manager

		to provide ongoing support to customers and slow down the upcoming phase of product development.		- Software Developer				be put in the loop as well. Operational team sign off is required during the User Acceptance Test (UAT).	milestone or deliverable circulated to the operational team.		
6	The project team does not produce clear and consistent documentation.	Project team fails to produce clear and consistent documentation to support transition and as part of project accountability.	Process	- Business Analyst - System Analyst - Hardware Engineer - Software Developer - Quality Control	Possible	Minor	Low	Project Manager and Co-Project Manager should provide a clear and consistent template to be updated by the whole team members. Project Manager should also require the availability of the document as part of formal deliverables.	Project Manager and Co-Project Manager should evaluate the documentation produced for each deliverable. If the result is not up to expectation, Project Manager and Co-Project Manager should provide an example and walk through the next deliverable.	- Project Manager - Deputy Manager	Project Manager
7	One or multiple project constraint(s) are breached.	Project's scope, time, or budget or combination of it being breached. Project Manager is likely to alter particular constraint to keep the overall project from failing.	Finance / Process	- Project Manager - Deputy Manager	Likely	Significant	High	Project Manager and Co-Project Manager should record resource usage and project accomplishment every two weeks to calculate the Schedule Performance Index (SPI) and Cost Performance Index (CPI). Based on the indicators, we could determine whether the project is running late (time constraint) or running inefficiently (cost constraint). While scope constraint could be detected if a particular function is challenging to implement, it could require additional funds or time or other resources.	Based on SPI, CPI, and fortnightly reports, Project Manager and Co-Project Manager should evaluate project development and intervene to minimise possible breach.	- Project Manager - Deputy Manager	Project Sponsor