PROJECT TITLE: Development of cost-effective soil moisture monitoring system for Broadacre Cropping
CLIENT: The University of Western Australia (Atif Mansoor & Gustavo Alckmin)
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AIM AND BACKGROUND

Soil moisture is crucial for agricultural productivity, especially in regions like South West Western Australia, where clay soils and compaction issues hinder water infiltration and root growth. Traditional manual testing methods for soil compaction are labor-intensive and slow, while satellite-based solutions lack real-time data and adequate resolution. This project aims to address these challenges by developing a simple physical prototype focused on communication, data storage, and visualization. The prototype will serve as a foundation for future development, allowing for expanded functionality and optimization to meet comprehensive project requirements. Due to limited time, team capabilities, and resources available, this stage of the project is to show feasibility of a soil moisture monitoring system with a focus on documentation, power management, a visualization dashboard and provide an API Payload structure that aligns with John Deere API assets.

KEY BENEFITS

Optimized machinery operations, integration with existing systems, and improved crop yield and irrigation efficiency. Real-time soil moisture data enables farmers to effectively schedule machinery use, preventing soil compaction, crop damage and bogged machinery. Our solution should integrate with current management platforms, simplifying decision-making for machinery operation, irrigation and harvesting. Continuous soil moisture monitoring supports data-driven machinery operations, irrigation, thus enhancing water use efficiency and boosting crop yields.

DELIVERABLES

This project's goal is a feasibility study to develop a solution for monitoring soil conditions in Western Australia's broadacre cropping industry with a focus on building a solution that can serve as a foundation for future phases as the scope is large and timeframe should be over multiple years. By using IoT technologies, the project enhances data-driven decision-making and optimizes farm management practices.

Key Deliverables:

1. **Project Documentation:** Develop a comprehensive report that covers our current phase and future areas to consider across the project lifecycle. Contents will include defining the problem, current phase solution development and other key areas that need to be explored eventually to deliver and deploy a robust remote real time soil moisture monitoring solution.
2. **Soil Moisture IoT Prototype :** Our prototype is there to demonstrate the capturing of soil moisture data, power management and will consist of a microcontroller with three soil moisture sensors, power management with sleep cycle/duty cycle functionality, and node-to-gateway communication using LoRa communication.
3. **Gateway Communication and Cloud Storage:** Gateway will receive the data from IoT Prototype and transmit data to a scalable cloud platform storage service using the Internet.
4. **PRIORITY 1 - Insights and Analytics Visualization Dashboard:** A simple analytics and visualization dashboard connected to cloud platform storage, enabling near real-time monitoring and visualization for users to make data-driven decisions and track key performance indicators. We have provided a live PowerBI prototype dashboard as an example (Appendix).
4. **PRIORITY 2 - John Deere API integration**: Our goal is to develop a structure of the payload for API Assets that aligns with John Deere API requirements as the MVP. If time permits, we will showcase successfully sending data from DynamoDB to John Deere Platform.

PROPOSED METHODS

As the scope of the project is large, we will be relying on the hyperlinked guides in the Solution System Components Section and diagrams in appendix of this report, with the Gantt Chart (Appendix) and client feedback to prioritize and develop particular areas of the deliverables.

Task 1: Project Documentation: The documentation will include background on the current problem including the impact on South West WA. The goal is to produce a document that shows the development of the prototype Soil Moisture Monitoring system in the current phase so that it can serve as a foundation for future teams to build upon in future phases. Initially, we'll create a report structure and share it with the client with Sections and subsections of the document contents. Once we have feedback we will add contents to the document, in parallel to the other tasks. An important section to include is the 'Future Works' section of areas identified by us and the client that need to be explored in future phases.

Task 2: Soil Moisture IoT Prototype

In this phase of the project, we will develop a simple prototype focusing on selecting a microcontroller and appropriate communication protocol for transmission of soil moisture, TimeDate, and GPS data. We'll have a power management system for optimized sleep and duty cycles; and three simple soil moisture sensors to measure and 'mock' soil moisture readings at three different depths. This will transmit moisture data using LoRa to a Gateway. We'll use an iterative development process based on client feedback. If time permits, we'll include demonstration of multiple Soil Moisture IoT Prototypes connecting to the Gateway.

Task 3: Gateway Communication and Cloud Storage

Gateway will connect to the Soil Moisture IoT prototype and transmit the data to the internet to a cloud provider platform that supports cloud storage. Gateway receives data from IoT system(s) through LoRa communication and temporarily stores: soil moisture data at three depths per Soil Moisture IoT prototype (including TimeDate, GPS location). The gateway will append the payload it receives with its own metadata (GatewayID, GPS location, transmissionTime) then send the data to the cloud provider for processing and storage which will then serve as a data warehouse for other operations such as integration with Visualization dashboard. We will develop this iteratively with the client in parallel with Task 4 as they are dependent.

PRIORITY 1 - Task 4: Insights and Analytics Visualization Dashboard

We will create a visualization dashboard to provide near real-time insights and analytics. It will show historical data of Soil Moisture levels in the current phase. This can be used to analyze other key performance indicators of farming/agriculture in future phases, e.g. crop yield, water usage in Irrigation. We will display points in space soil moisture data at different depths. After we achieve this and if time allows, we will use data interpretation methods like Angular Distance Weighting (ADW) to interpolate soil moisture levels at different depths and geographic locations. We will use an iterative development cycle based on client priorities. Goal is that users should be able to see the near real-time data and make prompt data-driven farming decisions.

PRIORITY 2 - Task 4: John Deere API Integration

We will create a payload structure based on Assets API as MVP initially based on 'IoTSystem' and 'LoRaGateway' entities in Prototype UML Class diagram (Appendix). If time permits, we will connect DynamoDB with the John Deere Platform.

APPROACH TO PROJECT SPECIFICATIONS AND SOLUTION DESIGN

The deliverables, project timeline, Solution System Components, and IoT prototype components has been designed considering and balancing the following considerations:

- **Client Budget**: At prototype stage, we use existing UWA resources. If more materials e.g. sensors are required, we will list and breakdown the costs for future phases.
- **Client Priorities:** This phase of the project should be able to be used in future phases - breaking down the system into components that can be swapped out if required and noting down 'Future Work' to be addressed in future phases.

- **Project Risks:** Scope of the project is large and time is limited, we will manage the scope through the Gantt Chart and open communication with the client on our progress.
- **Team Capabilities and Experience:** Team experienced in Front End Web Development and limited Back End experience of deploying Web Apps on local machines. One member with some cloud deployment experience. For example, sensor selection and ruggedisation is out of scope for this phase.
- **Team Areas of Interest:** Majority of members want to develop their data analytics and data visualization capabilities.

SOLUTION SYSTEM COMPONENTS

For all technical deliverables, we created a Solution System Components and Dataflow Diagram that shows the system components and specific communication methods required to deliver this phase of the project and that are used in our STRIDE analysis.

Components description and justification:
IoT Prototype: MVP to showcase feasibility of project with a focus on power management, LoRa for communication of soil moisture and GPS data over long distances up to 15 kms to a Master Node.
Master Node (Internet Gateway): Eventually data needs to be transmitted to the internet, Master Node is responsible for receiving data from IoT Prototype and transmitting to AWS IoT Core using MQTT over HTTP which is a secure protocol.
AWS IoT Core: Selected because its designed for resource constrained devices and suitable for large scale IoT Deployment and Management which should be useful for future phases. Also supports MQTT and LoRaWAN if required. An AWS IoT Core Rule will be used to send data to the AWS DynamoDB table.
AWS DynamoDB: NoSQL fully managed database, flexible, suitable for high frequency of data and scalable. Supports code first approach and adding attributes easily compared to relational databases.
Priority 1 - AWS QuickSight: As the data is stored on AWS ecosystem, the most powerful visualization tool is AWS QuickSight, it can also integrate with third-party APIs and data external to AWS platform. We will connect DynamoDB table using AWS Athena.
AWS Lambda: Event-driven serverless function as a service, alternative to an EC2 instance which requires lots of management. We'll use this to simply demonstrate sending data to John Deere API using HTTP RESTful API and OAuth 2.0. Future phases could use dedicated resources if the number of events warrant dedicated EC2 instances or resources.
Priority 2 - John Deere Platform/API: John Deere Platform will receive data from DynamoDB table and show the data on front end, this platform is a client preference and used by farmers in industry.

APPENDIX

a. Insights and Analytics Visualization Dashboard Prototype: For Client - Visualisation Prototype
b. Soil Moisture IoT Prototype Diagram: For Client - Diagram of the MVP
c. Soil Moisture IoT Class Diagram: For Client - Diagram of Data captured and transmitted
d. IoT Components Selection: For Client & Team - Selection rationale, list of components, relevant libraries and guides to develop MVP
e. Gantt Chart: For Client & Team - Timeline with tasks, deadlines and team members responsible for development and delivery
f. System Dataflow Diagram: For Unit - Dataflow diagram of entire system solution
g. Preliminary STRIDE Analysis: For Unit - Simple prioritized threat analysis of System Dataflow Diagram
h. Project Github Repository: For Both - Deliverables, Documentation, Code and Prototypes
i. Project Documentation: For Client - Google Document (Work in Progress)
j. Key Stakeholder Matrix: For Client - People involved in project and their expectations