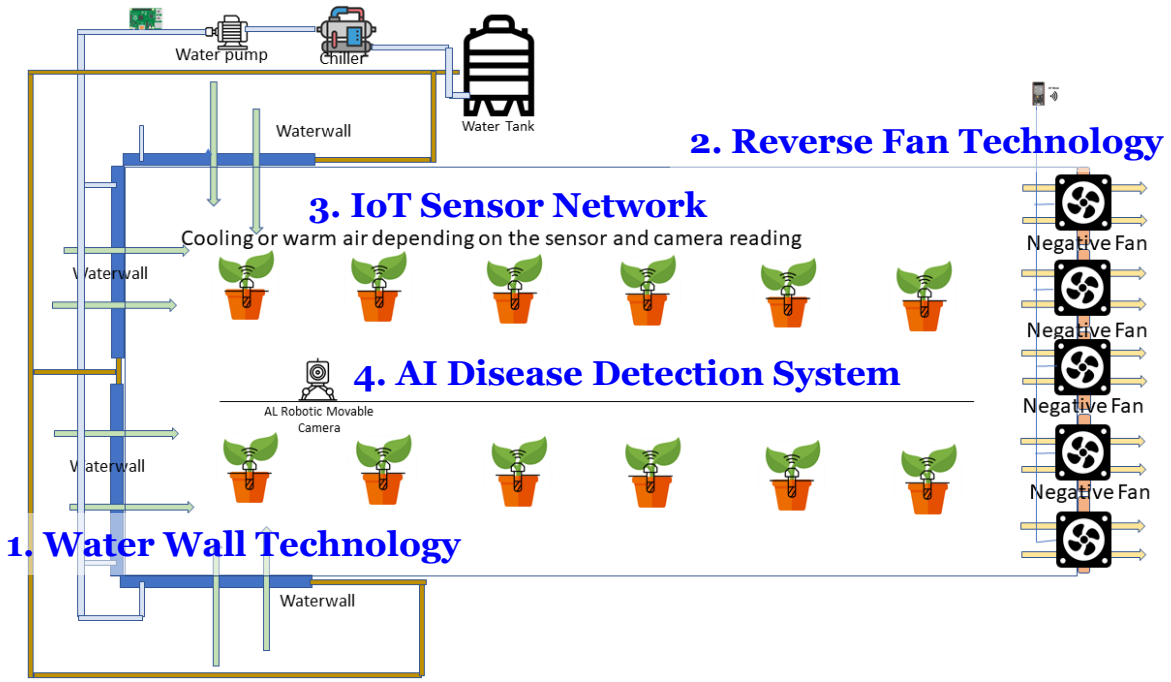
AI-Driven Smart Horticulture for Climate Sensitive Plant using Soil Analysis and Image Processing: A Tropical Perspective

Background:

In the dynamic and promising horticultural landscape of South East Asia, the potential for high-yield crops such as chilli, vanilla, and lettuces are considerable, particularly in regions with elevations exceeding 700 meters. The warm climate prevalent in the area minimizes energy costs, rendering heating systems unnecessary. To capitalize on these conditions, a tropical greenhouse is usually used to cultivate crops that demand varied growing conditions. The cultivation of these high yield crops on a small scale can contribute to the economic development of ASEAN countries, such as Malaysia, Brunei, Cambodia, and Laos. However, the varying climates across different locations within South East Asia present a significant challenge.

Targets:



The proposed project aims to study and develop an advanced energy-efficient smart greenhouse tailored for the diverse climate conditions of the ASEAN region for any variety of plan. With temperatures ranging from 21 to 40 degrees Celsius, this innovative greenhouse will incorporate cutting-edge internet-of-things (IoT) technologies and artificial intelligence (AI) to regulate temperature, humidity, and soil conditions, thus optimizing the cultivation of specific crops such as Vanilla (Malaysia), Chili (Brunei), and Lettuce (Cambodia). **Four key research activities** (as shown in figure) will be implemented by team members from 4 different ASEAN member countries.

Conceptual design of the smart environmental control greenhouse

AI-Driven Smart Horticulture for Climate Sensitive Plant using Soil Analysis and Image Processing: A Tropical Perspective

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Project Duration:

From : 01 June 2024
To : 31 May 2026
Duration : 2 Years

Project Budget:

Year 1 : USD 40,000.00
Year 2 : USD 40,000.00
Total : USD 80,000.00

Project Activities: Aims and Objectives

- To study and develop a **self-sustaining smart greenhouse** with **adaptive environmental control**, by incorporating internet-of-things (IoT) technologies and artificial intelligence (AI) ➔ regulate the temperature, humidity, and soil conditions based on diverse climate conditions of the ASEAN region.
- To **optimize the cultivation of specific crops**: **Vanilla** (Malaysia), **Chili** (Brunei), and **Lettuce** (Cambodia).
- To implement the proposed smart farming system at the targeted agriculture farms in Malaysia, Brunei, Cambodia, and Laos:
  - ☑ To optimize/maximize agriculture production of the targeted community throughout the year by adopting smart agriculture technology;
  - ☑ Appropriate platform to train the local farmers and nurture their capacities in operating and improving the smart farming system; and
  - ☑ Prototype can be used as pilot plant to carry out cost related studies, and to grow other agriculture products elsewhere.

Project Activities: Aims and Objectives

- The research and development activities and system implementations will be carried by 4 different ASEAN member countries:

1. **Water Wall Technology:** to customize heating or cooling effect based on the specific needs of the crops and the prevailing external climate conditions.
2. **Reverse Fan Technology:** to enable reversal of the fan's direction to redistribute warm air during colder periods and cool air during hotter periods.
3. **IoT Sensor Network:** to collect real-time data and automate greenhouse's adaptie response to the unique requirements of vanilla, chili, and lettuce growing environment and settings to optimize the plant growth.
4. **AI Disease Detection System:** to utilize computer vision and machine learning techniques for identifying subtle visual cues and anomalies associated with diseases affecting the crop health.

Project Activities: Key Deliverables

Research and Development Description	Milestones	Lead University
1 Self-sustaining smart greenhouse with adaptive environmental control	A Investigation of the water wall technology and reverse fan technique for optimizing temperature control within the greenhouse environment	UTB
	B Construction of a photovoltaic-battery renewable energy system with an integrated battery management module for optimal charging/discharging	MMU
2 IoT-enabled smart farm monitoring system and AI-driven data analytics solution	C Development of an IoT-assisted sensor network for enabling real-time data acquisition and automated actuators responses based on the unique growth requirements/settings of targeted crops	NIA, NUOL
	D Development of an AI-based data analytics solution using computer vision and machine learning techniques for enabling crop anomalies/disease detection	UTB

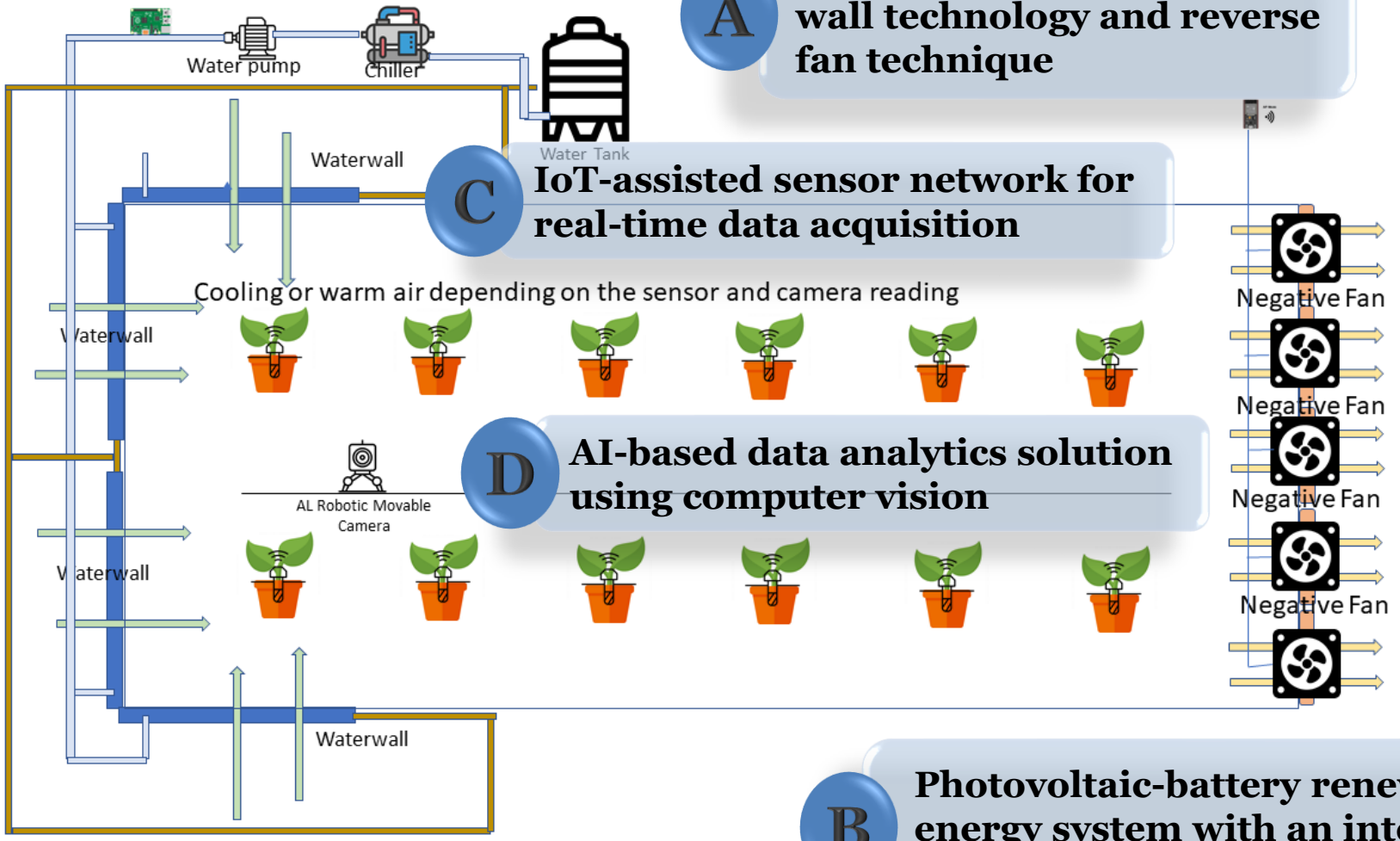
Project Activities: Conceptual Design of the Self-Sustaining Smart Greenhouse with Adaptive Environmental Control

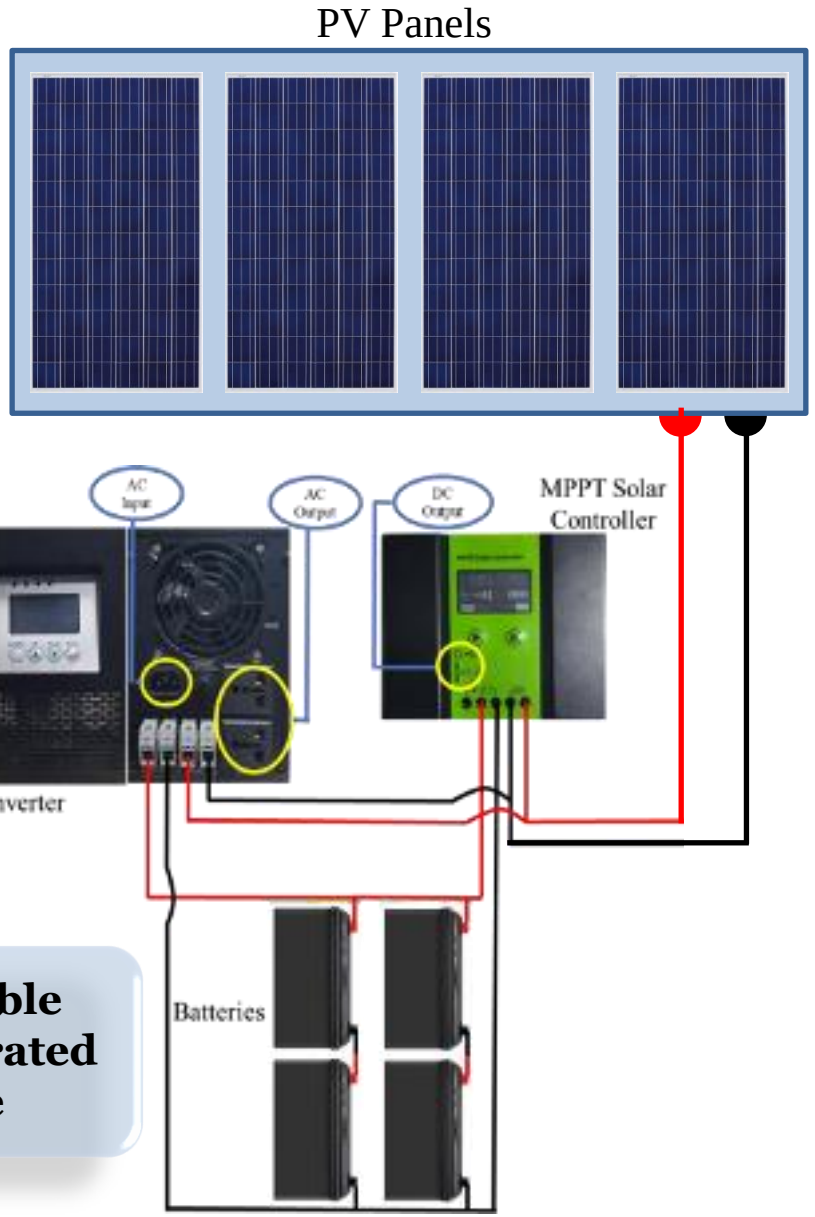
A Cooling system using water wall technology and reverse fan technique

C IoT-assisted sensor network for real-time data acquisition

D AI-based data analytics solution using computer vision

B Photovoltaic-battery renewable energy system with an integrated battery management module





Project Activities: Optimization and economic analysis of battery energy storage for photovoltaic-battery renewable energy system (MMU)

Stage 1: Data collection and simulation model

Data collection for simulation on the energy supply and demand required to maintain sustainable smart farming operation

Stage 2: Development of optimization models

Model 1: Searching for the optimal schedule in controlling the battery storage management.

Model 2: Optimal sizing of battery storage system for the off-grid/on-grid PV system.

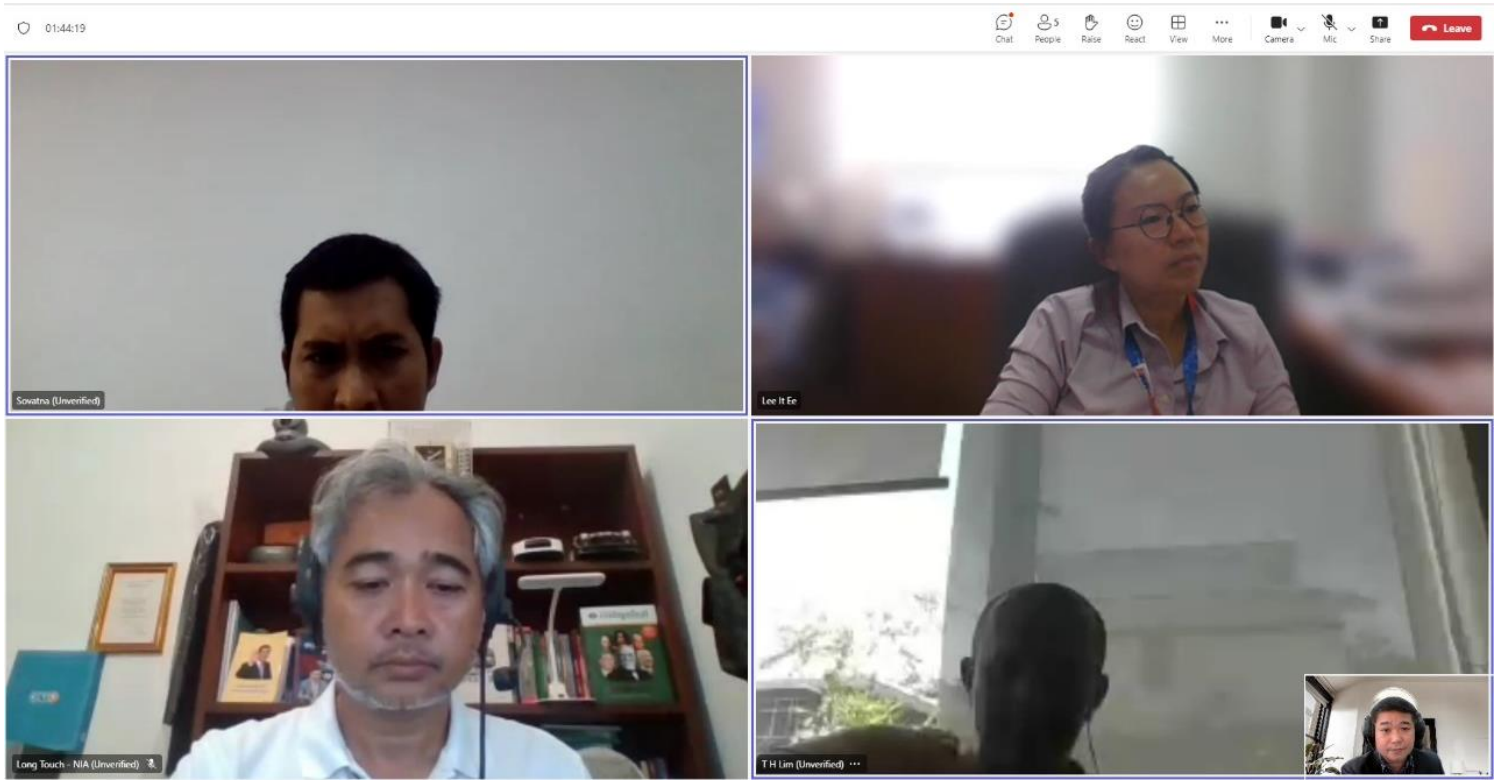
Stage 3: Long-term economic performance

Evaluation of the long-term economic performance of the photovoltaic-battery renewable energy system in terms of costs, benefits, risks, and timelines.

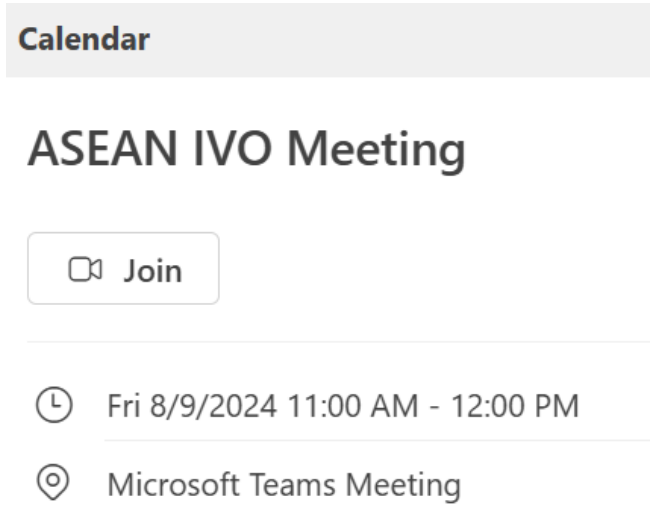
Project Activities: Budget Plan

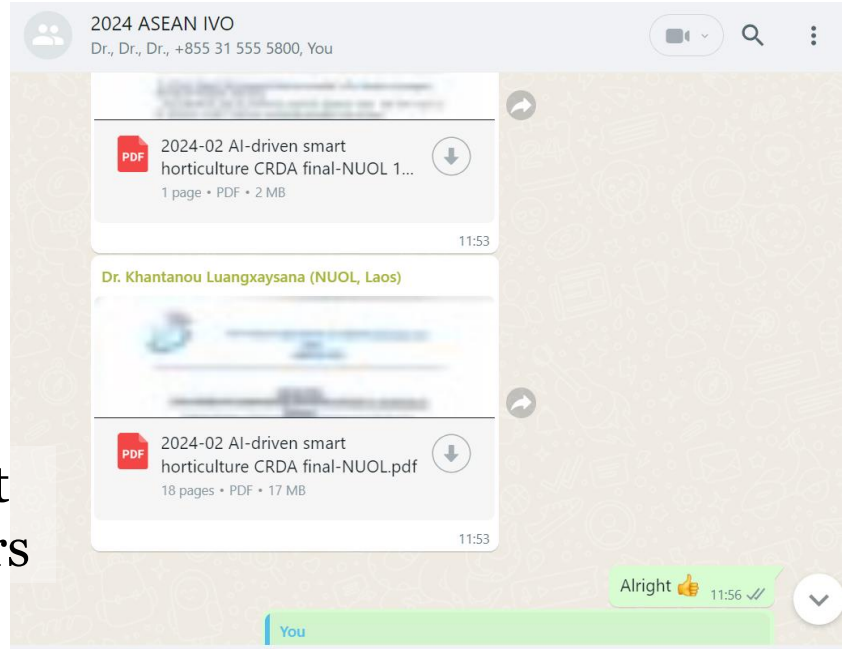
Description	Year 1 (USD)	Year 2 (USD)
Hardware and software:		
Cooling systems including waterwall and fans	10,000.00	
Greenhouse	3,000.00	
Soil analysis system	3,750.00	
Solar power system	4,000.00	
Consumables:		
Plants and fertilizer	1,250.00	
Study/field trips and project meetings:		
Brunei	6,000.00	
Malaysia	6,000.00	
Laos	6,000.00	
Cambodia		6,000.00
Bundu Tuhan, Sabah		16,000.00
Publication:		
Conference		8,000.00
Journal		10,000.00
Total	**40,000.00**	**40,000.00**

Project Activities: Discussions and Meetings



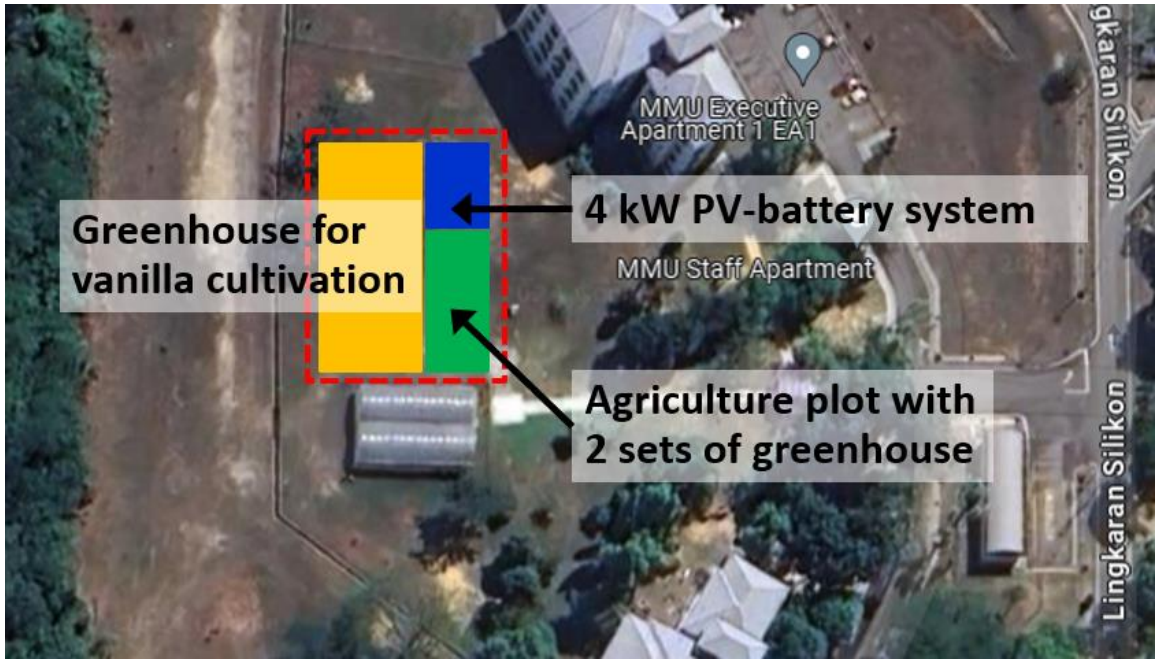
Virtual meeting to discuss on project milestones and deliverables and itinerary of our upcoming physical meeting at UTB





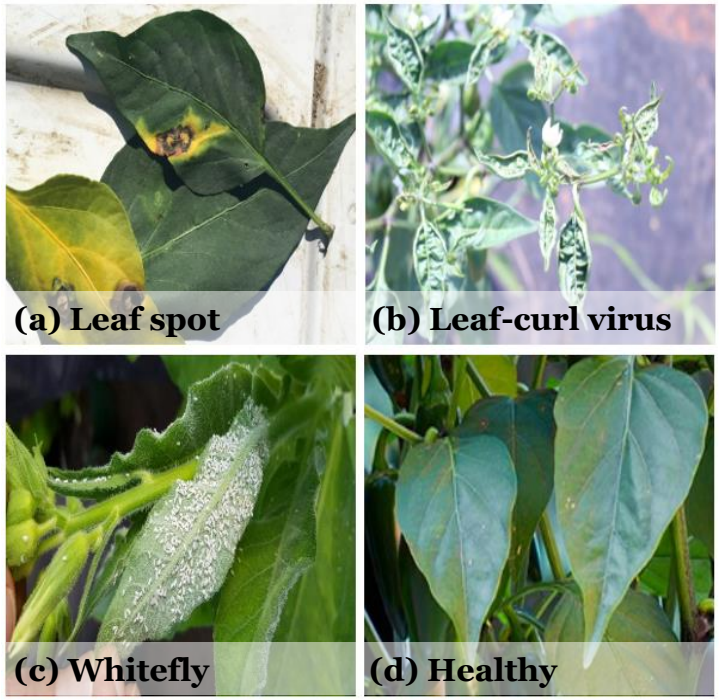
WhatsApp group for frequent discussions on project matters

R&D Results: Smart Greenhouse Implementation



- ☑ June 2024: Identified suitable deployment site at the MMU Cyberjaya campus
- ☑ September 2024: Completed the greenhouse setup and ventilation fans installation
- ☑ October 2024: Installed the solar panels at the 4-kW PV-battery system site.

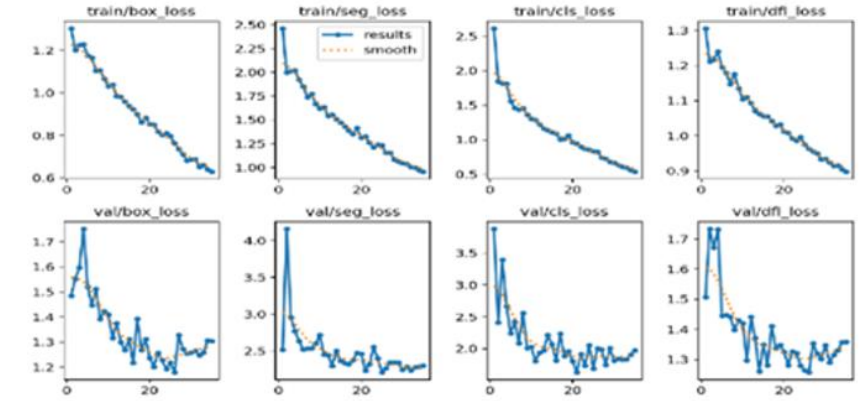
R&D Results: Optimization of Chilli Plant Disease Detection



Unseen data to be fed into the machine learning models

Roboflow 3.0 Instance Segmentation model

YOLOv8 model with 820 image dataset and 35 epochs



- ☑ Optimizing the YOLOv8 machine learning model to detect and classify four distinct chilli diseases.
- ☑ Comparative analysis of four YOLOv8 model variants and a fixed Roboflow 3.0 Segmentation model.

Scientific Contribution and Societal Impact

Prototype

- IoT-based smart farm demonstration platform
- Integrated photovoltaic-battery renewable energy system
- Pilot plant to carry out cost related studies and to grow other specialty agriculture products

Smart Agriculture

- Improve and optimize crop productivity and yields
- Reduce water consumption and mitigate pesticide usage
- Opportunities for income generation through eco-tourism (e.g., organic highland farms based on advanced IoT smart farming system)

PV-Battery System

- Access to reliable, clean, and affordable energy ➔ eliminate use of electricity from the grid
- Contribute to environmental sustainability and reduce carbon footprint ➔ supporting sustainable farming practices

Scientific Contribution and Societal Impact

Targeted Group:

- Local small scale farmers located at **Bundu Tuhan in Ranau, Sabah**

Social Innovation Aspects:

- One of the key deliverables of the project is **to implement the proof-of-concept prototype** at targeted small-scale agriculture communities at Bundu Tuhan.
- This will then allow the research team **to investigate the adoption rate of smart agriculture technologies** by the selected farmers at Bundu Tuhan for supporting the technology-related outcomes of this project.

Key challenges:

- Difficulties in reaching out to the local farmers due to geographical distances and lack of connections with the local farming communities at Bundu Tuhan.

Conclusions

- The project team has agreed on the key deliverables and planned milestones:
  - ☑ Self-sustaining smart greenhouse with adaptive environmental control
  - ☑ IoT-enabled smart farm monitoring system and AI-driven data analytics solution
- Prototype implementation works have started at the MMU Cyberjaya campus:
  - ☑ 2 completed greenhouses with hydrophonic setup and 1 planned greenhouse for vanilla cultivation
  - ☑ On-going deployment photovoltaic-battery renewable energy system with an integrated battery management module

Future Work

- **Project meeting at UTB:**
  - ☑ To align all members on the project's objectives, milestones and deliverables, timeline, and roles.
  - ☑ To outline and finalize the project's workplan, including the allocation of roles, responsibilities, and milestones, ensuring all team members have a clear understanding of their tasks.
- **Completion of a working proof-of-concept prototype at the MMU Cyberjaya campus by March 2025:**
  - ☑ To integrate IoT-assisted sensor network for enabling real-time data acquisition.
  - ☑ To introduce the water wall technology and reverse fan technique for optimizing temperature control within the greenhouse environment.
- **Difficulties in reaching out to the local farming communities at Bundu Tuhan:**
  - ☑ To seek the expertise of Earth Wonders Group to tap into the local farming communities in Bundu Tuhan.