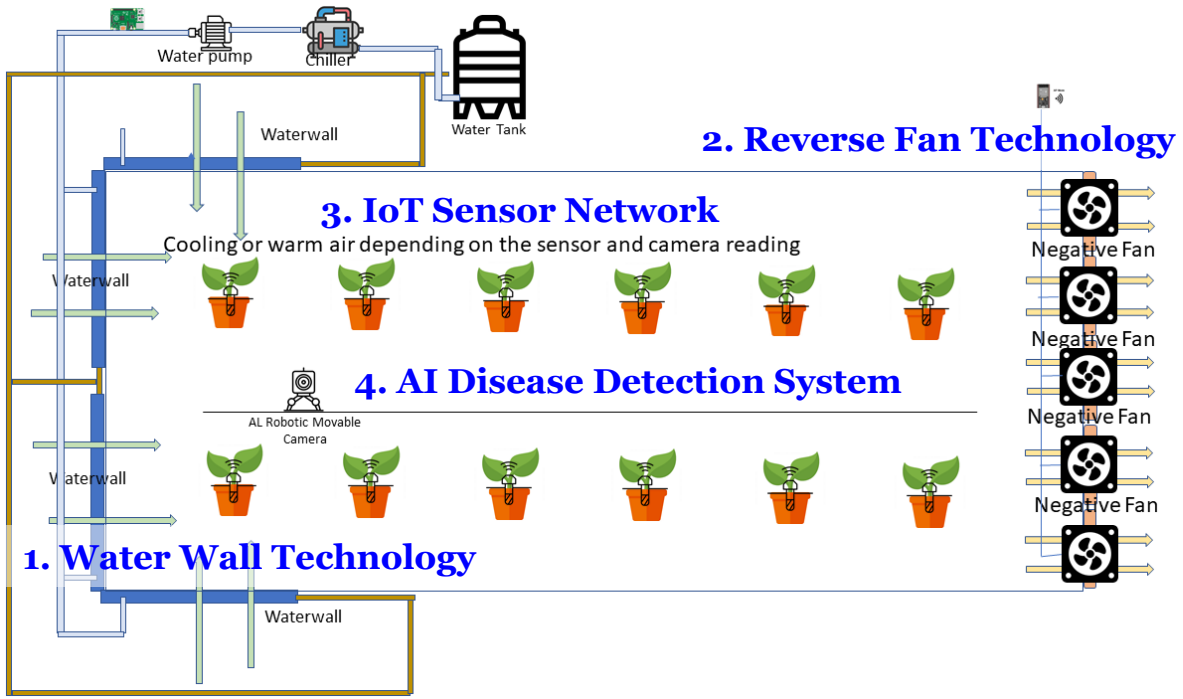
AI-Driven Smart Horticulture for Climate Sensitive Plant using Soil Analysis and Image Processing: A Tropical Perspective

Background:

In the dynamic and promising horticultural landscape of South East Asia, the cultivation of high yield crops on a small scale can contribute to the economic development of ASEAN countries, such as Malaysia, Brunei, Cambodia, and Laos. The proposed project aims to study and develop an advanced **energy-efficient smart greenhouse** tailored for the diverse climate conditions of the ASEAN region. 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).

Targets:



1. **Water Wall Technology:** to customize heating or cooling effect based on specific needs of the crops and 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 adaptive 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.
5. **Photovoltaic-Battery System:** to provide sustainable energy with integrated battery management module for optimal charging/ discharging.

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Speaker:

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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

New Project Member:


Olivia SL Tan
MMU (MYS)

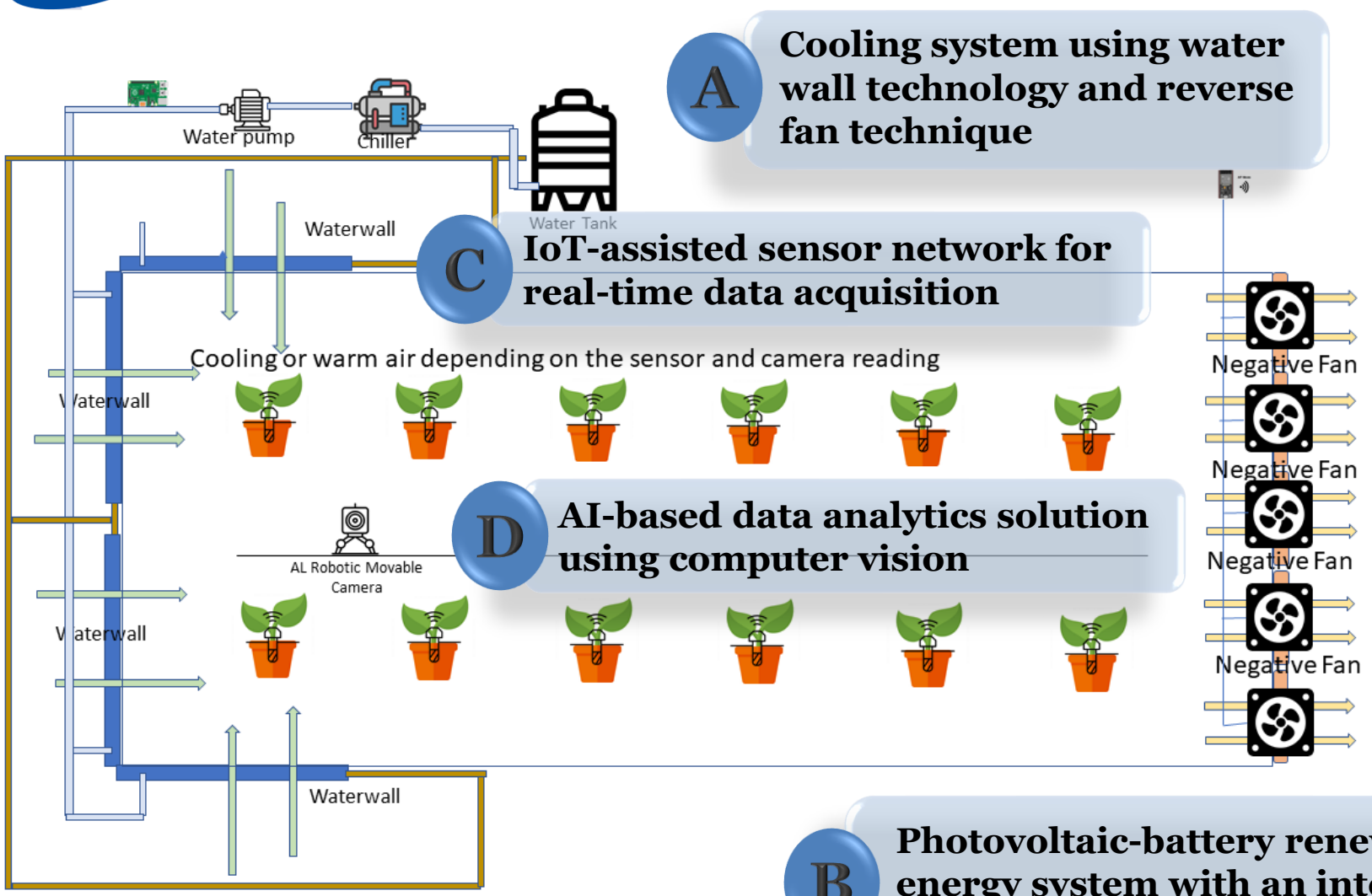
Project Activities: Conceptual Design of the Self-Sustaining Smart Greenhouse with Adaptive Environmental Control

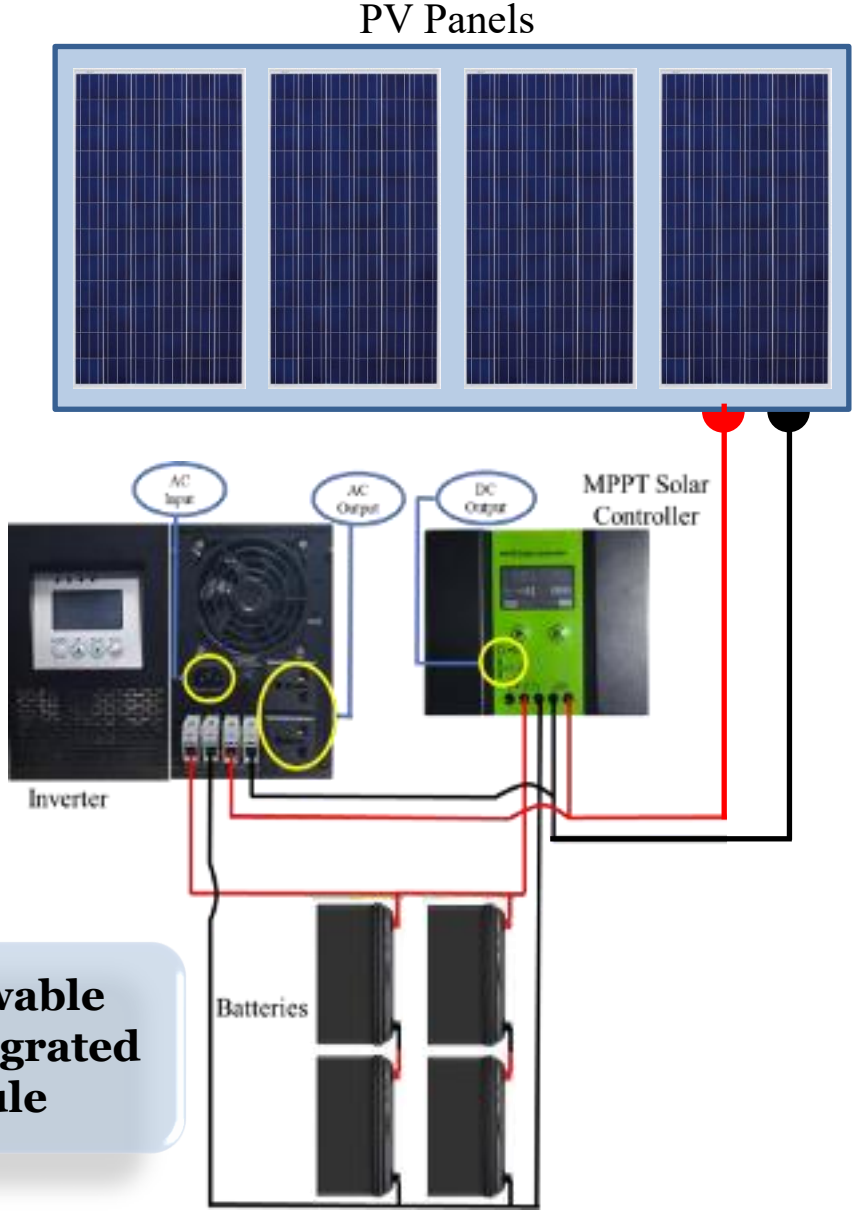
A Cooling system using water wall technology and reverse fan technique

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

D AI-based data analytics solution using computer vision

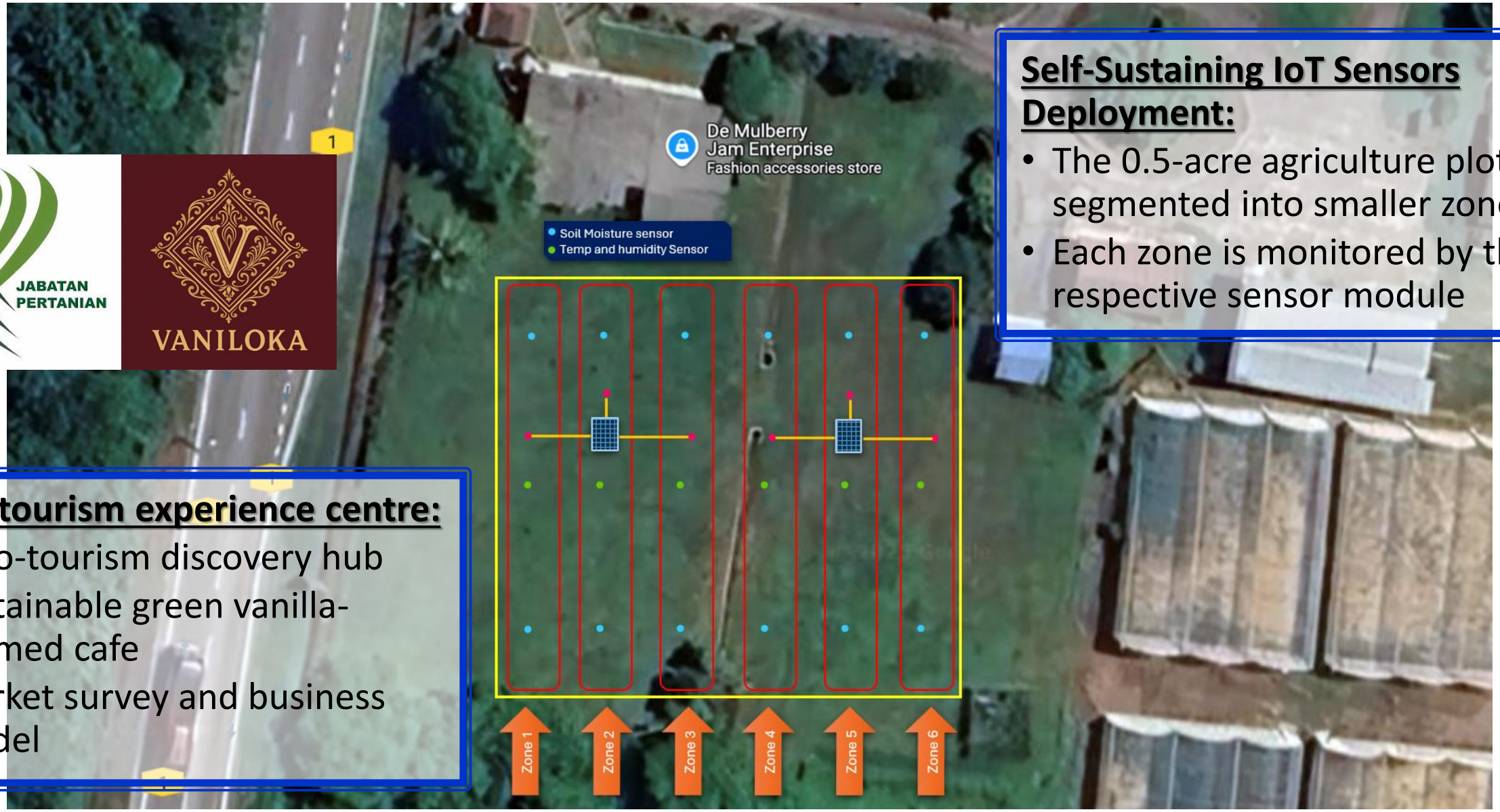
B Photovoltaic-battery renewable energy system with an integrated battery management module





Site Implementations

Design Layout: Batang Kali, Selangor



JABATAN PERTANIAN

VANILOKA

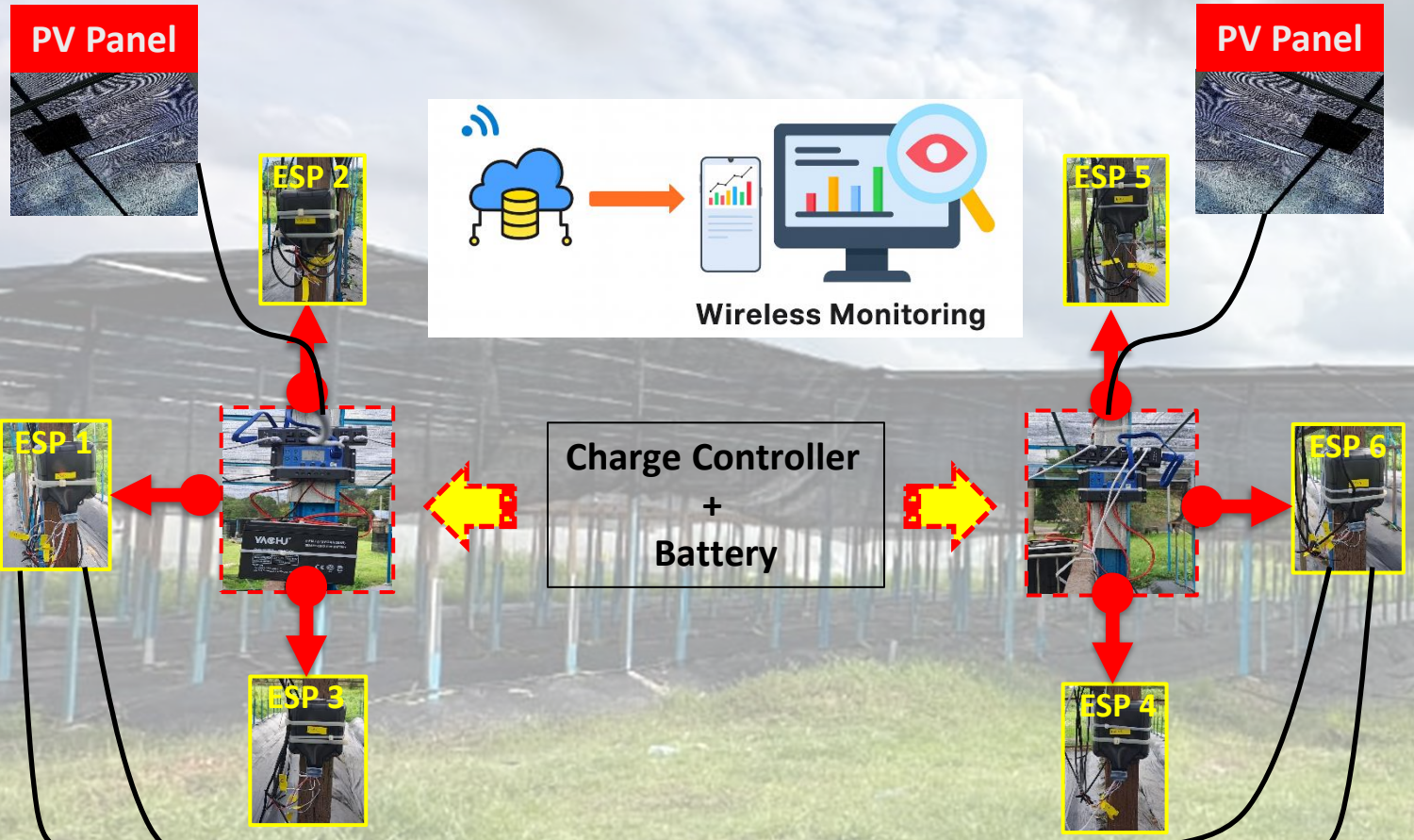
Self-Sustaining IoT Sensors Deployment:

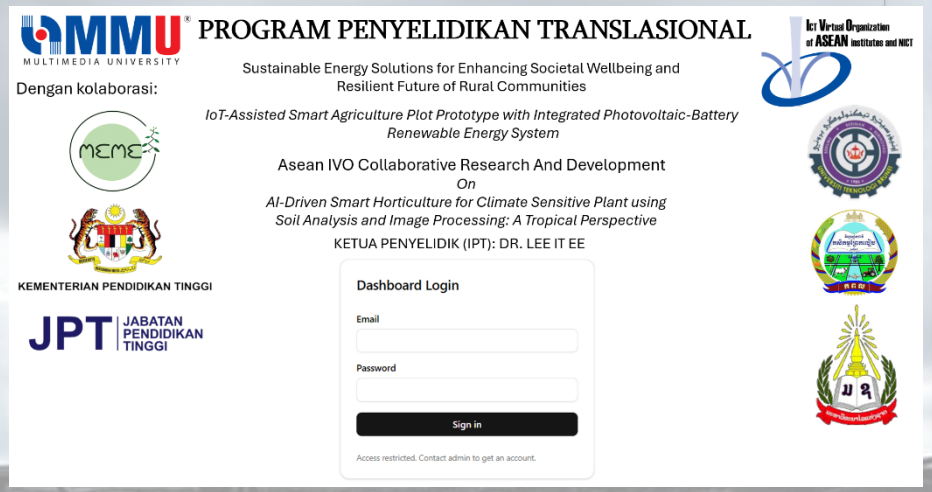
- The 0.5-acre agriculture plot is segmented into smaller zones
- Each zone is monitored by the respective sensor module

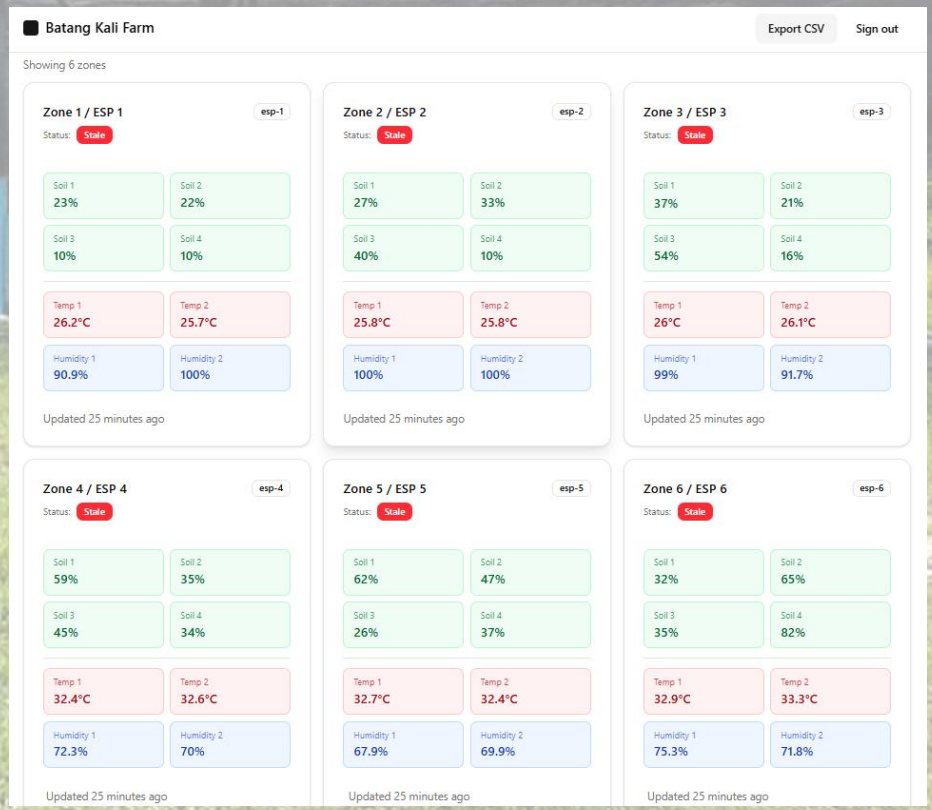
Agro-tourism experience centre:

- Agro-tourism discovery hub
- Sustainable green vanilla-themed cafe
- Market survey and business model

System Deployment: Batang Kali, Selangor

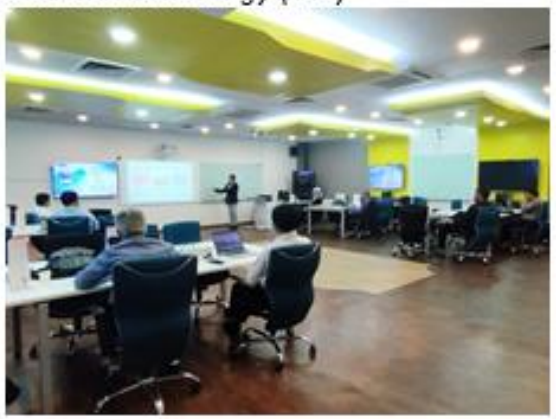






Project Review Meeting at MMU and Research Visits to the Smart Agriculture Plot at MMU Cyberjaya and TaniNoka Farm at UPM Serdang (3-4 June 2025)

Sharing session on innovations and safe technology transfer that promote eco-friendly commercialisation practices while enhancing yield and quality in sustainable smart farming from Centre for Law and Technology (CLT)

Site visit and sharing session on the system deployment at the sustainable smart agriculture plot in MMU Cyberjaya campus


Recently completed *Project Meeting and Site Visit at NUOL, Pawan Farm and Phachaleun Farm* (16-17 October 2025)

Farm tour and sharing session on current practices on sustainable and regenerative agriculture cultivation at TaniNoka Farm, Serdang




Project workplan review


Project Meeting and Site Visit at Universiti Teknologi Brunei (UTB) and HARQ Enterprise and Gropoint Sdn Bhd (14-15 July 2025)

Visit to HARQ Enterprise to understand the water wall cooling systems project and discussion on the chilli plant project highlighting the challenges and limitation of the greenhouse's cooling systems.

Figure 1a – Inspecting the waterwall installation.

Figure 1b. Negative Fans Inspection

Figure 1c. Chiller Demonstration

Figure 1d: Experiencing Chilli Greenhouse in the HARQ

Visit to UTB Centre of Research For ArgoTech and Food (CrAFT) to see the Agroponic development and Vertical Rice Farming project.

The project meeting strengthens project coordination among project members and ensure that all collaborative efforts are effectively aligned with the overall research objectives and timeline.

Figure 3a – Presentation by the Director of CrAFT

Figure 3b – Discussion on project Collaboration

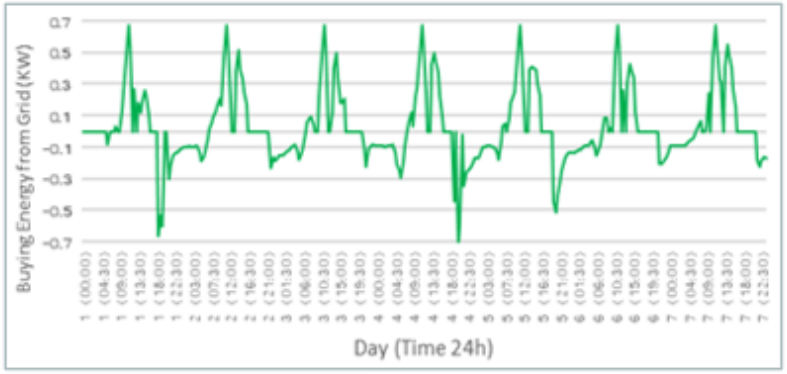
Figure 3c – Visit to UTB Vertical Rice Farming

Figure 3d – Visit to UTB Innovation Lab

R&D Results: Battery Management Optimization Model

MILP model successfully optimizes BESS operations. It enables farmers to invest in renewable energy with clear payback period estimates and additional revenue streams.

Adaptive Battery Management:
Algorithm adjusts battery operation based on solar availability and load demands. These patterns ensure efficient energy utilization.



Sunny Day Profit

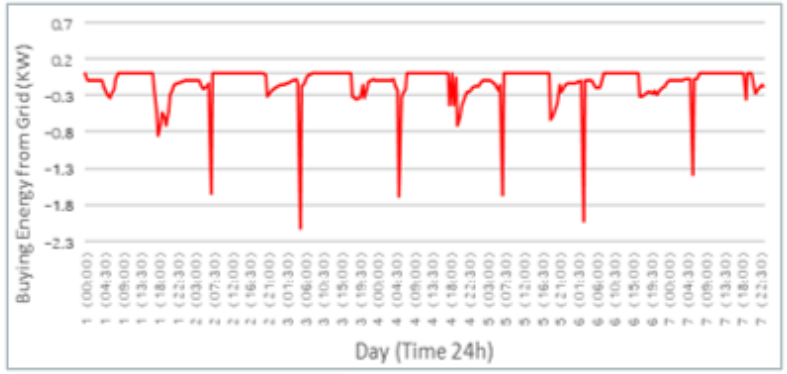
RM9.02

Sunny days yield a net profit of RM9.02 due to surplus energy sales.

Cloudy Day Loss

RM7.23

Cloudy days incur a net loss of RM7.23, reflecting reduced solar generation and higher grid purchases.



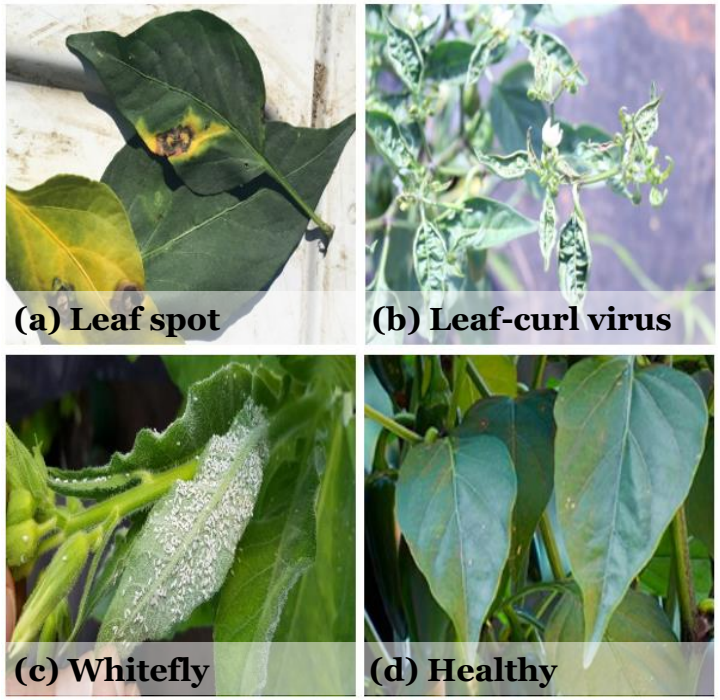
Rainy Day Loss

RM45.51

Rainy days result in a substantial net loss of RM45.51, driven by zero surplus sales and high grid dependency.

Impact on Operational Costs (1-week simulations):
Profitability is achievable on sunny days, while weather conditions significantly influence financial performance.

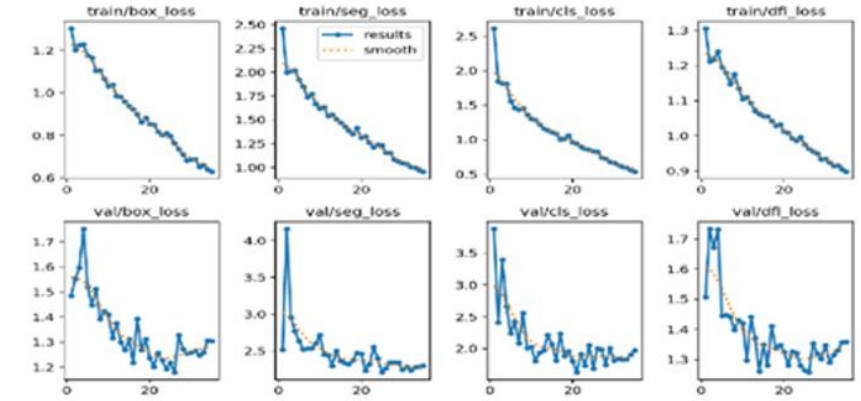
R&D Results: Optimization of Chilli Plant Disease Detection



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: Presentations at International Conferences

No.	Paper title	Author names	Affiliation	Conference name	Date	Venue
1.	Analyzing the Effect of LED Light on Plant Growth Using Logistic Regression and SHAP-Based Explainable AI Models	M.N.M. Nizam, S.Y. Ooi, Y.H. Pang, and I.E. Lee	▪ Multimedia University, Cyberjaya, Malaysia	IEEE ICoICT 2025	14-16 July 2025	Cyberjaya, Malaysia
2.	Evaluating the Effects of LED Light on Plant Growth Using XGBoost and Interpretable Machine Learning with SHAP	M.N.M. Nizam, S.Y. Ooi, Y.H. Pang, and I.E. Lee	▪ Multimedia University, Cyberjaya, Malaysia	AIP CITIC 2025	21-23 July 2025	Cyberjaya, Malaysia
3.	Optimal battery management model for profit-oriented grid-connected solar-powered smart farms	N.A. Rabbani, W.N. Tan, I.E. Lee, G.C. Chung, T.H. Lim, P. Sovatna, L. Touch, K. Luangxaysaxana, and P. Thongphanh	▪ Multimedia University, Cyberjaya, Malaysia ▪ Universiti Teknologi Brunei, Brunei Darussalam ▪ Prek Leap National Institute of Agriculture, Cambodia ▪ National University of Laos, Laos	13th ICSGCE 2025	17-29 October 2025	Chengdu, China
4.	Optimisation of Chilli Plant Disease Detection using Machine Learning and Image Segmentation	I. Mohamad, A.S. Abdullah, T.H. Lim, N.A.Z. Tashim, I.E. Lee, P. Sovatna, K. Luangxaysana and W.H. Lim	▪ Universiti Teknologi Brunei, Brunei Darussalam ▪ Multimedia University, Cyberjaya, Malaysia ▪ Prek Leap National Institute of Agriculture, Cambodia ▪ National University of Laos, Laos	9th CSAI 2025	12-15 December 2025	Beijing, China
5.	Design and development of an IoT-assisted automated fertigation system for sustainable smart agriculture	M.S. Pathy, I.E. Lee, G.C. Chung, O.S.L. Tan, T.H. Lim, K. Luangxaysaxana, P. Thongphanh, P. Sovatna, and L. Touch	▪ Multimedia University, Cyberjaya, Malaysia ▪ Universiti Teknologi Brunei, Brunei Darussalam ▪ Prek Leap National Institute of Agriculture, Cambodia ▪ National University of Laos, Laos	11th ICICT 2026	24-27 February 2026	London, UK

Scientific Contribution: Published Journal Papers

No.	Paper title	Author names	Affiliation	Journal name	The publisher of the Journal	The volume number and Pages
1.	Flexible perovskite solar cells: Recent breakthroughs, key challenges, and future perspectives	Q. Wali, I.E. Lee, M. Aamir, T.C. Chuah, and R. Jose	▪ Multimedia University, Cyberjaya, Malaysia ▪ Mirpur University of Science and Technology, Pakistan ▪ Ming Chi University of Technology, Taiwan	Surface and Interfaces	Elsevier	76 (2025) 107922
2.	Advances in thin layer deposition techniques in perovskite solar cells	Q. Wali, N. Rabbani, S. Afrin, I.E. Lee, M. Y. Khan, and M. Aamir	▪ Multimedia University, Cyberjaya, Malaysia ▪ North Carolina A&T State University, USA ▪ Qilu Institute of Technology. China ▪ Mirpur University of Science and Technology, Pakistan	RSC Advances	Royal Society of Chemistry	2025, 15, 40286-40298
3.	Silver nanowires network for transparent electrode in dye-sensitized solar cell	Q. Wali, S. Yousaf, N. Rabbani, and I.E. Lee	▪ Multimedia University, Cyberjaya, Malaysia ▪ University of Peshawar, Pakistan	Nano-Structures & Nano-Objects	Elsevier	44 (2025) 101559
4.	First principles investigation of bandgap modulation and light matter interaction in cubic X_2ScInI_6 halide double perovskites for emerging energy applications	M.Y. Khan, M. A. Jehangir, I. E. Lee, Q. Wali, T. Usman, L. Xiaojie, and A.A. Souwaileh	▪ Qilu Institute of Technology. China ▪ Islamia College, Peshawar, Pakistan ▪ Multimedia University, Cyberjaya, Malaysia ▪ King Saud University, Saudi Arabia	Chemical Physics Impact	Elsevier	11 (2025) 100920
5.	First-principles study of XSrBr3 (X = Li, K, Ag) halide perovskites for solar-blind photodetector applications	M.Y. Khan, M.A. Jehangir, I.E. Lee, Q. Wali, T. Usman, L. Xiaojie, and A.A. Souwaileh	▪ Qilu Institute of Technology. China ▪ Islamia College, Peshawar, Pakistan ▪ Multimedia University, Cyberjaya, Malaysia ▪ King Saud University, Saudi Arabia	Chemical Physics Impact	Elsevier	11 (2025) 100933

Societal Impact

Proof-of-concept prototype:

- The proof-of-concept prototype was successfully implemented at Mas Vanilla (Batang Kali, Selangor) in October 2025, showcasing an IoT-assisted smart farming system integrated with a PV-battery renewable energy platform.
- The system enables real-time monitoring of soil moisture, temperature, and humidity through a centralized cloud dashboard, allowing farmers to make data-driven decisions on irrigation and crop management.
- System deployment at Meme Vanilla (Tuaran, Sabah) is scheduled for December 2025, pending infrastructure readiness and calibration.

Knowledge transfer and capacity-building:

- Knowledge sharing activities have been initiated alongside the Batang Kali deployment, where local farmers are being trained on IoT sensor data interpretation, system operation, and PV-battery module, for establishing basic understanding and early adoption of technology.

Potential of agro-tourism:

- The project surveys the potential of agro-tourism as a supplementary income source, aiming to strengthen the socio-economic resilience of rural farming communities.

Conclusions

1. Prototype Deployment

- ☑ Implemented a proof-of-concept IoT-assisted smart farming system integrating PV-battery renewable energy and cloud-based data analytics at Mas Vanilla (Batang Kali, Selangor) in October 2025.
- ☑ Second deployment at Meme Vanilla (Tuaran, Sabah) scheduled for December 2025, marking the transition to dual-site validation across Peninsular and East Malaysia.
- ☑ Conducted early-stage knowledge transfer sessions in Batang Kali on IoT data interpretation, system operation, and renewable energy practices, empowering farmers and promoting technology adoption.

2. Scientific Outputs

- ☑ Developed an AI-based disease detection framework using YOLOv8 and Roboflow 3.0 for early crop health monitoring.
- ☑ Designed a battery management optimization model to enhance energy efficiency and system reliability in PV-battery applications.
- ☑ Advanced the adaptive smart greenhouse concept incorporating Water Wall and Reverse Fan systems for improved climate control in tropical environments.

3. Collaborations and Networking

- ☑ Conducted project review meetings and research visits at MMU (Malaysia), UTB (Brunei), and NUOL (Laos), to align milestones, share R&D progress, and harmonize deployment strategies.

Future Work

1. Project Coordination and Strategic Planning 📁

- ☑ Convene Project Meeting at Prek Leap National Institute of Agriculture (Cambodia) to finalize deliverables, partner responsibilities, and updated milestones.
- ☑ Execute field trips to NUOL (Vientiane, Laos) and collaborating vanilla farm (Tuaran, Sabah) to coordinate site preparation, validate equipment readiness, and engage with local farmers.
- ☑ Develop a fully operational proof-of-concept prototype at the UTB by January 2026, by integrating the water wall and reverse fan technologies for dynamic temperature and humidity regulation.

2. Field Deployment and Validation 🌱

- ☑ Conduct site deployments and field trials at Batang Kali (Selangor) and Tuaran (Sabah) to evaluate system performance under varied tropical climates.
- ☑ Collect environmental and agronomic datasets for AI model refinement, focusing on crop health, energy performance, and system reliability.

3. Expansion, Agro-Tourism and Community Engagement 🌾

- ☑ Conduct techno-economic and sustainability assessments at field sites to evaluate scalability and cost-effectiveness.
- ☑ Explore the potential of agro-tourism as a complementary income source linking technology, education, and community-based enterprise.
- ☑ Implement participatory action research to involve farmers and local stakeholders in co-design, data collection, and evaluation, fostering ownership and sustained adoption.