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Agricultural Engineering

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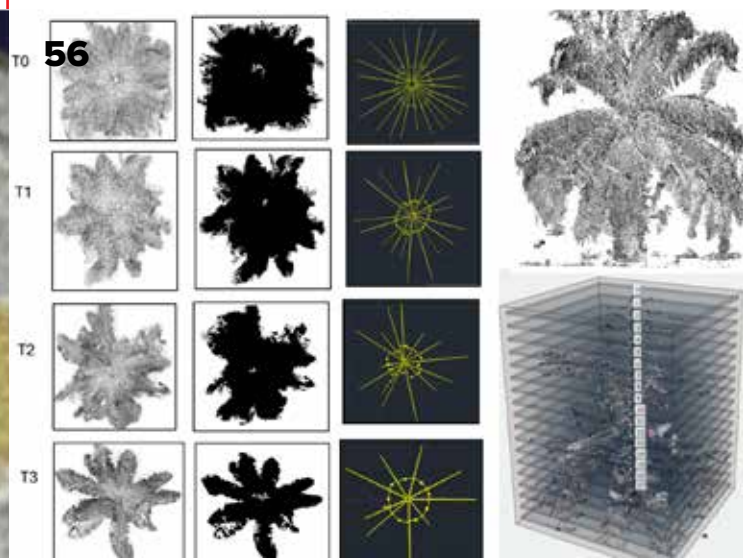
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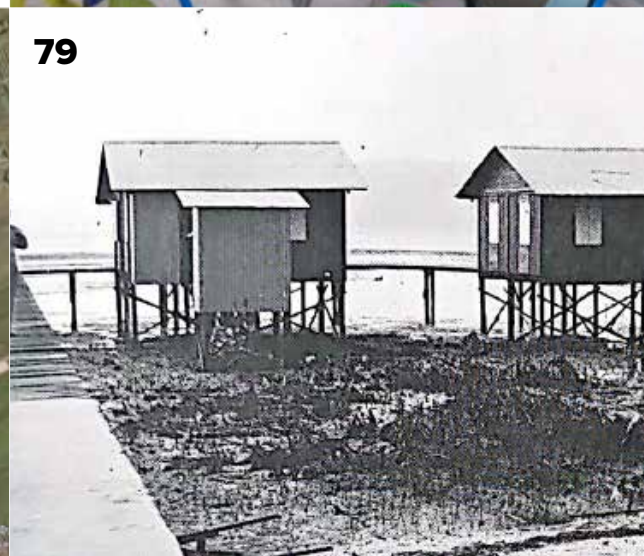
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BS 31 CLASS B (SCREWED) / MANUFACTURER'S STANDARD

NOMINAL SIZE	OUTSIDE DIAMETER				WALL THICKNESS				CALCULATED WEIGHT WITH COUPLER			NUMBERS OF THREADS	LENGTH OF THREADS			
	MINIMUM		MAXIMUM		MINIMUM		MAXIMUM						MINIMUM		MAXIMUM	
in	mm	in	mm	in	mm	in	mm	in	kg/m	kg/ft	lb/ft	PER INCH	mm	in	mm	in
¾	18.76	0.7387	19.05	0.7500	1.52	0.060	1.63	0.064	0.713	0.217	0.479	16	12.70	0.5000	14.29	0.5625
1	25.11	0.9887	25.40	1.0000	1.52	0.060	1.63	0.064	0.972	0.296	0.653	16	15.88	0.6259	17.46	0.6875
1¼	31.46	1.2387	31.75	1.2500	1.52	0.060	1.63	0.064	1.240	0.376	0.830	16	17.46	0.6875	19.05	0.7500
1½	37.80	1.4880	38.10	1.5000	1.73	0.068	1.83	0.072	1.680	0.511	1.130	14	19.05	0.7500	20.64	0.8125
2	50.50	1.9880	50.80	2.0000	1.93	0.076	2.03	0.080	2.510	0.765	1.690	14	22.23	0.8750	23.81	0.9375

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	MINIMUM	MAXIMUM		MINIMUM	MAXIMUM		MINIMUM	MAXIMUM
mm	mm	mm	mm	kg/m	kg/m	mm	mm	mm
20	19.7	20.0	1.6 ± 0.15	0.643	0.783	1.5	13	15
25	24.6	25.0	1.6 ± 0.15	0.811	0.995	1.5	16	18
32	31.6	32.0	1.6 ± 0.15	1.069	1.301	1.5	18	20

MS IEC 61386-1 / MS 61386-21 CONDUIT SYSTEM FOR CABLE MANAGEMENT

NOMINAL SIZE	OUTSIDE DIAMETER		INSIDE DIAMETER	EXTERNAL THREAD LENGTHS
	MINIMUM	MAXIMUM	MINIMUM	MINIMUM
mm	mm	mm	mm	mm
20	19.7	20.0	1.6 ± 0.15	13
25	24.6	25.0	1.6 ± 0.15	16
32	31.6	32.0	1.6 ± 0.15	18



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Agricultural Engineering

Agricultural Engineering stands at the intersection of technology, sustainability and food security, thus playing a pivotal role in addressing some of the most pressing challenges of our time. From improving crop yields to ensuring the efficient use of water resources, agricultural engineering is essential to sustaining the growing global population and preserving the environment.

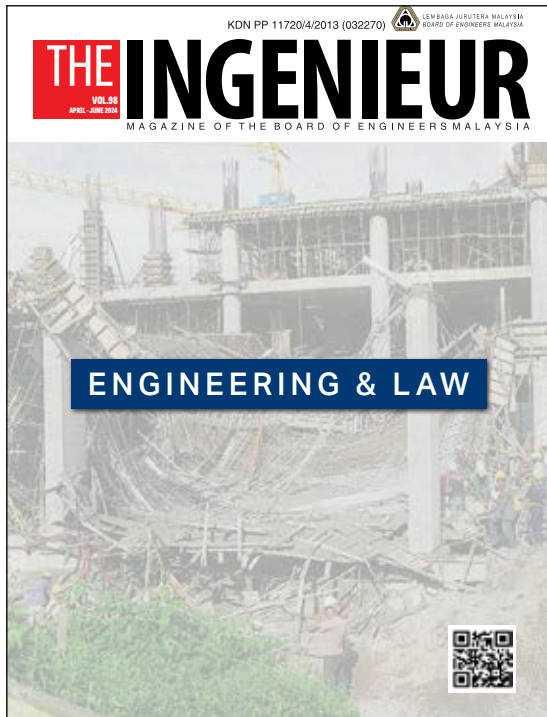
The integration of advanced technologies in agriculture is given prominence in Agricultural Engineering. The advent of precision farming, driven by GPS technology, drones, and IoT devices has revolutionised how we approach crop management. These innovations allow farmers to monitor soil health, track crop growth and optimise resource use with unprecedented accuracy. By harnessing big data analytics and machine learning, we can make informed decisions that enhance productivity while minimising environmental impact.

Sustainability is at the heart of Agricultural Engineering. The article on 'Keeping up with

Agriculture Technology' elaborates on the use of technology to generate higher yield with improved quality of crops for farmers. The article on 'Soil Properties Mapping System' outlines how a system, developed locally by UPM, serves to provide precise and real-time data on essential nutrients to accurately assess and map soil characteristics and fertility. This will enable farmers to make informed decisions to optimise crop yield and reduce environmental impact.

Looking forward, the role of Agricultural Engineering will continue to grow in importance. The challenges we face are immense but so are the opportunities. By embracing innovation, sustainability and collaboration, we can build a resilient agricultural sector that supports global food security and environmental health.

Datuk Ir. Ahmad Redza bin Ghulam Rasool
President, BEM



CALL FOR ARTICLES

The Ingenieur is published quarterly by the Board of Engineers Malaysia. The following are the themes for the coming issues.

- Vol. 100 Oct-Dec 2024
VOLUME 100 - The Centennial
- Vol. 101 January-March 2025
Waste Management
- Vol. 102 April-June 2025
Digitisation
- Vol. 103 July-Sept 2025
Maritime Engineering

Articles and other contributions relevant to the themes are welcomed, but the decision to publish rests with the Editorial Board.

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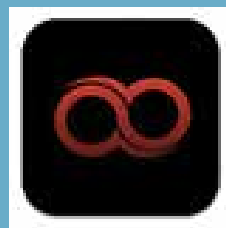


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Ameera Liana Kamal – SMART and SPUNKY

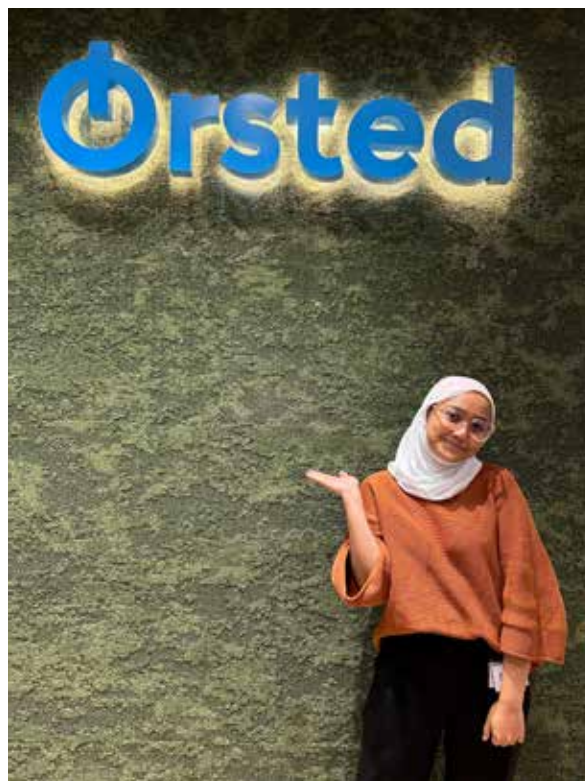
Top Mara Scholar, Ameera Liana Kamal, 26, took the limelight when she graduated with First Class Honours for her Bachelor in Electronics and Electrical Engineering degree at the University of Edinburgh, Scotland in 2022.

In an interview with *The Ingenieur* from Copenhagen, Denmark, Ameera comes across as intelligent and adventurous. She showed courage to venture into new areas and challenging environments.

At the time of the interview, Ameera was in Copenhagen because she was undergoing training at Orsted. The company develops, constructs and operates wind farms in Europe, Asia and the US. As part of her training, Ameera had the opportunity to gain hands-on experience, working in projects such as the Sunrise Wind (New York). She also visited installation yards in Norway and Denmark and an onshore sub-station in Taiwan. Ameera is attached to the power transmission department which handles transporting energy from wind turbines to the Grid. After her eight-month training, she will continue her work at Orsted's Kuala Lumpur office.

Ameera is the youngest in a family of five from Bangi, Selangor. She comes from a well-to-do and supportive family. Her mother, a former university lecturer, made sure she had ample learning resources like extra classes and tuition. Ameera says she shares her interest in science and engineering matters with her father, who is involved in an engineering-related business. “We would talk about physics stuff like $E=MC^2$,” she illustrates.

By nature, Ameera has an adventurous spirit. She has travelled to 32 countries, either solo or with family members. She is also musically inclined – plays the piano, guitar and ukelele plus enjoys singing.



Ameera Liana Kamal

Good grades were Ameera's hallmark in school. At SMK Putrajaya Presint 8 (1) she scored 9As in SPM and was awarded the MARA convertible loan under the Young Talent Programme. At A-levels, she excelled with 3As in Physics, Mathematics and Chemistry at Mara College, Seremban.

Ameera had many choices when it came to university education. She recalls considering three choices – medical, accounting and engineering – and had offers from four universities. As the youngest in the family, she weighed her choices looking at the professions of her older brothers and sisters besides seeking their advice. Eventually, she decided on engineering based on her



Ameera with her family



Working at the MNLG plant in Bintulu



Class Medal award during her fourth year

academic strengths in Physics and Mathematics and selected the University of Edinburgh.

Being smart, Ameera thought university education would be a breeze but it was not as she envisaged. “As smart as you are, you must manage your studies. I had to learn time management and sticking to a planned schedule. At A-levels, there was not much effort needed; at university, you have push yourself,” she explains. She struggled in the early years at university and failed some assignments. The third year was extra difficult because of the Covid-19 pandemic. Learning went online and there was little contact with fellow students. But she overcame the challenges with hard work and discipline. She was rewarded with a Class Medal for scoring the highest marks in her class. On top of this, her thesis on “Feasibility of reusing electric car batteries with an off-grid solar PV via simulations” was given an ‘A’ grade. She used MATLAB, a high performance language for technical computing which integrates computation, visualisation and programming in modelling, simulation and prototyping.

Like most overseas students, Ameera had her share of adapting to a foreign land. “In the beginning, it was a drastic change — no parents and no family support. The weather was so cold. I had difficulty understanding my lecturers with their Scottish accent,” she relates. Over time, she acclimatised and engaged herself in varsity life. Connecting with fellow Malaysian students made a lot of difference to her. She made many friends when she became Vice President of the Edinburgh Malaysian Student Association (a society of 250 plus Malaysians on campus) in her second year. To earn more money, she worked part-time in the University Library in her final year, and got to know more students and staff.

The high achiever was brave to start her career in a remote LNG plant in Sarawak. Ameera’s first job was as an electrical engineer at Malaysia LNG (MLNG) Sdn Bhd for two of its plants, MNLG Satu and MNLG Dua, Bintulu, focusing on maintaining electrical equipment. “As my first job, I was scared working on an installation yard and being a minority (male dominated),” she reveals. There were no female toilets where she worked but she took it all in stride. Ameera was there for five months and left after getting three job offers.

She chose to join Orsted in June 2023 as the company offered a two-year graduate employment programme. This took her to more challenges — job training in Denmark and adjusting to a new work culture.

Ameera’s scope of work covers low voltage and utility for offshore sub-station from concept, detail installation and commissioning. Besides the technical aspects, she has learnt a lot about networking and working with people from different parts of the world. She sees the obvious differences between Westerners and Asians. “The Danish are very direct in what they say but there are no hard feelings. They like to talk and it is normal to book someone for a coffee chat to catchup, network or just talk about work,” she notes. Her colleagues also come from other countries such as India and Iran.

Ameera acknowledges that she can apply about 50 per cent of what she learnt in her engineering course in her current work environment. In the longer term, she plans to sharpen her knowledge with a Masters in Electrical Power Engineering. She is also contemplating an MBA if she wants to progress to managerial positions in the corporate world. Her advice to aspiring engineers is to be courageous – “be scared but take calculated risks and bear the consequences”. - *Inforeach*

Thermal Imaging for Postharvest Handling

By Dr Maimunah Mohd Ali

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Postharvest handling is a critical phase in the agricultural supply chain that encompasses all activities from the time of harvest until the final delivery to consumers. This phase includes processes such as sorting, grading, packaging, storage, and transportation. The primary goal of postharvest handling is to maintain quality and extend the shelf life of agricultural produce while minimising losses and ensuring food safety. However, the efficiency of these processes is often challenged by various factors including spoilage, disease, quality deterioration, and physical damage to the agricultural produce. These challenges can significantly impact the quality, safety, and marketability of fresh produce, leading to economic losses and reduced consumer satisfaction. In this context, advanced technologies have been increasingly adopted to enhance the effectiveness of postharvest handling.

One such technology that has shown significant promise is thermal imaging. Thermal imaging, which is also known as thermography, involves the use of infrared cameras to detect and visualise temperature variations on the surface of objects. By capturing heat patterns, thermal imaging provides valuable insights into the physiological and physical state of the agricultural produce without the need for direct contact. This non-invasive method allows for real-time monitoring and rapid assessment, making it a powerful tool in postharvest handling and management.

Generally, the basic principle behind thermal imaging is the detection of infrared radiation emitted by objects. Every object with a temperature above absolute zero (-273.15°C) emits infrared radiation which can be captured by thermal cameras to create thermal images. These images, also known as thermograms, display temperature variations using a colour palette, where different colours represent different temperature ranges. By analysing these thermograms, it is possible to identify areas of concern such as hot spots indicating spoilage, bruises, or infections as well as cold spots pointing to poor cooling efficiency or dehydration.

There have been diverse applications of thermal imaging in the postharvest handling of agricultural produce. For instance, it was used to detect spoilage and diseases by identifying temperature anomalies caused by microbial activity. This early detection is crucial for implementing timely interventions to prevent the spread of infections and reduce losses. Additionally, thermal imaging can assess the ripeness and quality of fruits and vegetables by monitoring temperature changes associated with metabolic processes. This capability helps in determining the optimal harvest time and ensuring that the agricultural produce meets quality standards.

Another significant application of thermal imaging is in detecting physical damage such as bruising, which may not be visible to the naked

eye but can lead to accelerated deterioration and quality loss. By identifying early damage, it is possible to segregate the affected agricultural produce and prevent them from contaminating the rest. As advancements in thermal imaging technology continue to emerge, its integration into postharvest handling practices is likely to become increasingly prevalent, contributing to more sustainable and profitable agricultural supply chains.

Detection of Spoilage and Disease

The detection of spoilage and disease in agricultural produce is crucial for maintaining quality, reducing waste, and ensuring food safety. Conventional methods of detecting spoilage, such as visual inspections and microbiological testing, can be time-consuming, subjective, and often inadequate for early detection. Thermal imaging technology offers a promising alternative by adopting the principle that metabolic activity and microbial growth often produce heat, which can be detected as temperature variations on the surface of produce.

In this case, thermal imaging cameras detect infrared radiation emitted by objects by converting it into temperature readings. Spoilage and disease in fruits, vegetables, and other agricultural produce can cause localised temperature changes due to metabolic heat production from microbial activity or physiological responses. For instance, fungal infections like *Penicillium* in citrus fruits generate heat as they metabolise the fruit sugars, creating hot spots detectable by thermal cameras even before visible symptoms appear. Thermal imaging has been adopted for identifying the growth level of dry rot disease in potato tubers (see Figure 1). Apart from that, thermal imaging has been effectively used in various studies and practical applications. These applications demonstrated the potential of thermal imaging to identify problems that are not visible to the naked eye.

Unlike microbiological sampling or chemical testing, thermal imaging does not require physical contact with the agricultural produce, reducing the risk of contamination and allowing for repeated monitoring. Thermal imaging offers immediate

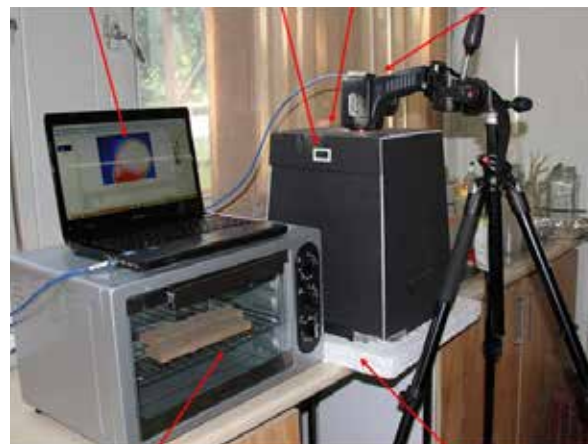


Figure 1: The thermal imaging system for the detection of dry rot disease in potato tuber. Courtesy: Farokhzad et al. (2024).

results by facilitating rapid decision-making in postharvest management. This imminence is crucial for large-scale operations where delays can lead to significant losses. Apart from that, high-resolution thermal cameras can scan large quantities of produce quickly, making it feasible for use in the detection of spoilage and disease in the field. In commercial settings, integrating thermal imaging into conveyor systems allows for the continuous monitoring of agricultural produce. Automated systems equipped with thermal cameras can identify and separate items that show signs of spoilage or disease, ensuring that only high-quality produce reaches the market. This integration enhances operational efficiency and product quality, thus reducing postharvest losses.

Ambient temperature and humidity can affect thermal readings. High ambient temperatures, for example, can mask the heat signatures of spoilage, leading to false negatives. Proper calibration and controlled environments are necessary to ensure accurate results. Thermal imaging can detect temperature anomalies but cannot identify the specific type of spoilage or pathogen. Complementary methods such as molecular diagnostics or microbiological assays are needed to pinpoint the exact cause of spoilage.

Thermal imaging represents a significant advancement in the detection of spoilage and disease in postharvest handling. Its ability to provide non-invasive, real-time monitoring on

a large scale makes it an invaluable tool for maintaining produce quality and reducing waste. As the technology evolves and becomes more accessible, thermal imaging is set to play an increasingly vital role in modern postharvest management practices.

Monitoring Ripeness and Quality

Monitoring the ripeness and quality of agricultural produce is a critical aspect of postharvest handling that directly impacts market value, consumer satisfaction, and food waste reduction. The ripening process in agricultural produce involves metabolic activities that generate heat, which can be detected as temperature variations on the surface of the produce. For example, as fruits ripen, they undergo physiological changes, such as increased respiration and ethylene production, that could lead to detectable heat patterns. Thermal imaging allows for the assessment of ripeness and quality without damaging the agricultural produce, preserving its market value and extending its shelf life. In this sense, thermal imaging provides immediate feedback by enabling continuous monitoring of ripeness and quality throughout the supply chain. This real-time capability is crucial for making timely decisions in sorting, packaging, and distribution.

Thermal imaging has been successfully applied in various studies to monitor the ripeness and quality of a wide range of fruits and vegetables. In assessing ripeness in tomatoes, thermal imaging has been utilised to detect temperature changes for the identification of optimal harvest times and the segregation of fruits based on ripeness levels. For monitoring postharvest quality in grapes, thermal imaging was used to track the cooling process after harvest, ensuring uniform temperature distribution and preventing quality degradation due to uneven cooling. Thermal imaging has shown promising results for the quality evaluation of different pineapple varieties during postharvest storage (see Figure 2).

The interpretation of thermal images can be complex, requiring advanced image processing techniques and expertise to accurately correlate temperature variations with ripeness and quality parameters. While thermal imaging provides



Figure 2: Prediction of quality parameters of pineapple using thermal imaging. Courtesy: Mohd Ali et al. (2022).

valuable data on surface temperature variations, integrating it with other sensing technologies such as near-infrared (NIR) spectroscopy or hyperspectral imaging, can offer a more comprehensive assessment of ripeness and quality. The future of thermal imaging in monitoring ripeness and quality lies in the development of advanced, user-friendly systems that can be easily integrated into existing postharvest handling processes. As technology advances and integration with other sensing methods improves, thermal imaging is set to become an indispensable component of modern postharvest management practices, ensuring high-quality produce reaches consumers while minimising waste.

Assessing Physical Damage

Physical damage to agricultural produce during postharvest handling can significantly affect quality, shelf life, and marketability. Bruises, cuts, and other forms of mechanical damage often lead to increased respiration rates, ethylene production, and microbial invasion which accelerate the deterioration process. Thermal imaging detects infrared radiation emitted from the surface of an object, converting it into a temperature map. When agricultural produce is physically damaged, the affected areas exhibit different thermal properties compared to undamaged regions. For example, bruises on fruit can cause localised changes in heat transfer due to disrupted cell structures

and increased metabolic activity. Thermal imaging allows for the assessment of produce without causing further damage. This is crucial for maintaining the integrity and value of the produce throughout the supply chain. In addition, thermal imaging systems can quickly scan and analyse the produce in real-time, enabling the immediate identification and sorting of damaged items. Unlike visual inspections, thermal imaging provides objective, quantifiable data on the extent and location of physical damage, reducing reliance on subjective judgment.

Bruising is a common type of physical damage in fruits and vegetables, often resulting from impact during handling and transportation. Bruised areas typically exhibit different thermal properties compared to undamaged tissue. Thermal imaging can detect these differences, as bruised tissues often have altered metabolic activities leading to localised temperature variations. Thermal imaging can effectively identify surface defects such as cuts, abrasions, and punctures. These defects can disrupt the normal temperature distribution on the produce surface. By capturing high-resolution thermal images, it is possible to identify and quantify the extent of surface damage. This is particularly useful for quality control processes in packing houses and during transportation. Internal damage such as fractures or voids can significantly affect the quality of produce. Traditional inspection methods might miss such defects as they are often not visible externally. Thermal imaging, however, can detect internal damage based on the heat transfer properties of the agricultural produce. Damaged areas often exhibit different thermal conductivity and capacity, resulting in distinct thermal patterns that can be identified and analysed.

Thermal imaging has been successfully applied in various studies and industries to detect physical damage in a wide range of fruits and vegetables. The bruised areas on apples exhibit distinct thermal signatures due to changes in tissue properties and metabolic responses that are not visible to the naked eye (see Figure 3). Citrus fruits such as oranges and lemons can suffer from handling damage that leads to internal bruising. Thermal imaging can detect these bruises early, allowing for better sorting and reducing spoilage during storage and transport. Thermal imaging

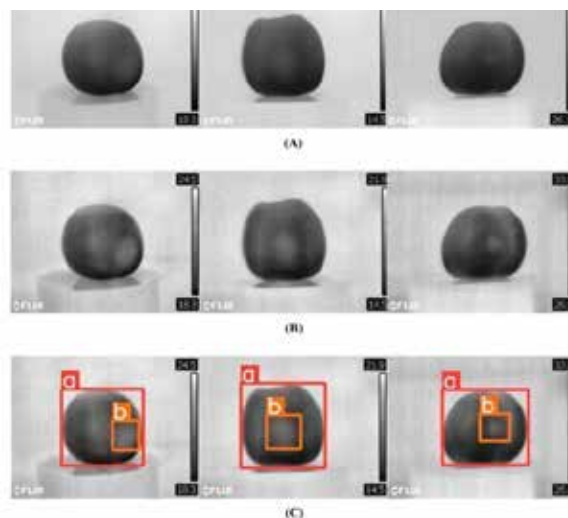


Figure 3: The apple images using cold excitation thermal imaging; (A) Thermal images; (B) Thermal images after histogram equalisation; and (C) The labelling for apple ('a') and bruises ('b'). Courtesy: Lin et al. (2023).

has also been used to identify impact damage in potatoes that contribute to bruising and soft spots. This technology can help ensure that high-quality potatoes are sent to market, improving consumer satisfaction.

The future of thermal imaging in assessing physical damage lies in the development of more sophisticated, user-friendly systems that can be seamlessly integrated into automated sorting and grading lines. Advances in image processing techniques and chemometrics can enhance the accuracy and speed of thermal image analysis, making it easier to identify and quantify physical damage. The ability of thermal imaging to provide rapid, real-time, and objective data makes it a valuable addition to traditional quality control methods. As technology advances and becomes more accessible, thermal imaging is poised to play a crucial role in ensuring the quality and longevity of produce, ultimately reducing postharvest losses and enhancing consumer satisfaction.

Challenges and Limitations

Thermal imaging has emerged as a promising technology for enhancing postharvest handling of agricultural produce. However, despite its

potential, several challenges and limitations must be addressed to fully realise its benefits. This section outlines the key issues that impact the widespread adoption and effectiveness of thermal imaging in postharvest applications.

One of the primary challenges in using thermal imaging for postharvest handling is the need for proper calibration and standardisation. Thermal cameras must be accurately calibrated to ensure consistent and reliable temperature measurements. Variations in ambient conditions, such as changes in temperature and humidity, can affect the accuracy of thermal images. Establishing standardised protocols for calibration and image acquisition is essential to minimise these variations and ensure that the thermal imaging systems provide reproducible results across different environments and types of produce.

Interpreting thermal images to identify and quantify damage or spoilage can be complex. The temperature differences detected by thermal cameras may not always be straightforward to interpret as they can be influenced by several factors including surface moisture, ambient temperature, and the presence of non-damaging features like natural blemishes. Advanced image processing techniques and algorithms are required to accurately differentiate between actual damage and benign temperature variations. Developing robust software solutions that can automatically analyse thermal images and provide actionable insights is a significant challenge. The effective use of thermal imaging technology requires a certain level of technical expertise. Operators must be trained not only to handle the equipment but also to understand the principles of thermal imaging and the nuances of image interpretation. This need for specialised knowledge can be a barrier to adoption, especially in areas where technical training and support are not readily available.

While thermal imaging is effective at detecting surface temperature variations, it may have limitations in identifying internal defects or damage that do not manifest as surface temperature changes; for instance, internal bruising or fungal infections that have not yet affected the surface temperature might go undetected. Combining thermal imaging with

other non-destructive sensing technologies, such as hyperspectral or multispectral imaging, could enhance detection capabilities but this will also add to the complexity and cost of the system. Furthermore, external environmental factors can significantly influence the effectiveness of thermal imaging. Variations in lighting conditions, ambient temperature, and airflow can affect the thermal signatures of agricultural produce, leading to potential inaccuracies. Ensuring that thermal imaging systems can operate reliably across a range of environmental conditions is critical but challenging.

Thermal imaging generates large amounts of data that need to be processed and analysed. Managing this data efficiently and extracting meaningful insights require sophisticated data management systems and analytical tools. Developing these systems and ensuring they are user-friendly and scalable is another challenge that needs to be addressed.

Future Trends and Conclusion

The future of thermal imaging in postharvest handling holds significant promise as technological advancements continue to evolve. Several emerging trends are set to enhance the application of thermal imaging, making it more accessible, accurate, and integrated into the broader agricultural value chain.

One of the most promising trends is the integration of thermal imaging with artificial intelligence algorithms. This can enhance the interpretation of thermal images by automatically identifying patterns and anomalies associated with spoilage, ripeness, or physical damage. Future developments are likely to see thermal imaging integrated with other sensing technologies such as hyperspectral imaging, NIR spectroscopy, and X-ray imaging. Multi-sensor systems can provide a more comprehensive analysis of produce by combining data from different modalities. The Internet of Things (IoT) is set to play a crucial role in the future of thermal imaging for postharvest handling. IoT-enabled thermal cameras can be part of a larger network of smart devices that monitor various parameters throughout the supply chain.

Thermal imaging holds significant potential for revolutionising postharvest handling by improving the detection of spoilage, disease, ripeness, and physical damage in agricultural produce.

Advancements in sensor technology and manufacturing processes are expected to lead to more portable and affordable thermal imaging devices. Smaller and handheld thermal cameras that can be easily used by farmers and postharvest workers will democratise access to this technology. Additionally, cost reductions will make it more feasible for small and medium-sized enterprises to adopt thermal imaging, thereby broadening its impact.

Thermal imaging holds significant potential for revolutionising postharvest handling by improving the detection of spoilage, disease, ripeness, and physical damage in agricultural produce. It is poised to become an integral part of the postharvest handling process, offering a non-invasive and efficient means of ensuring the quality and safety of various agricultural produce. Continued research, technological advancements, and industry collaboration will be essential to overcome existing challenges and unlock the full potential of thermal imaging in the agricultural sector. As these developments unfold, thermal imaging will play a critical role in reducing postharvest losses, improving food quality, and contributing to a more sustainable agricultural future. ■

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Soil Properties Mapping System for Fertiliser Management

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The macronutrients, nitrogen (N), phosphorus (P), and potassium (K) are pivotal constituents in agriculture, forming the foundation of nearly all fertilisers. Assessing the presence of NPK fertilisers in agricultural fields is indispensable for optimising fertiliser application rates in accordance with crop requirements.

Traditionally, soil nutrient measurements relied solely on chemical analyses conducted in laboratory settings. However, implementing a precision fertilisation regimen necessitates intricate and resource-intensive laboratory assessments, rendering the sampling and evaluation of soil samples across vast expanses of farmland physically impractical and financially burdensome [1]. Consequently, fertiliser application has historically been tailored on a hectare scale or larger. Although fertiliser is typically broadcasted uniformly throughout a field, it is well-established that soil fertility exhibits significant spatial variability. Notably, elevated concentrations of fertiliser in soil correspond to heightened nutrient uptake by plants [2]. Prior investigations underscore the imperative of discerning fertiliser content to facilitate precise application at optimal locations and during critical growth stages, thereby advancing best management practices [3]. Consequently, the development of expeditious soil nutrient

measurement tools such as on-the-go devices is imperative for effective crop field management.

Numerous researchers have documented the development and elucidation of on-the-go soil measurement devices and soil sampling methodologies [4], [5], [6], [7], [8], [9], [10]. Notably, the advent of technologies such as the soil electrical conductivity sensor (ECa sensor) has garnered attention for its reliability in characterising field conditions and nitrogen content [10]. Designed for real-time measurement of soil properties, the sensor is a pragmatic tool for mapping diverse soil attributes due to its capacity for rapid measurement at predefined locations.

The apparent Electrical Conductivity (ECa) of soil is influenced by various soil characteristics including soil water content, clay content, salinity, temperature, organic compounds, and metallic elements [11]. While certain soil factors affecting ECa remain relatively stable over time (e.g., clay content), others may exhibit pronounced seasonal variations. Furthermore, investigations employing ECa sensors have explored their utility in establishing co-relations between rice yield and soil ECa, revealing a close association between ECa values and rice productivity [12].

The utilisation of apparent soil electrical conductivity sensors holds promise in delineating management zones characterised by varying



Figure 1: Conventional practices to distribute fertiliser uniformly on the entire paddy field.

productivity levels and nutrient demands, owing to their capacity to assess soil properties [13]. By leveraging soil ECa measurements, it becomes feasible to estimate potential yield through the determination of topsoil thickness, thereby enabling the implementation of variable-rate fertiliser strategies [14]. Empirical evidence suggests the efficacy of this approach in fertiliser management across diverse crop types [15].

In Malaysia, the conventional fertilisation recommendations commonly employed by farmers in paddy cultivation often engender adverse environmental impacts, compromise soil properties, diminish production efficiency, and adversely affect crop health. Moreover, such practices escalate production costs through excessive fertiliser usage, imposing a significant financial burden on the Government's allocation of fertiliser subsidies to farmers. Consequently, the utilisation of advanced technological tools such as soil electrical conductivity sensors for fertilisation management in Malaysia is strongly advocated, particularly within the context of the rice industry.

Soil Properties Mapping System using soil electrical conductivity sensors

Recognising the critical importance of effective fertiliser management in rice farming, a team of researchers from Universiti Putra Malaysia (UPM)

has developed an innovative system designed to deliver comprehensive information on soil fertility. This system, named the Soil Properties Mapping System (SoilProp®), integrates advanced technologies including soil electrical conductivity sensors, global positioning systems (GPS), robust computers, and specialised software to accurately assess and map soil characteristics and fertility.

SoilProp® is engineered to provide precise, real-time data on essential soil nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K), which are fundamental to plant growth. The system's ability to offer detailed insights into soil nutrient levels enables farmers to make informed decisions regarding fertiliser application, thereby optimising crop yield and reducing environmental impact.

The soil data collected by the system is visually represented on a computer screen, displaying a detailed map that correlates with the actual geographic location of the surveyed area. This visual representation allows end-users to easily identify variations in soil fertility across different parts of their fields, facilitating targeted and efficient soil management practices.

The system operates using machinery such as tractors, which are capable of navigating agricultural fields with an attached soil sensor. This sensor measures soil electrical conductivity at one-second intervals. Each measurement is precisely geotagged using GPS. The soil electrical conductivity and GPS data are transmitted to a data logger, which then sends the information to a rugged laptop. The SoilProp® software processes this data to generate a detailed map displaying soil nutrient information.

This technology was specifically developed to aid farmers, particularly those managing paddy fields, by providing critical insights that allow for the precise application of nutrients. By supplying fertilisers in the right quantities, at the optimal times, and in the exact locations where they are needed, farmers can ensure that the nutrients are fully utilised by the crops. This targeted fertilisation process not only enhances crop yield by ensuring that the plants receive adequate nutrients for growth but also contributes to environmental sustainability by preventing over-fertilisation.

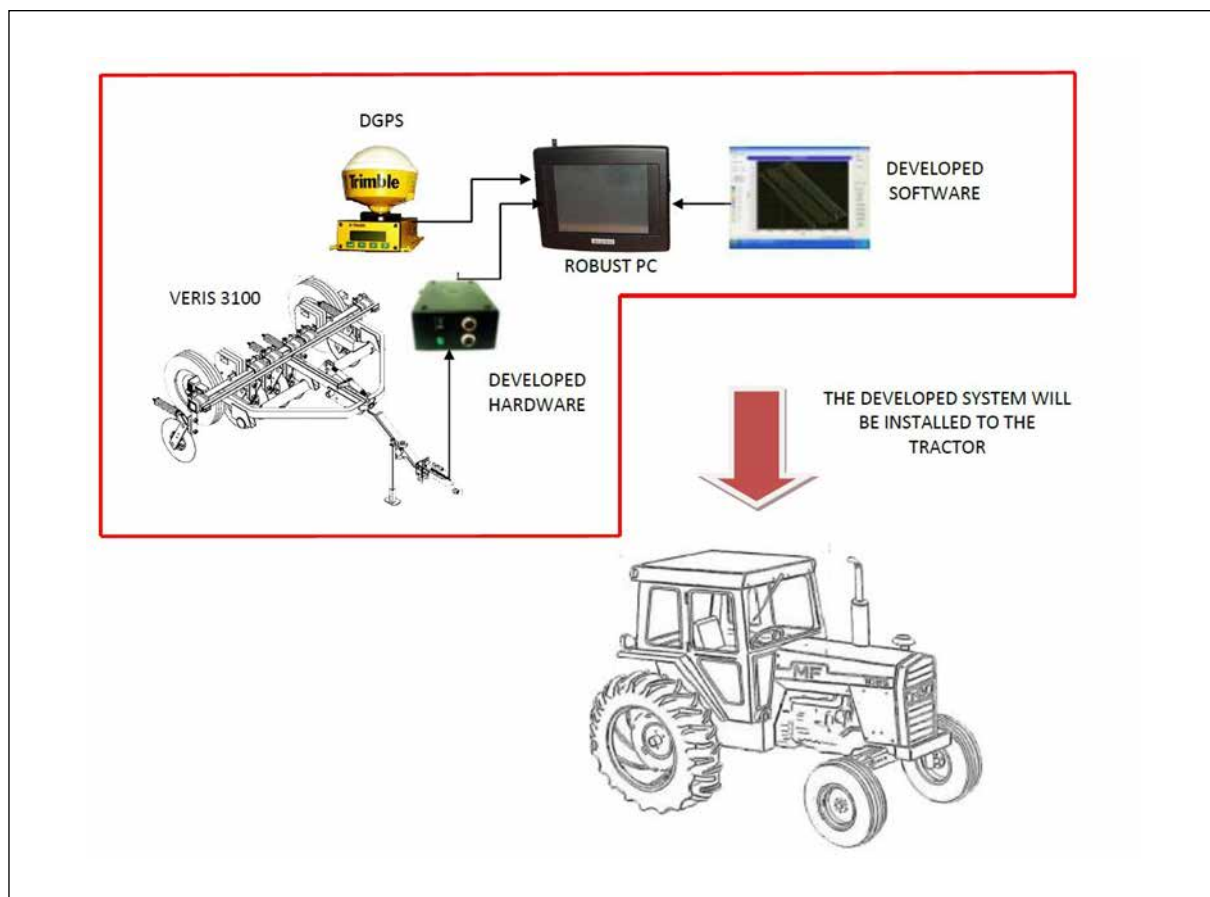


Figure 2: A diagram of the Soil Properties Mapping System (SoilProp©).

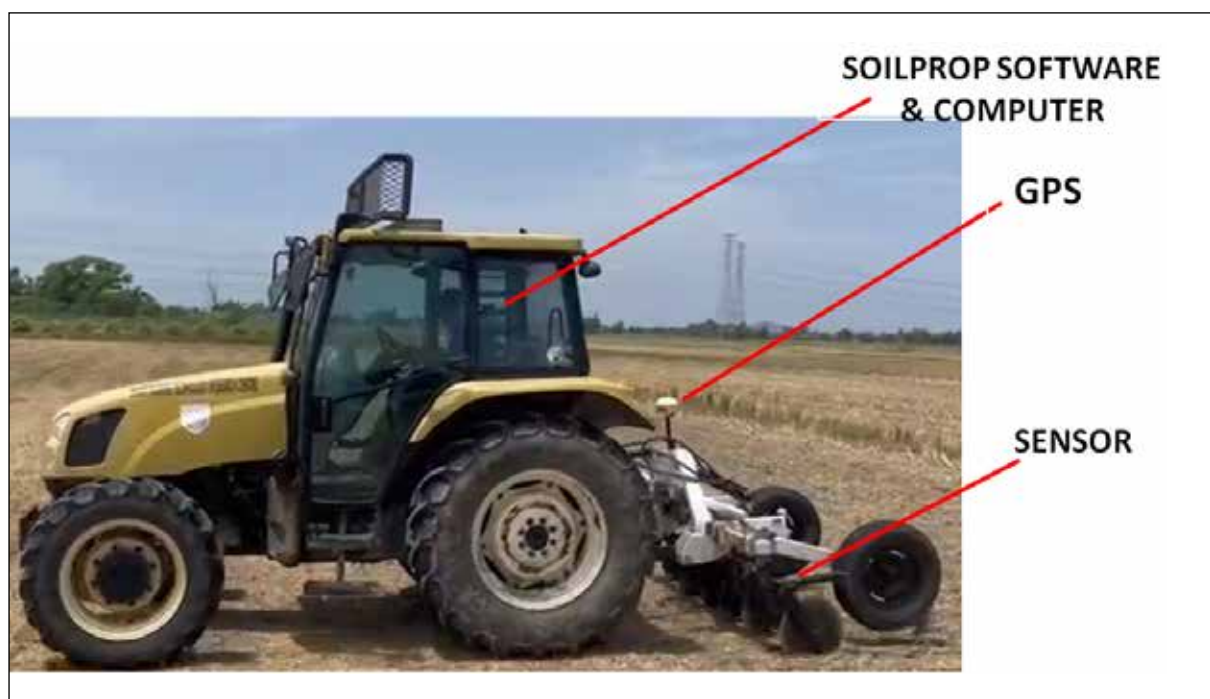


Figure 3: The actual components of the Soil Properties Mapping System (SoilProp©).

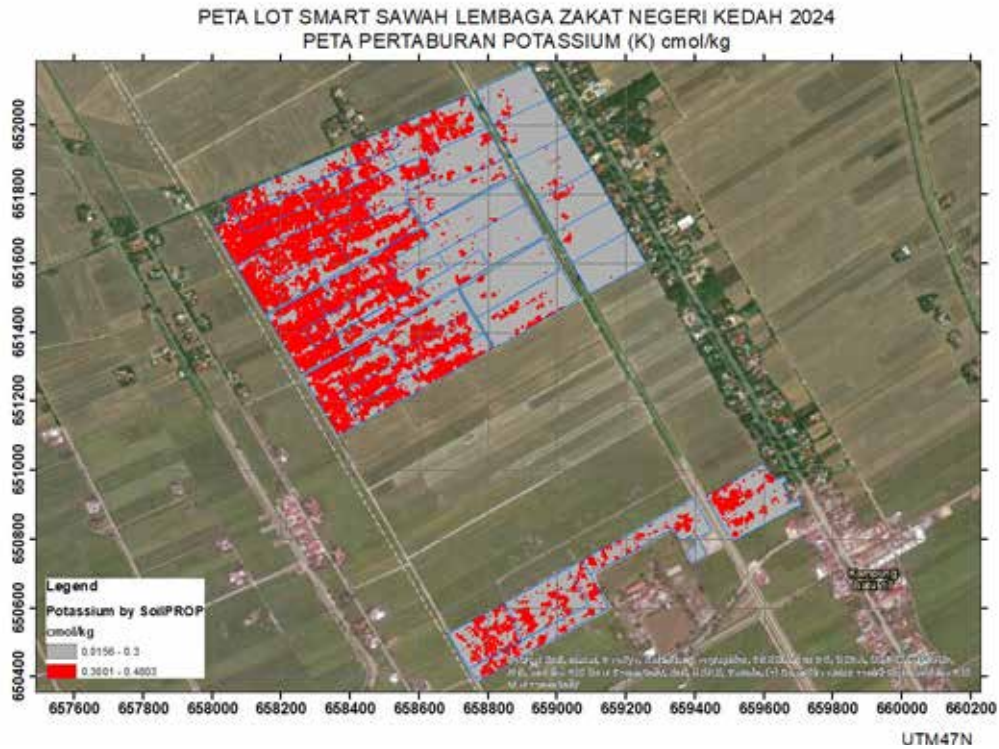


Figure 4: Sample of soil variability map produced by SoilProp®. The map shows the variability for Potassium in a rice field in the district of Yan, Kedah

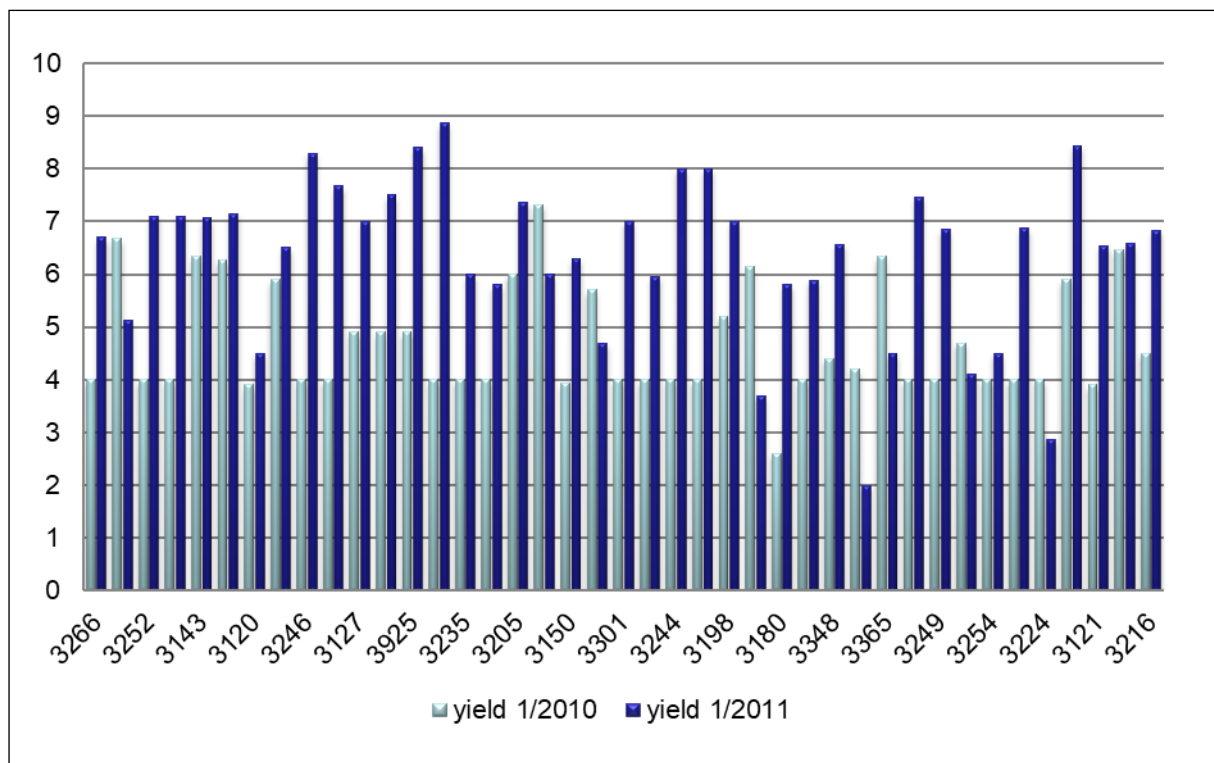


Figure 5: Comparison of the rice yield by using conventional fertilisation practices (1/2010) to the SoilProp® fertilisation recommendation (1/2011).

The impacts

Reducing over-fertilisation is crucial for minimising environmental degradation. Excessive fertiliser use can lead to nutrient runoff, which contaminates water bodies and disrupts ecosystems. By using SoilProp®, farmers can significantly reduce the environmental impact of their agricultural practices, promoting more sustainable and eco-friendly farming methods.

SoilProp® is designed to rapidly provide accurate soil information, significantly improving efficiency compared to conventional methods. For an area of 100 hectares, SoilProp® can deliver results within three to four days, whereas traditional soil fertility assessment methods typically take two to four weeks. These traditional methods are labour-intensive, costly, and time-consuming, requiring substantial human resources and financial investment.

By implementing the SoilProp® system, farmers can achieve notable economic benefits. Crops cultivated using this system have shown an increase in yield by up to 26%, while fertiliser costs can be reduced by up to 50%. This dual advantage not only boosts farmers' income but also enhances overall agricultural productivity. Moreover, by optimising fertiliser use, the system helps farmers apply the precise amount of nutrients needed, reducing waste and ensuring that crops receive optimal nourishment for growth.

In addition to the direct benefits to farmers, the system also offers significant advantages for Government agricultural policies. Fertiliser subsidies constitute a major portion of Government support for farmers. By enabling more efficient and effective fertiliser use, SoilProp® allows for better control and a potential reduction of these subsidies, leading to substantial savings in public expenditure.

Furthermore, the system plays a critical role in environmental conservation. By minimising the overuse of chemical fertilisers, SoilProp® reduces nutrient runoff into water bodies, thereby reducing pollution and mitigating the negative impact on ecosystems. This technology supports sustainable farming practices, promoting a balance between agricultural productivity and environmental stewardship. ■

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Application of Drones Towards Agricultural Excellence

By Lim Guang Ming
Chief Remote Pilot – Drone Academy Asia

Dato' Prof. Ir. Dr Eric Goh, FASc
Honorary Professor – SMMRE, Universiti Sains Malaysia



The engineering fraternity and the respective industrial sectors are increasingly demanding Drone Solutions in project problem solving, which allows faster and more precise production decision-making for enhanced workflow efficiency. Accurate site surveys, data compilation and rapid data analysis can help in effectively monitoring work site progress, strategically increasing industrial productivity, and implementing efficient site environmental management and occupational safety standards. Thanks to the recent leap in digital technology, drones have emerged as invaluable tools for the agricultural sector to progress towards world-class excellence via improvement in remote data collection and enhancement in project management and productivity, resulting in a positive upsurge in profits – definitely a win-win situation for all in the industry.

The objective of the application of smart engineering technology is to yield optimal benefits and project outputs within the existing operating budget. Cost-effective state-of-the-art technology and work practices should thus focus on the best, most efficient, accurate and effective techniques to eventually further increase overall profitability and maintain good governance practices. Innovations in any industrial technology should assist overall savings in duration of implementation, data analysis and project expenditure.

Imagine a technology that can complete a 2-hectare aerial survey in six minutes with high-resolution data outputs and produce an accurate digital harvested product model with 3cm accuracy. This unique feat is made possible using Unmanned Aircraft Systems (UAS) technology, commonly known as drones.

The specifications of drone technology are improving rapidly, complemented by a reduction in costs. We are confident that geo-referenced aerial surveys can be effectively used to increase agricultural site surveys and agricultural productivity and even shorten the time for accurate environmental studies from the present project execution of weeks to hours at any agricultural site worldwide.

LEGAL REGULATIONS FOR THE USAGE OF DRONES IN MALAYSIA

The use of drones is bound by legal regulations set up by the relevant regulatory agencies, namely, the Civil Aviation Authority of Malaysia (CAAM), the Malaysian Communications and Multimedia Commission (MCMC), the Department of Survey and Mapping Malaysia (JUPEM) and SIRIM. Highlights of the major legal regulations to be noted for the appropriate use of drones for flights and projects are:

- Regulatory authorities' approval to be obtained before the start of the project;
- Drones must only operate at less than 122m (400ft) above ground level;
- Drones are not allowed to fly closer than 30m to people, buildings/vehicles;
- Drones are not permitted to fly into restricted/prohibited/security areas;
- Special permission is needed to operate within 9.26km of airports/helipads;
- Drone communication must use only approved sets of radio frequencies;
- Airspace Management Classification for Drones to be strictly adhered to;
- A permit is required for any Drone Aerial Work which takes photographs; and
- The designated 'Drone No-fly Zone' areas must be strictly observed.

There is a great emphasis worldwide placed on industrial safety, site security, individual protection against potential accidents, and privacy expectations in the responsible usage of drones. A heavy fine of up to RM50,000 and/or maximum imprisonment of three years for any negligent individual drone operator penalised for not adhering to the established legal drone regulations is thus instituted to encourage the accountable

safe use of drones. The fine is increased to RM100,000 if the task is carried out under the directive of a body corporate or company.

BENEFITS OF USING DRONES FOR INDUSTRIAL OPERATIONS

Acknowledging the present-day emphasis on operation economics and personnel occupational safety risks in data collection for production monitoring and inspections at any industrial site, the application of drone technology can greatly reduce the risks involved by minimising the time personnel spend at high-risk accident-prone areas such as those with steep slopes or are environmentally sensitive or chemically hazardous.

Drone-based data collection can also boost productivity since survey projects which used to take weeks to finish can now be completed in a few hours. Since it is airborne, a lot of time is saved in not having to overcome challenging topographical surface terrain problems at the respective industrial sites. A high-resolution drone photo can quickly verify any site information required, thus minimising the risks of inaccurate reporting on the selected site. A large economic saving in this data monitoring and collection phase is possible since fewer hours are now required to collect large yet accurate data sets for rapid analysis and decision-making by the top management.

A drone evaluation study carried out in the industry reported some operators as saying that a single imaging drone can pay for itself in a few months. The financial savings are derived from the ability to make quick management decisions based on market trends and overall time savings in data collection and information analysis. The precise drone information outputs often help in optimal decision-making by the respective Government and corporate management teams.

STRATEGIC APPLICATIONS OF DRONES TOWARDS AGRICULTURAL EXCELLENCE

Drones can greatly assist the agricultural industry and the respective operators to manage their tasks more efficiently, reduce costs and increase crop yields while enhancing occupational safety

and minimising potential environmental impacts. Highlights of the major applications of drones in agriculture are as follows:

Aerial Field Mapping



Field Mapping methodology using drones has revolutionised the agriculture industry by providing precise, high-resolution imagery data that enhances agricultural management and decision-making processes. Drones can provide detailed 3D maps for soil analysis, helping operators in the agricultural sector make informed decisions about efficient irrigation and strategic soil management.

Drones equipped with advanced sensors, including RGB cameras, multispectral cameras or LiDAR sensors, can capture rich data to provide managers with multiple data outputs such as 3D Models, Orthomosaic images, Multispectral data, Digital Terrain Models and more, enabling them to create accurate maps of their fields, monitor their plantation sites — including the borders — for land utilisation (via soil analysis), land terrain setup and water stressed areas.

Thermal cameras on drones can also identify areas of the agricultural site that need more water, helping plantation operators optimise their irrigation systems. The status of a plantation can be obtained more quickly and easily. The use of drones for aerial mapping reduces the need for manual field inspections, saving time and labour costs while increasing the accuracy of data collection.

The integration of Real-Time Kinematics (RTK) modules in drones ensures centimetre-level accuracy in terms of geospatial information, which is essential for precision agriculture.

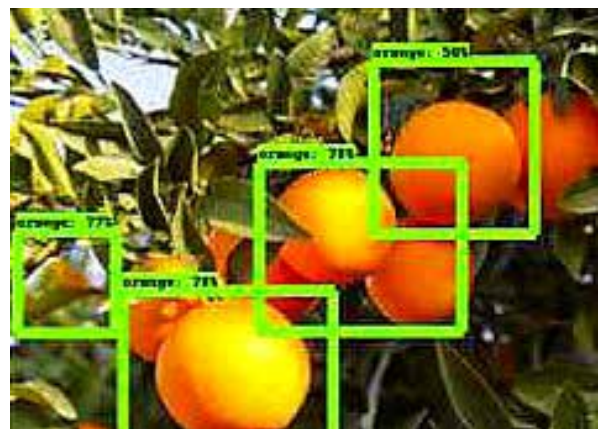
Overall, the strategic application of drones in aerial field mapping can create detailed

maps of agricultural sites, including topography, crop distribution and variations, enabling great improvements in efficient resource management, boosting crop yields, and improving precision farming techniques resulting in a positive outcome in sustainable agricultural practices worldwide.

Crop Monitoring

Specialised agricultural drones equipped with multispectral, thermal and visual cameras can effectively monitor crop health and assess plant growth and development while also helping to identify issues like potential crop diseases and pest infestations. Multispectral and thermal imaging is a transformative technology in agriculture — it provides critical insights into crop health and soil conditions. Multispectral sensors normally provide five wavelengths data: Red, Green, Blue, Red Edge and Near-Infrared. Drones equipped with multispectral and thermal cameras can capture data in these wavelengths which can then be used to calculate vegetation indices to estimate crop health since crops perform photosynthesis differently under different health conditions. The data is used to generate vegetation indices such as the Normalised Difference Vegetation Index (NDVI) which greatly helps agricultural operators and managers to quickly assess their crop health and detect diseases, allowing rapid decision-making in the optimisation of their irrigation, fertiliser and pesticide application practices. Multispectral, thermal and visual imaging allow for the early detection of crop stress, enabling timely interventions that can prevent probable yield losses.

Another useful application of drones is in estimating crop yields by analysing plant height,



density and health, providing plantation managers with invaluable information for strategic planning and economic market predictions.

Some agriculture-centred drones can be designed to plant seeds at sites, especially in difficult-to-reach areas, thus providing a faster and more efficient method than traditional planting techniques.

After severe weather events like storms or flooding, drones can be quickly deployed to carry out damage assessments of the affected crops and infrastructure. The drone data obtained will provide plantation/farm operators with a quick assessment of the damage so that they can respond faster and more effectively to mitigate the situation. Drones can also help document crop damage and losses during ill-timed incidents, providing accurate data for insurance claims. The ability to accurately monitor large agricultural areas quickly and efficiently makes this technology invaluable for precision agriculture management.

Aerial Spraying



Aerial spraying is typically categorised into two categories: Blanket Spraying and Spot Spraying. Blanket Spraying is suitable for flat terrain crops such as paddy (rice crops), pineapples and others. Spot Spraying is more suitable for fruit trees or crops on varying terrain such as oil palms. Spot Spraying maximises spraying efficiency as it directs the fertiliser sprays to the crown or top of the trees.

Drones can be effectively used to apply pesticides, herbicides and fertilisers precisely, helping to reduce excessive chemical usage and minimising potential hazardous environmental impacts. Systematic aerial spraying using

drones has significantly improved the efficiency and effectiveness of pesticide and fertiliser applications in the agricultural industry. This unique technology allows for accurate targeted aerial spraying, thus ensuring that only the necessary areas are treated. The beneficial outcomes are the conservation of resources and the reduction of production costs.

The ability of drones to operate in various terrains and conditions provides flexibility and ensures accurate spraying, adhering to the strategically planned crop maintenance programme. Agricultural spraying drones also reduce the unintentional exposure of farm personnel to hazardous chemicals, resulting in improved occupational safety and health.

Based on information obtained from precision aerial mapping or geospatial information, drones can limit spot spraying to just the crown and inner fronds of crops to maximise the efficient use of fertilisers and herbicides. Optimising spraying processes using aerial spraying with drones can improve crop health, increase personnel productivity and contribute to an upsurge in overall yield.

CONCLUSION

The specifications of present-day technology for agriculture-centred drones are improving rapidly, resulting in a sharp reduction in drone ownership costs when compared to the costs of earlier drone models. The logistical and cost advantages of drones include a 99+% result accuracy, the ability to safely complete the task up to 85% faster and costing five times less for project implementation with more deliverables when compared to traditional work practices. Other project operational rewards include improved accuracy with outputs of higher resolution images (2.6 cm/pixel resolution)—an impressive benefit for more effective top management decision-making. These innovative geo-referenced drone-centred aerial surveys and site monitoring projects can thus be confidently carried out with increased efficiency and productivity at any respective agricultural site worldwide. The present evolution of drone technology towards 5G-powered smart drones will advance this essential industrial sector to world-class excellence in due course. ■

Machine Learning and Global Climate Modelling for Projecting Irrigation for Rice Cultivation

By **Muhammad Adib Mohd Nasir**
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Did you know that the irrigation supply for large-scale rice granaries comes from river basins and rivers? Malaysia has rice granaries that contribute up to 690,000 ha relying on these water resources (Dorairaj & Govender, 2023). Massive amounts of water are required to irrigate the rice granaries, which have become a pillar of sustainable rice production in Malaysia. However, the use of water resources requires proper management and planning to ensure their availability to fulfil irrigation demand. Therefore, future prediction of the availability of water resources is crucial to strategise rice granary cultivation.

It is not an easy task to deal with hydrological system stochasticity which is at the same time worsened by climate change. Today, machine learning (ML), a branch of artificial intelligence (AI), has shown its talent as a powerful predictive tool in agro-hydrological modelling. In addition, with the huge amount of data required for Global Climate Models (GCMs), ML is becoming crucial in handling this data with impressive accuracy. The goal of ML and GCMs in agro-hydrology is to improve prediction outcomes, reduce the cost and time of implementation, and advance irrigation and water resources research.

Rice Granary

Rice is cultivated across 142 million hectares globally and serves as a staple food for the world.

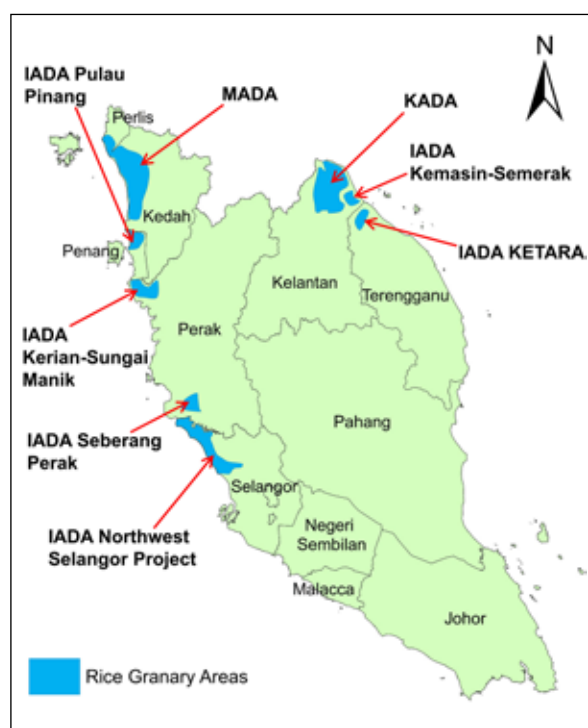


Figure 1: The eight rice granary areas in Peninsular Malaysia

Approximately 90% of it is found in the monsoon regions of Asia, with 75% relying on irrigation supply while the rest is rainfed (Rowshon et al., 2019). In Malaysia, two-thirds of rice granaries are distributed across Peninsular Malaysia, and the remainder is in Sabah and Sarawak. It encompasses eight main rice granaries located in Peninsular Malaysia as shown in Figure 1: Muda Agricultural Development Authority (MADA),

Irrigation scheme	Irrigation water resources	Reference
MADA	Muda River Basin, Pedu river	Firdaus et al. (2020)
KADA	Kelantan River Basin, Kemasin river, Ketereh river, Semarak river	Mohd Aris et al. (2023)
IADA Kemasin-Semerak	Semerak River Basin	Samsudin et al. (2023)
IADA KETARA	Besut River Basin, Angga river, Pedu river	Lee et al. (2005)
IADA Kerian-Sungai Manik	Kurau River Basin	Adib & Harun (2022)
IADA Northwest Selangor Project	Bernam River Basin	Ismail, Rowshon, et al. (2020)

Table 1: Irrigation water resources for rice granaries in Malaysia

Kemubu Agricultural Development Authority (KADA), Integrated Agriculture Development Project (IADA) Kerian-Sungai Manik, IADA Pulau Pinang, IADA Seberang Perak, IADA Northwest Selangor Project, IADA Kemasin-Semerak, and IADA North Terengganu Integrated Agriculture Development (KETARA).

Apart from these granaries, there are mini granaries that contribute approximately 76,094 ha, making a total area of 689,268 ha (Dorairaj & Govender, 2023; Vaghefi et al., 2016).

Rice is a staple food in Malaysia and a defining feature of our culture. Khazanah Research Institute (2019) reported that in 2016, Malaysian citizens consumed 80 kg of rice per person, costing an average of RM44/month per household. In the same year, the consumption of rice reached 2.7 million metric tonnes (m MT²), with 67% domestically produced, and the remaining portion imported from Thailand, Vietnam, and Pakistan.

Irrigation Supply

To successfully achieve the five pillars of the National Food Security Policy Action Plan (2021–2025), which are availability, accessibility, consumption, stability, and sustainability for rice (Dorairaj & Govender, 2023), it starts with irrigation water availability as a massive volume of water is a key element for rice growing areas. In Malaysia, rice is planted twice annually (double cropping) over two seasons. The main season (humid weather, normally the last six months of the year) is less irrigation-dependent, whereas the off-season (dry

weather, normally the first six months of the year) depends on irrigation (Nasir, Harun, et al., 2024; Rowshon et al., 2019; Tukimat et al., 2017). The rice is cultivated under constant irrigation to ensure sustainable and continuous production.

Rice irrigation for double-cropping practices consumes nearly 80% of Malaysia's water resources. Rice field systems in Malaysia rely primarily on river water from river basins to meet the high irrigation requirement, although they are often inadequate, especially during the off-season. Consequently, difficulty arises in allocating irrigation water supply to rice fields. Table 1 shows the river basins and rivers that act as the primary irrigation sources for the rice fields. Some rice schemes integrate river flow from river basins with reservoirs to overcome water shortages and fulfil irrigation needs. Therefore, forecasting streamflow is needed to understand the complicated phenomena of this hydrological system (Yaseen et al., 2016) which could help decision-makers plan and manage the irrigation supply optimally according to rice irrigation demand and to ensure that the water resources from river basins and rivers are capable of irrigating the rice fields for the whole year.

Hydrological Modelling

ML is an application of AI that is a versatile field encompassing various algorithms and techniques, arguably the most noteworthy contemporary advancement in hydrological modelling. The ML process follows the human learning process as

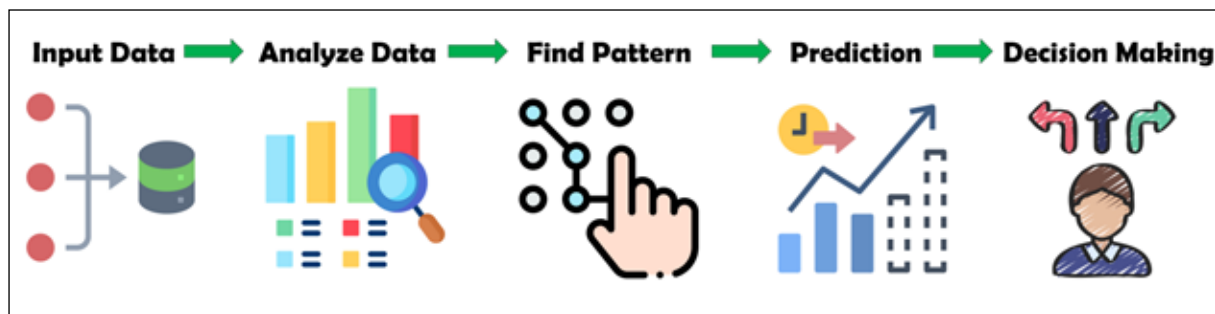


Figure 2: Machine learning workflow

Reference	Models used	Timescale / Study	Study area
Tongal and Booj (2018)	SVR, RF	Daily streamflow	North Fork River, Chehalis River, Carson River, Sacramento River (United States)
Fox and Magoulick (2019)	RF	Monthly and annual hydrologic disturbance of stream	Arkansas, Missouri, eastern Oklahoma (United States)
Li et al. (2019)	ELM, RF, BPNN, SVR	Daily streamflow	Wei River Basin (China)
Sahoo et al. (2019)	SVR, ANN-ELM, GPR	Monthly low flow time series	Mahanadi River Basin (India)
Hussain & Khan (2020)	MLP, SVR, RF	Monthly streamflow	Hunza River Basin (Pakistan)
Konapala et al. (2020)	LSTM, PB, LSTM-PB	Daily streamflow	United States
Li et al. (2020)	ENR, SVR, RF, XGB, MSES	Monthly streamflow	Yangtze River Basin (China)
Pham et al. (2021)	RF, MLR, Naïve	Short-term daily streamflow	Watersheds in Pacific Northwest (United States)
Adib & Harun (2022)	SVR, RF	Monthly streamflow	Kurau River Basin (Malaysia)
Saravanan et al. (2023)	SVR, RF, M5P, MLP, LR	Daily streamflow	Godavari River (India)
Nasir et al. (2024)	SVR	Monthly streamflow	Kurau River Basin (Malaysia)

Table 2: ML-based models application for hydrological processes

illustrated in Figure 2. The ability to autonomously learn from past occurrences, deal with nonlinear physical processes, and address their complexity to make precise predictions using minimal data and mathematical equations without being explicitly programmed to do so has recently garnered significant attention from hydrologists (Xu & Liang, 2021). Physical-based models like SWAT (Arnold et al., 2012), HEC-HMS (USACE-HEC, 2000), and MIKE SHE (Refshaard & Storm, 1995), as well as

conceptual models like IHACRES and TOPMODEL (Abdulkareem et al., 2018), demand substantial input data comprising topography, soil moisture content, initial water depth, topology, and other physical catchment characteristics, rendering them resource-intensive, time-consuming and expensive. As water scarcity and extreme weather events are giving alarming signals, the application of ML in modelling future irrigation availability from river basins and rivers holds great potential

to contribute to sustainable water management practices, mitigate risks, and ensure the efficient utilisation of this precious resource. Collaborative efforts between hydrologists, data scientists, and policymakers are essential to harness the power of ML for a more resilient and water-secure future.

Employing ML techniques is crucial to deal with the increasing amounts of data to cope with the challenges of climate change and the ever-increasing human impact on the environment. The rapid progress made in ML is arguably the most relevant development currently in the field of hydrology and climate change. Only in the past few years have these ML techniques become more prominent among researchers in hydrological processes and climate change (Ardabili et al., 2020).

Several ML algorithms have proven to be very efficient in hydrological modelling, as listed in Table 2, including support vector regression (SVR), random forest (RF), extreme learning machine (ELM), back-propagation neural network (BPNN), artificial neural network-extreme learning machines (ANN-ELM), gaussian process regression (GPR), multilayer perceptron (MLP), long short-term memory (LSTM), process-based (PB), elastic net regression (ENR), extreme gradient boosting (XGB), modified stacking ensemble strategy (MSES), multiple linear regression (MLR), M5-pruned model (M5P), and linear regression (LR).

Climate Change Impact and Assessment

Today, climate change caused by increased greenhouse gas (GHG) concentrations and CO₂ levels in the atmosphere has worsened the water availability status for rice irrigation in Malaysia. Rice cultivation has shown a sign of critical irrigation, particularly in the northern region, where the water stress index for rice production surpasses that of other states (Hanafiah et al., 2019), and the western part is predicted to experience future depletions in water sources from river basins (Ismail et al., 2020). The uncertain trajectory of climate change in the future is poised to have an impact on water resources and the need for crop irrigation, which is highly sensitive to changes in precipitation and temperature, making the effective management and allocation of water resources a challenging task (Srivastav et al., 2021). The expected rise in food demand under climate

change would also significantly impact irrigation demand, adversely impacting rice production. Therefore, the predicted shortage in future available water resources makes it imperative to evaluate the fluctuations and uncertainty of future water supply under the influence of climate changes to ensure the sustainability of rice production and water resources (Mirzabaei et al., 2023; Molotoks et al., 2021).

Within Southeast Asia, climate change primarily stems from alterations in precipitation, surface temperature, sea temperature, and sea level (IPCC, 2022). Scientists utilise advanced climate models to understand the complex dynamics of the evolving climate to make well-informed decisions. Global Climate Models (GCMs) have been developed by many international groups participating in the Coupled Model Intercomparison Project (CMIP). GCMs are the climate models covering Earth at a relatively lower resolution with their grid systems, including ocean circulation, which are used to simulate decades to centuries. The period covered is typically up until 2100, but in some scenarios, experimental data can reach up to 2300. As shown in Figure 3, GCMs divide the globe (atmosphere and oceans) into horizontal and vertical grids, creating gridboxes. The climate models are the most dependable datasets for assessing forthcoming challenges, signifying a collective and interdisciplinary endeavour that significantly advances the comprehension of climate dynamics. These models provide valuable insights into possible strategies for mitigation and adaptation (Han et al., 2020). The latest of its kind, CMIP and CMIP6, fall under the Fifth Assessment Report (AR5), presenting advancements in land use, energy considerations, and uncertainties linked to greenhouse gas emissions compared to the previous versions (Moss et al., 2010). Compared to its predecessors, CMIP6 is more expansive regarding the number of models and scenarios it encompasses (Zarrin & Dadashi-Roudbari, 2021), with an increased horizontal resolution, increased complexity in the physical modelling schemes, and novel shared socioeconomic pathways (SSPs) (Abbasian et al., 2019; Ahmadi et al., 2020; Riahi et al., 2017; Taylor et al., 2012). Specifically, CMIP6 stands as a foundational element in modern climate science, delivering a comprehensive perspective of Earth's climate system and its

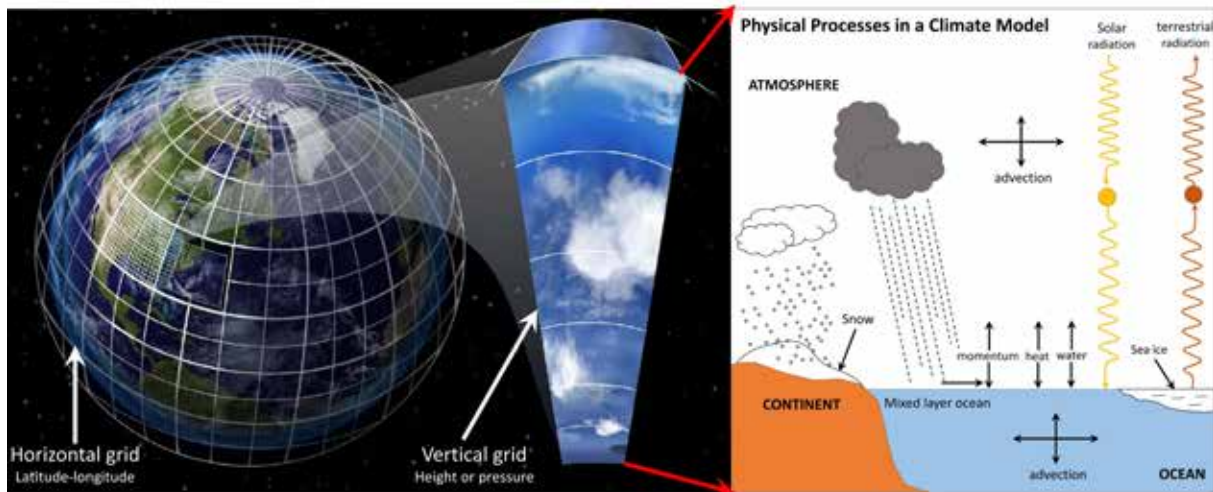


Figure 3: GCM grid system component (Adapted from Lukas et al., 2014)

potential trajectories. With increased realism, expanded scope, and diverse scenarios, CMIP6 equips us with the essential knowledge to navigate the evolving climate responsibly and forge a sustainable path toward a resilient future (Eyring et al., 2016).

Coupling of Machine Learning and Global Climate Models

ML coupled with GCMs for modelling future irrigation water availability from river basins and rivers for rice granaries has made the process much easier, relying solely on climate data. The only key data needed to successfully model future rice irrigation water availability using ML are precipitation, temperature, relative humidity, and wind speed for observed and GCMs. Figure 4 shows the framework of the ML technique as a streamflow predictive model considering future climate change.

The observed streamflow (river flow rate) data is also needed for training and testing purposes under ML. These climate data will be trained and tested under the selected ML technique to study and capture the pattern of observed streamflow. Adib and Harun (2023) have evaluated the performance of two MLs, named support vector regression (SVR) and random forest (RF), to predict streamflow patterns of the Kurau River from the Kurau River Basin solely based on climate parameters. The models successfully achieved

good performance results, as categorised by Moriasi et al.(2015). The validated ML model can then be used for future river flow projection to model the availability of irrigation supply for rice granaries (Adib & Harun, 2022). At this point, future climate data extracted from GCMs that have been downscaled to the required study area are injected into the validated ML model. The validated ML will then use the GCM data to generate future streamflow values from river basins and rivers to assess the availability of water resources for rice irrigation. The GCM can provide future projections up until 2100, while certain scenarios can reach 2300.

ML algorithms can expedite the process of model calibration, parameter optimisation, and uncertainty quantification, reducing the computational burden associated with traditional hydrological modelling techniques and enabling easy access to water resource availability statuses. This efficiency enables researchers and practitioners to perform ensemble simulations, sensitivity analyses, and scenario assessments more quickly and cost-effectively.

Future projections of irrigation availability for rice are crucial for several reasons:

- **Food Security:** Rice is a staple food for a large portion of the world's population, particularly in Asia. Reliable irrigation is essential for ensuring stable rice production. Future projections help policymakers and farmers anticipate potential water shortages or changes in

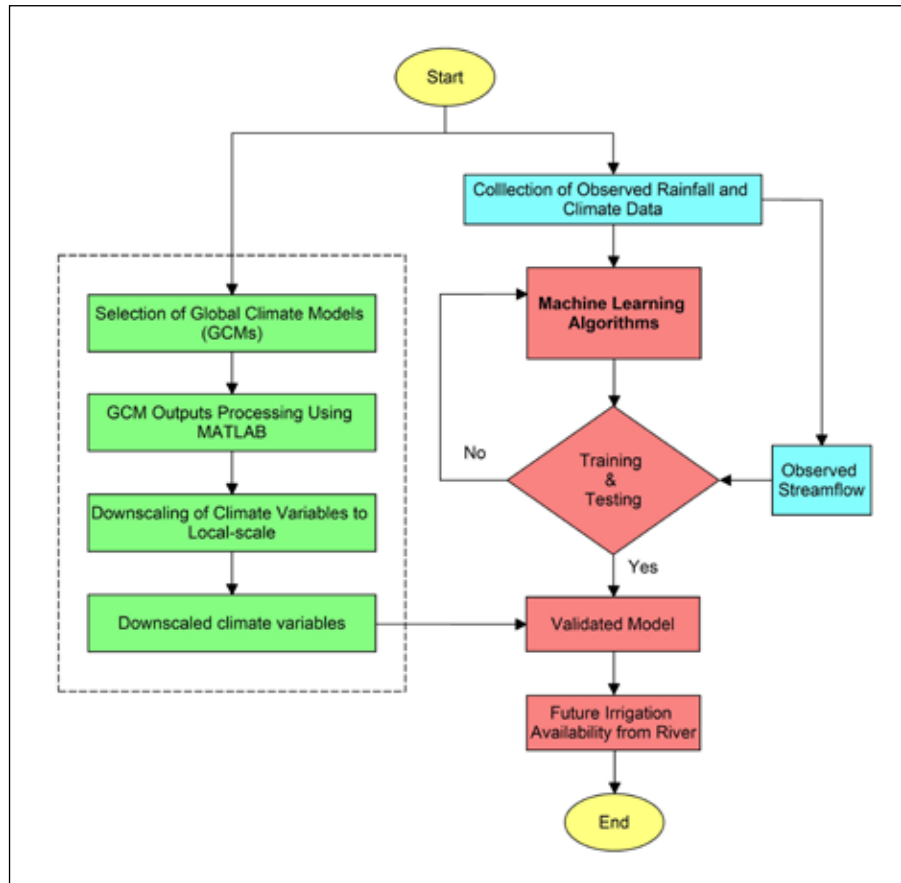


Figure 4: Coupling ML and GCMs for modeling future irrigation water availability

water availability due to factors such as climate change, population growth, and competing water demands.

- **Climate Change Adaptation:** Climate change is expected to alter precipitation patterns, increase temperatures, and affect the availability of water resources. Future projections of irrigation availability for rice can help farmers and policymakers develop adaptation strategies to cope with these changes, such as implementing more efficient irrigation techniques, shifting planting schedules, or diversifying crop choices.
- **Water Resource Management:** Understanding future irrigation availability allows for better management of water resources. It enables policymakers to allocate water resources efficiently, prioritise water use among different sectors, and implement measures to

conserve water and improve water-use efficiency.

- **Economic Stability:** Rice farming is not only important for food security but also for the economy of many regions. Predicting irrigation availability helps farmers make informed decisions about crop selection, investment in irrigation infrastructure, and risk management strategies, which ultimately contribute to economic stability and livelihood security.
- **Environmental Sustainability:** Irrigation practices can have significant environmental impacts such as depletion of water resources, soil degradation, and habitat loss. Future projections of irrigation availability can inform efforts to balance agricultural production with environmental sustainability, promote practices that minimise water waste, preserve soil health, and protect natural habitats.

Challenge in the Application of Machine Learning in Hydrological Modelling

When dealing with hydrology systems, we are actually dealing with the stochasticity of nature. Therefore, it is not easy to perfectly replicate the streamflow data due to its complexity and dynamic nature. The climate conditions in Malaysia are very inconsistent, especially for the two planting seasons. The difference in climate nature between these two seasons somewhat disrupts the streamflow modelling process under ML (Adib & Harun, 2022; Nasir et al., 2024), and this also eventually impacts the future projections under GCMs. Although the model performance for streamflow modelling under ML easily achieves acceptable results, to maximise the model performance and especially to capture irregular extreme low flow or extreme high flow, it is suggested to either run the model development separately for the off-season and the main-season or use different ML algorithms for these two different seasons (Nasir et al., 2024). In addition, Adib and Harun (2022) put together two ML algorithms, SVR and RF, to minimise errors in the prediction of low flow and peak flow. These solutions could potentially improve the model performance but require additional work or more than one ML algorithm.

Conclusion

The intricate balance between water availability and the demands of rice cultivation underscores the critical importance of effective water resource management in sustaining food security, economic stability, and environmental sustainability, particularly in regions like Malaysia which has a significant rice production sector. The reliance on river basins and rivers for irrigation supply necessitates proactive planning and management strategies to address challenges posed by climate change and population growth. Integrating ML with GCMs presents a promising approach to projecting future irrigation water availability for rice granaries. By harnessing the power of ML algorithms to analyse climate data and simulate streamflow patterns, researchers and policymakers can gain valuable insights into

potential water resource scenarios and develop adaptive strategies to ensure the resilience of rice production systems. In essence, the synergy between ML and GCMs offers a pathway towards a more resilient and water-secure future for rice cultivation, not only in Malaysia but also in other rice-producing regions globally. Through collaborative efforts among researchers, practitioners, and policymakers, we can leverage advanced technological tools to address the complex challenges facing agricultural water management and pave the way for sustainable rice production in the face of evolving environmental dynamics. ■

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Keeping Up With Agriculture Technology

By Majidah Hashim

I wonder how many of us have actually seen an original banana? They are nothing like the soft, yellow, seedless fruit we enjoy today. In fact, as one of the oldest fruits known to humankind, the banana has gone through quite a drastic evolution, mostly human-made.

Very little of the original banana could be eaten. The fruit pods were filled with cavities that held bullet-like seeds surrounded by hard pulp. Through several generations of cross-breeding and genetic modification, we have created the yellow banana that we all recognise today.

THE SUPER BANANA

All modern bananas that we have today are Cavendish bananas. And while there are a variety of them, they are all of a similar banana species. How similar? I mean exactly and precisely similar, as in, they all share the same DNA and scientists view them as essentially clones of each other.

Genetically engineering bananas has not only made them more edible to humans, but we can now grow a lot of them and they have been strengthened against many banana diseases (though because they are all clones, it would now take just one disease to wipe out the entire species).

Of course, we did not stop at bananas. From corn to potatoes to papayas, the moment humans started to adopt a more agrarian lifestyle, we have been on a mission to produce with abundance. We have been able to delay the softening of ripe tomatoes, allowing them to have a longer shelf life. We have created special rice variants with increased beta-carotene (vitamin A). Countless crops have been made more pest-resistant, enabling farmers to use less pesticide. We have made some crops grow faster, enabling farmers to have more harvest rotations in a year. We have even been able to make our crops weather-

resistant, allowing them to thrive in drought and increased precipitation.

It all comes down to making these crops a more viable part of the human food chain.

While there are a number of on-going health and ethical concerns about genetic modification of food, it is clear that without it we would not be able to feed this planet's growing population.

Labs all over the world are continuing with breakthroughs that include engineering lab-grown meats. Increasing numbers of blind taste tests have shown that lab-grown meats are becoming indistinguishable from animal meats. We can certainly expect these products to appear on our supermarket shelves in the near future.

ENTER THE ROBOTS

I think that the agriculture sector has witnessed some of the most exciting feats of engineering in the last few decades, maybe even more than most other sectors. Let's just say we have come a long way since our dependence on water buffaloes. Agriculture today has become quite a science.

Not only can we genetically engineer the seeds, we can now control every single aspect of the seed's life. The seeds can be germinated in a climate-controlled environment, where weaker shoots are immediately discarded and only the strongest seedlings are prepared for cultivation. The land is ploughed by machines, achieving in one afternoon what would have taken humans (and water buffaloes) weeks to do.

Even sowing the seedlings into the ground can be done with precision using machines. Throughout the growth of our little plants, more robots and drones can be deployed for anything from measuring the moisture in the soil to fertilising, weeding, pruning, and eventually, harvesting. In some places, satellites are used

“ One of the things we do need to be careful of is to make sure that no one is left behind with the development of agricultural technology, as some of its participants are among the most impoverished in society.

to predict the weather. In other places, huge greenhouses are built to control the weather.

Even in the cities, there is a growing trend in urban farming. From balconies to rooftops, many are taking to growing simple plants and herbs to reap both their benefit to our nutritional needs and also their benefit to our mental health.

Vertical farming, often coupled with aquaponics, is also on the rise with hundreds of kilos of crops harvested from very small spaces. This soil-less method of farming means that crops can now be grown anywhere, including inside malls, as we have seen in the Klang Valley.

THE MODERN FARMER ENGINEER

Given all the advancements in technology in the agriculture sector, there are still numerous serious unresolved issues for engineers and scientists to address.

Despite the benefits of the genetic modification of food, its ethical debate remains a hot potato topic. It is practically unpredictable to say if genetically modifying a banana or tomato will have adverse effects on humans in the long term.

What is clearer is how making some crops resistant to pests, has altered the delicate biodiversity of our natural ecosystems. The insect population, in particular, have been inadvertently affected by the engineering that we have done. There is a rising concern in some countries that the local bee population is dwindling to a point where it is affecting pollination among crops.

Other sectors have also started to look into agriculture as a means of obtaining their resources. The development and production of biofuels, in particular, has been quite controversial over the last few years with its competition against food sources.

And then there are the robots. It is an ongoing debate if robots are going to replace farmers

in the fields even as they have replaced many workers in other sectors. It used to be that families would encourage their children to pursue higher education so that they could get nice jobs in the city and not need to do the backbreaking work of taking care of farms in the *kampungs*.

It does seem, however, that increasingly one needs to have at least an IT degree to be able to keep up with all the technology that is flooding the agriculture sector today. With dashboards and robots and all sorts of tools, farmers these days have so much information available to them at their fingertips, from the pH of the soil to weather forecasts for the next three weeks.

With so much investment made into farms these days, there is a worry that small farms will not be able to keep up with those who can afford expensive technology. One of the things we do need to be careful of is to make sure that no one is left behind with the development of agricultural technology, as some of its participants are among the most impoverished in society.

Climate change is also an issue that the agricultural sector needs to be mindful of and be adaptive to. In many parts of the world, extreme weather, such as flash floods, has annihilated whole farms in a matter of days, wiping out the crops that farmers have worked so hard to cultivate. Extreme heat experienced in parts of the world has also made it unhealthy for farmers to stay out in fields for long hours.

As Malaysians, food plays a central role, not only in providing us nourishment but also as an integral part of our culture and our way of life. For this reason, we will always be curious about and interested in where our food comes from. As one of the primary industries in our country, the doors of innovation in the agriculture sector are wide open, and it is truly exciting to see what will come through them. ■

3D Modelling for the Agrifood Industry

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Chong Jia En
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Three-dimensional (3D) modelling has revolutionised various fields by providing accurate, detailed visual representations of real-world objects and environments. Its applications in engineering for monitoring purposes are well-established. For example, in building monitoring, 3D models enable precise inspections, facilitating the identification and rectification of structural issues to enhance safety and efficiency. In the agrifood industry, 3D modelling allows for detailed analysis of crop growth, soil conditions, and irrigation patterns, promoting precision farming and post-harvest practices that optimise output and resource use. The technology also supports advanced simulations and predictions, enabling evidence-based management and decision-making in both sectors. 3D modelling's ability to capture and analyse complex data sets makes it an invaluable tool across diverse applications. This article aims to demonstrate the use of 3D modelling for crop monitoring and post-harvest handling, highlighting their contribution to enhancing precision agriculture and enabling data-driven decision-making, ultimately improving outcomes for all stakeholders in the agrifood value chain.

3D modelling techniques refer to the methods and processes used to create 3D representations of objects or environments. In the context of crop growth monitoring, these techniques enable the

visualisation and analysis of plant structures, allowing precise measurements and assessments to inform agricultural practices. The fundamental principles of 3D modelling include accurate data collection, precise data processing, and detailed visualisation.

Accurate data collection involves capturing spatial information using technologies like LiDAR, photogrammetry and laser scanning, ensuring that the model reflects real-world dimensions and features. Precise data processing is crucial to convert raw data into usable 3D models, involving steps such as noise reduction, point cloud generation, and mesh creation. Detailed visualisation allows for the inspection and analysis of complex objects, enabling users to identify and address issues effectively.

In agricultural settings, one unique challenge is the dynamic and changing nature of the environment. Crops grow and change shape over time, requiring timely data collection and updates to the 3D models. Additionally, factors such as varying light conditions, weather, and seasonal changes can affect the quality and consistency of data collection. Furthermore, agricultural settings often span large areas. UAVs or drones can be used for data collection in open areas, while mobile and compact 3D image-capturing technologies are more suitable for indoor environments.

From Physical Objects to Virtual Models

The process of developing a 3D model begins with gathering initial data using methods like LiDAR scanning and photogrammetry to capture detailed spatial information about the object or environment. The raw data is then processed to create a point cloud, involving noise filtering, alignment of multiple scans, and ensuring precise measurements.

A point cloud comprises a group of unrelated or disconnected points; the points cannot be defined as having a shape. Subsequently, the point cloud data is converted into a mesh structure comprising vertices, edges, and faces that define the object's shape. Following this, textures and additional details may be applied to enhance realism to accurately portray colours, surfaces, and fine features. Lastly, the completed 3D model will be validated to verify its accuracy and completeness. High-density point clouds often result in higher computational costs. Therefore, further optimisation efforts may be performed to reduce file size or improve performance for specific applications.

LiDAR, RGB-D cameras, and photogrammetry operate on different principles to capture spatial data for creating 3D models. LiDAR uses laser pulses to measure distances precisely by calculating the time it takes for the light to bounce back from a surface. RGB-D uses structured light or time-of-flight technology to measure depth, producing a depth map along with colour information (RGB) and providing real-time 3D data. Photogrammetry involves taking multiple overlapping 2D images of an object or environment from different angles and using software to stitch these images together to create a 3D model. It relies on identifying common points in the images to reconstruct the spatial structure.

In terms of the captured data, LiDAR produces highly accurate and dense point clouds that can capture fine details of complex surfaces across large areas and is particularly effective in different lighting conditions. RGB-D technology is beneficial for indoor environments, short-range applications and dynamic environments as it can provide real-time data useful for applications like robotics and augmented reality. Photogrammetry can produce detailed and photorealistic 3D models, hence ideal

for applications requiring visual fidelity and texture detail. However, its accuracy depends on the quality and number of images, and it is sensitive to lighting conditions and surface textures.

Software tools like Pix4D and Agisoft Metashape are then used for processing and analysing aerial imagery and point cloud data. In agriculture, these tools are instrumental for creating detailed virtual 3D representations of fields and crops, facilitating precision agriculture practices such as crop monitoring, yield estimation, and soil analysis through accurate spatial data processing and visualisation.

Examples of 3D modelling for Crop Growth Monitoring and Post-Harvest Handling

The agricultural sector has long recognised the importance of developing time- and work-saving systems while maintaining the necessary efficiency and accuracy in producing the outcome. For crop growth monitoring, an accurate 3D representation of the crop is extremely important, but its development is highly time-consuming.

In our work at the Smart Farming Technology Research Centre, University Putra Malaysia (UPM), in collaboration with the Malaysian Agricultural Research Institute (MARDI), we utilised 3D modelling technology for monitoring crops grown in an indoor farming facility at MARDI. Specifically, we explored the feasibility of using photogrammetry-reconstructed 3D point clouds for crop height measurement, by comparing the height measured on the 3D point cloud to the physical height of the crop. The images used in the study were captured with a mobile phone camera, which is widely accessible to farmers and growers compared to LiDAR or RGB-D technologies.

Butterhead lettuce and rubber seedlings ($n = 20$ for each type) were randomly selected over a period of 45 days. A phone camera with 12 MP resolution and a focal length of 26mm was used to capture 30 to 50 images of each plant sample. Images were captured all around the crop without any preferential position, at irregular intervals using ambient lighting (see Figure 1a). For physical height measurement, a ruler was placed vertically next to the plant to get the height measurement

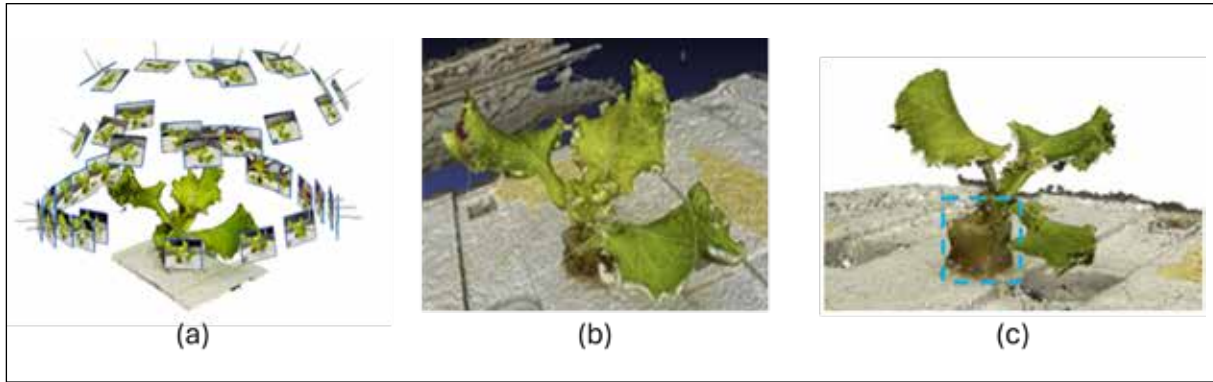


Figure 1: The process of 3D point cloud reconstruction using photogrammetry: (a) Multiple images were captured from different angles, (b) images were registered and matched to each other to form a point cloud, whereby each point contains location (co-ordinates X, Y, Z) and colour (R, G, B) data, and (c) the point cloud was then filtered to leave only objects used in analysis. The scaling object is the planting medium (blue rectangle with dashed line) with a height of 2cm.

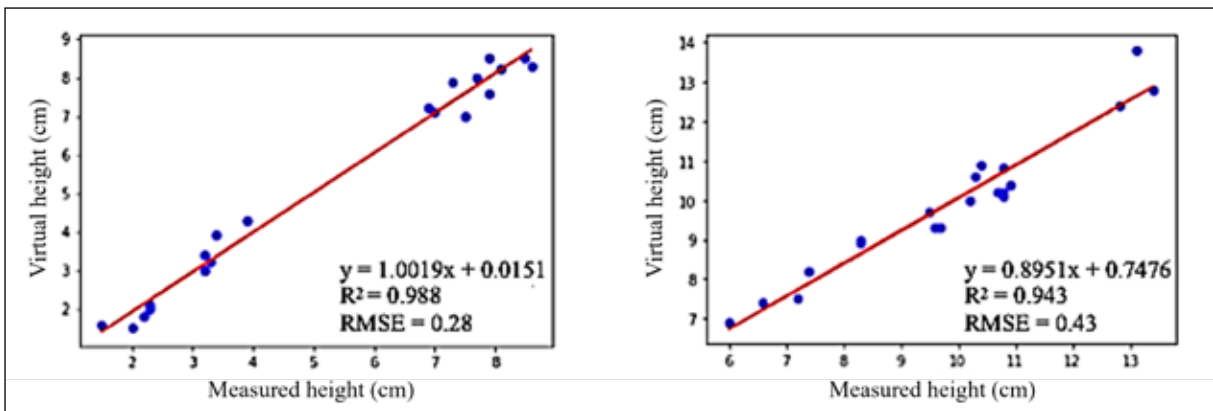


Figure 2: The virtual height obtained from the 3D point cloud of the crops matched the real-world height of the physical plants ($R^2 > 0.9$, $RMSE < 0.5$ cm).

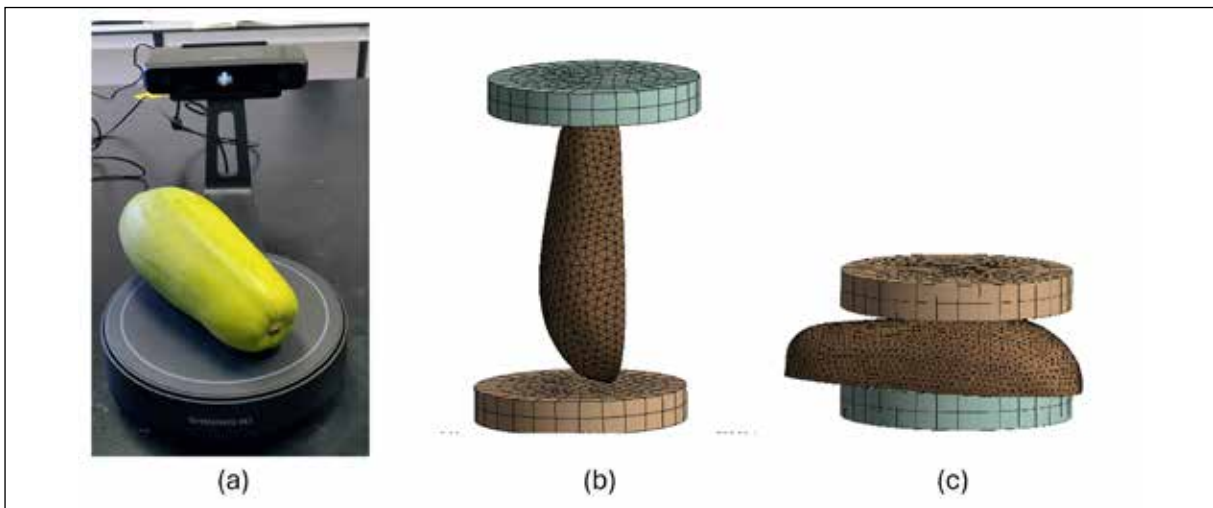


Figure 3: Using a 3D model of the papaya fruit to assist post-harvest handling. (a) The 3D model of papaya was reconstructed using a 3D scanner (b and c). The 3D model is exported into a finite element modelling software for mechanics analysis, whereby the effects of two loading orientations on papaya were investigated.

from the collar to the base of the highest fully extended leaf.

An open-source photogrammetric software, ColMap, was used to generate the 3D point cloud using the captured images (Figure 1b) and exported into another open-source 3D modelling software to filter the environment of any unwanted objects (Figure 1c).

To determine the virtual height of the plant using the 3D point cloud, a scaling factor that relates the real world to the virtual measurement is required. For this purpose, the planting medium, with a 2cm height (Figure 1c), was used to determine the scaling factor. The virtual plant height was measured from the highest point to the base of the plant's point cloud. This value is then multiplied by the scaling factor and carries the same unit as the real-world dimension.

To compare the real world to the virtual measurements, linear regression was performed, and the root mean square error (RMSE) was calculated. Particularly good agreements between the two measurements were found (see Figure 2) highlighting that the 3D point cloud reconstructed with the photogrammetry technique using images captured from mobile phone cameras can produce comparable real-world plant height measurements for crop growth monitoring.

At the Centre, we also utilised 3D modelling to assist in the post-harvest handling of papaya fruit. A 3D model of the fruit was used with finite element analysis to determine the mechanical injury extent (see Figure 3). The results informed the best orientation for storing or transporting papayas to minimise mechanical damage. This is crucial due to the papayas' thin skin, irregular shape and high water content, particularly as they ripen.

Pros and Cons of using 3D Models for the Agrifood Industry

Using 3D point clouds for crop growth monitoring enables farmers and agronomists to gain a deeper understanding of plant health, growth patterns, and environmental interactions. This allows for precise monitoring and management strategies tailored to specific areas within a field, optimising resource use such as water, fertiliser, and electricity. Furthermore, 3D models enable

enhanced data analysis through tools like spatial analytics and machine learning algorithms, facilitating predictive modelling for yield estimation and disease detection. The ability to visualise and analyse data in three dimensions provides a holistic view of crop conditions, empowering decision-making processes aimed at maximising productivity and sustainability in agriculture.

Despite its advantages, 3D modelling in agricultural settings faces several challenges. Most importantly, ensuring data accuracy and reliability remains a critical concern, as errors in data collection and/or processing can lead to inaccurate models and subsequent decision-making. It is well established that environmental factors such as varying light conditions, weather changes, and seasonal variations can impact the quality and consistency of data collection, affecting the accuracy of 3D models. Moreover, the complexity of agricultural landscapes, including uneven terrain and dense vegetation, poses challenges for data acquisition using traditional methods like UAVs or ground-based sensors. Additionally, the scalability and cost-effectiveness of deploying 3D modelling technologies across large agricultural operations require careful consideration, balancing the potential benefits with the challenges of practical implementation. Addressing these challenges involves on-going advancements in technology, methods, and data processing techniques tailored to the unique needs of agricultural applications.

Future Directions

For crop monitoring, emerging trends in 3D modelling technology include advancements in remote sensing techniques such as hyperspectral imaging and multi-sensor fusion. These technologies allow for more comprehensive data collection, providing insights into crop health beyond visual and geometric data. Integration of artificial intelligence and machine learning algorithms is another trend, enabling automated analysis of 3D models to detect subtle changes in crop conditions, predict yield outcomes, and diagnose diseases at early stages. Furthermore, advancements in cloud computing and data analytics offer scalability and real-time processing

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Integrating IoT devices with 3D models to create an integrated biosystem.

capabilities, enhancing the efficiency and accessibility of 3D modelling applications in agriculture. Finally, the development of low-cost and miniaturised sensors, coupled with advancements in UAV technology, is making 3D modelling more accessible and practical for small-scale farmers and precision agriculture applications in the open field.

Potential innovations for crop growth monitoring include integrating IoT (Internet of Things) devices with 3D models to create an integrated biosystem, essentially forming a digital twin of the agricultural system and its key components. This will include real-time monitoring of environmental factors such as soil moisture, temperature, and nutrient levels, directly influencing irrigation and fertilisation strategies based on spatial data insights.

Enhanced visualisation techniques, such as augmented reality (AR) and virtual reality (VR), could revolutionise how farmers interact with and analyse 3D models, providing immersive

experiences for training and decision-making processes.

Additionally, the development of predictive modelling tools that simulate crop growth scenarios based on historical data and current conditions could optimise planting schedules and crop rotations.

Finally, advancements in 3D printing technology could enable the rapid prototyping of agricultural structures and equipment tailored to specific spatial data, enhancing efficiency and sustainability in agricultural operations.

Countless examples show how specific components within a biosystem, or an agricultural system, can be optimised using specific technologies. However, properly integrated and synergistic biosystems are rarely encountered in Malaysia. Therefore, a concerted transformational effort is needed to integrate these technologies and create a synergistic biosystem that improves outcomes for all stakeholders in the agrifood value chain, from farmers and growers to consumers. ■

Advancements in Agricultural Robotics and Automation in MARDI

By **Ten Seng Teik**

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With the world population projected to reach 9.7 billion by 2050, food production will need to increase significantly to sustain the current level of living. Therefore, agriculture needs to be modernised and expanded. Otherwise, it will be difficult to achieve the second Sustainable Development Goal of the UN, which is to eradicate hunger. In addition, problems, including the depletion of natural resources and lands, climate change, erratic weather patterns, and the consequences of the coronavirus pandemic, challenge humanity. Food security is a pressing worldwide concern as a result of the COVID-19 pandemic's effects on agricultural food yield. To bring existing agricultural practices into the new era of Agricultural Revolution 4.0 with the use of Industrial Revolution 4.0 (IR4.0) advanced technologies, especially agricultural robotics, to reduce labour force dependency, production time, increase productivity, and improve food security, MARDI's research work aims to improve existing agricultural practices through mechanisation, automation, and the adaptation of advanced technologies. The following agricultural tasks have been developed by MARDI in terms of robotics and automation—planting, crop monitoring, pesticide applying, harvesting and grading.

Currently, the COVID-19 epidemic is significantly impeding agricultural food productivity, resulting in a heightened global emphasis on guaranteeing food security. There has been a decline in the number of people working in the agricultural industry in Southeast Asia, affecting a total of 100.77 million individuals [1]. Furthermore, it is noteworthy that the average age of farmers in Malaysia surpasses 50 years, and there is a dearth of involvement from the younger generation [2]. Moreover, the COVID-19 pandemic has emphasised the necessity of

converting the agricultural sector into industries to improve agricultural efficiency and guarantee food security in Malaysia. Thankfully, agriculture may be considered a type of industrial production that can make use of the progress achieved in successive industrial revolutions.

Smart farms are a clear sign of the onset of the Fourth Industrial Revolution in the agricultural sector. Smart farms are similar to smart factories in that they seek to incorporate cutting-edge technology, such as the Internet of Things, robots, and advanced systems like artificial intelligence

and machine learning, into the agricultural setting. To modernise and enhance agriculture, it is essential to understand the relationship between the industrial and agricultural revolutions. This phenomenon can be attributed to the synchronicity between agricultural revolutions and industrial revolutions in recent times [3]. The progress in agriculture is closely aligned with advancements in science and technology, and it is swiftly integrating IR4.0 technologies to develop a new model known as Agriculture 4.0. Agriculture can be envisaged as a kind of industrial production, able to tag on the benefits from the successive industrial revolutions. Smart farms are the initial sign of IR4.0 happening in farming. Smart farms are similar to smart factories that pursue the interconnection of modern technologies such as the Internet of Things (IoT), robots and sophisticated systems like Artificial Intelligence (AI) and machine learning within agricultural fields. Modern vegetable production is a type of sophisticated agriculture in which intelligent technologies and systems aid in carrying out tedious jobs such as planting, crop monitoring, pesticide applying, and harvesting. Grading processes can be helped by smart machines and intelligent systems.

Seed Sowing Robot

Planting begins with getting seedlings ready in the media before moving them to the production area. This is called the plant nursery system. The nursery uses a variety of media, and MARDI uses Ezgrow technology, which is a peat block designed specifically for the nursery. Moist peat, cocopeat, slow-release fertilisers, and other components necessary for plant growth make up Peat Block Ezgrow, a comprehensive media formulation. All plant types, including foliage, fruit, and flowering plants, can benefit from peat block Ezgrow.

The Ezygrow peat blocks may be automatically seeded with vegetable seeds thanks to a seed-sowing gantry system. The “3-axis Cartesian” robotics system (see Figure 1), which is the foundation of the seed-sowing gantry system, determines the planting of seeds according to media co-ordinates. The mechanical, electrical, and control systems make up the system. Round,



Figure 1: Seed sowing gantry robotics system

coated seeds in a variety of sizes can be sown with this equipment. It is also possible to utilise the seed-sowing gantry system for other plant seeds, like those from fruits and flowers. Peat blocks of $\frac{3}{4}$ inch, 1 inch, and 1.5 inches can be seeded. For IoT systems with connectivity components installed in the Human Machine Interface (HMI) control system, the seed-sowing gantry system is also available.

Smart Crop Monitoring System

In practice, farmers usually make visual assessments for crop monitoring to guarantee that tomatoes are selected at the ideal level of maturity for commercialisation. With IR4.0, one way to improve the effectiveness of current traditional methods is through the deployment of AI technology. The Ministry of Agriculture and Food Industry (MAFI) has developed a categorisation model for establishing the tomato ripeness index specifically for greenhouse tomato cultivation through the IR4.0 project initiative. Through the use of patterns or trends in the data it learns from, AI technology enables computers to make decisions that are similar to those made by humans. Data is essential to the development of any AI model and an AI model's accuracy may drop in the absence of appropriate data, making the model less capable



Figure 2: Processes for deep learning in detection and maturity index classification of tomatoes in a greenhouse: (A) Data collection and (B) annotation

of correctly predicting outcomes. Thus, the ripeness index categorisation model for tomatoes was created to give consumers information on the ripeness distribution for tomatoes based on the ripeness index.

This research focused on the implementation of a deep learning technique to construct a detection and maturity index classification system for tomatoes in a greenhouse. This study involved the development of two models, with the result of the first model serving as the input for the second model. Initially, a total of 2,000 tomato picture samples were obtained through the process of image data collecting (see Figure 2A). Subsequently, a tomato detection model was created utilising the annotated original image samples (see Figure 2B). The confidence level is assessed to determine the efficacy of the primary mode, yielding a score of 95.78%. Additionally, the tomato maturity index classification was established by utilising the original image samples that were cropped and named, based on their respective indexes. Afterwards, the accuracy of the second model was determined using a confusion matrix, resulting in an accuracy of 92.33%. Finally, a dashboard is constructed to allow users to simultaneously monitor the whole distribution of tomatoes.

Pesticide Applying Flying Robot (Drone)

The increasing demand for efficient and precise agricultural practices has led to the exploration of state-of-the-art technology in the field of farming. The purpose of this preliminary inquiry

is to assess the feasibility and effectiveness of utilising drone (flying robot) sprayers for the distribution of pesticides in rice fields (see Figure 3). Compared with traditional human or tractor-based spraying methods, drones are better equipped to enhance accuracy, reduce environmental impacts, and optimise resource utilisation. The research seeks to assess the effectiveness of drone sprayers in pest management in rice fields, investigating the effectiveness of using a drone sprayer to apply pesticides in a rice field in Malaysia. The study evaluated the efficacy of the drone sprayer compared to the traditional knapsack sprayer. The results indicated that there was no significant difference in the control of insect pests and diseases when comparing the use of drones with manual methods. However, there was a reduced period for spraying each plot with a drone sprayer as compared to manual application.



Figure 3: Application "Flying Robot" (Drone) in pesticide spraying

Harvesting Robot

Before executing the harvesting task, a robot, similar to a human, must acquire the essential information regarding the nature and position of the target objects. Consequently, the advanced technology incorporated a three-dimensional (3D) camera as the "eye" for the robot, while delicate human fingers were replaced with soft grippers. Several researchers have reported the development of a machine vision system that captures photos, identifies fruits, and determines their location. This system is designed for the goal of robotic fruit picking. These investigations encompass research conducted by [3] [4] [5] [6] [7] [8] [9].

Harvesting robots require 3D spatial position data of the selected fruit to guide the end effectors accurately during the harvesting procedure. However, the camera only records the 2D co-ordinates of the target in the image space. This requires establishing a mapping association between the target's position in the 2D image space and its corresponding position in the 3D space [10]. For these purposes, 2D cameras equipped with either charge-coupled device (CCD) sensors or complementary metal oxide semiconductor (CMOS) sensors are often utilised [11]. To obtain 3D spatial position data from a single 2D camera, it is necessary to incorporate either an additional calculation model or an additional sensor. Parish and Goksel [3] used a single camera to determine the centre of mass of the fruit in the image. Subsequently, a mathematical transformation was performed to ascertain the association between the 2D co-ordinates of objects and a 3D co-ordinate system.

Colour is an essential feature used in machine vision systems to distinguish fruit from leaves, branches, and other objects in the background of an orchard environment during target detection. Multiple research [12] [13] [14] [15] [16] have utilised colour-based segmentation to detect fruits that have easily recognisable hues, such as tomatoes, red apples, peaches, mangoes, pineapples, and citrus fruits.

Various 3D acquisition and range-measuring techniques have been created. However, stereo vision, structure light, and time-of-flight (TOF) are the main principles used in industrial applications for 3D imaging [17]. Consequently, an examination is conducted on these specific methods of 3D data collection and measurement.

The tomato harvesting robot (see Figure 4) was successfully developed by using a detection algorithm that utilises colour and geometric cues for item detection, as well as a localisation method that utilises three-dimensional spatial data from a 3D camera coupled with COBOT and a soft gripper. COBOT is a cutting-edge and contemporary phenomenon in the realm of robot advancement, specifically engineered to collaborate and operate in conjunction with humans. Since the harvesting procedure took place within the building, the researchers conducted tests on the structural light 3D imaging approach.

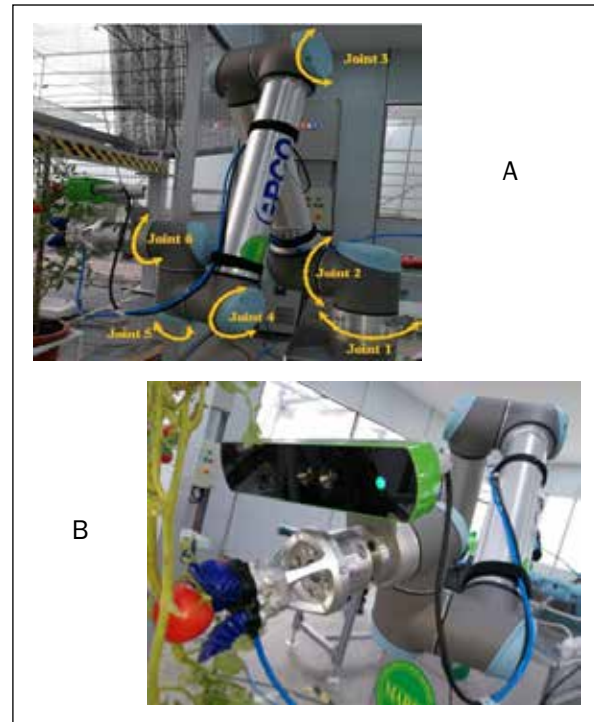


Figure 4: Harvesting process with COBOT with 3D camera: (A) Joints and angles inverse kinematics calculation, (B) Tomato picking

Firstly, it achieves high accuracy when measuring target objects in close proximity. Secondly, it is capable of rapidly acquiring data. Thirdly, it has the capacity to measure a significant volume of data. Additionally, it involves less complicated computation compared to stereo vision and consumes less computational power compared to TOF. Lastly, the performance of this technique is dependent on ambient light, which can be effectively controlled in the close area of the greenhouse (see Figure 4). Furthermore, a structured light-type 3D camera called Pickit 3D camera is available for purchase on the market. The harvesting procedure is fully automated, requiring no input or decision-making from the operator. As depicted in Figure 4, the system possesses the capability to autonomously scan the tomato plant. The image processing is effectively executed to facilitate the recognition of the tomato by the object detection algorithm, which relies on colour and geometric characteristics. Subsequently, the structure light 3D imaging approach effectively localises the designated tomato. The 3D spatial data can be transmitted to the COBOT controller

to perform inverse kinematics calculations on the joints and angles (see Figure 4A). Ultimately, the COBOT successfully completes the harvesting process by manipulating the end effector, a flexible gripper, to the specified tomato location based on the inverse kinematics calculation data for each joint rotation angle, and then proceeds to harvest it (see Figure 4B). The entire process can be viewed and altered remotely by wireless connection, such as WIFI and internet, using a computer, tablet, or smartphone. The probability of successfully reaching the tomato exceeds 80%. The performance of machine vision systems in recognising and locating fruit can be influenced by the unpredictable and changeable illumination conditions in the field environment, as well as the different and complex canopy structures [18] and the changing colour, shape, and size of the fruit. Moreover, the capacity to precisely identify fruit in canopy photographs is greatly impeded by the hindrance provided by leaves, branches, and other fruits [11]. In the near future, the success rate could be enhanced by incorporating AI through the process of machine learning. This would involve training the system to overcome variations in lighting conditions and enabling it to identify objects even when they are partially obstructed.

Fruit Grading Robot

MARDI has created a robotic arm system (see Figure 5) specifically designed to perform the task of grading watermelons depending on their weight. The robotic arm system comprises a robotic arm, automated control software, an electronic “load cell” scale, and a table designed for watermelon collection depending on weight. The robotic arm system is equipped with a “suction cup” that is utilised to elevate and transport watermelons from the digital weighing area (see Figure 5A) to the grading table (see Figure 5B). The utilisation of this robotic arm technology becomes advantageous in the efficient manipulation of weighty watermelons, particularly in the laborious task of manually grading post-harvest watermelon produce. This method minimises the likelihood of physical harm to watermelons as compared to manual handling. This robotic arm technology can also decrease the spatial need of the machine floor area when

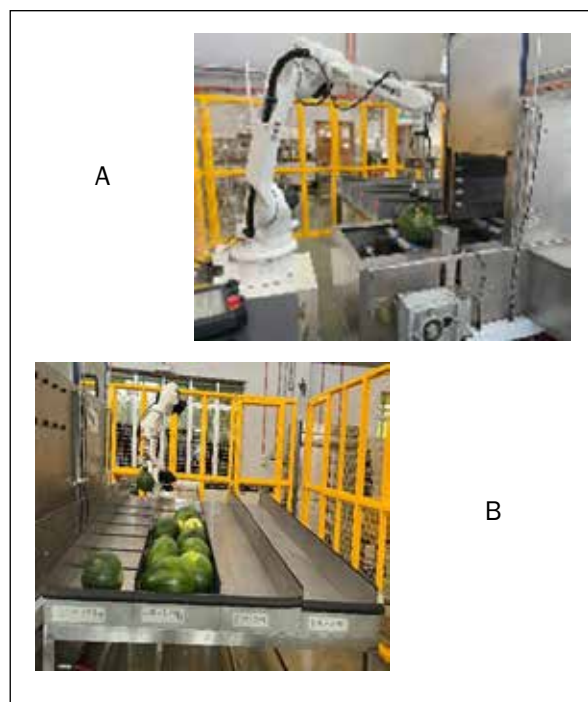


Figure 5: Watermelon grading robotic system: (A) The robotic arm system lifts the watermelon on the grading table, (B) The robotic arm system transfers watermelon to the pre-determined weight slot

compared with using a “conveyor” system for transferring watermelons from the weighing section to the watermelon collection section.

The robotic arm system follows the Standard Fresh Water Melon MS 1028 (2005) for evaluating watermelons, which is based on a weight size grading scheme. The practice of classifying watermelons by weight has been devised to fulfil the export standards for watermelons destined for international markets, particularly Dubai, Hong Kong, and European countries. The watermelons will be sorted and packaged into boxes based on the specific size requirements set by the export market.

Employing robotic arm technology for watermelon grading can address the issues of labour scarcity and reliance on foreign workers. It can assist in managing the weighty watermelon, and the technique does not have any adverse effects on the quality of the watermelons. This technology can also be utilised by entrepreneurs with restricted workspaces. The robotic arm system for watermelon grading is more space-



Agricultural productivity can be increased and worker scarcity can be addressed by utilising advanced robotic and other AI-enabled smart systems to carry out tasks such as planting, crop monitoring, pesticide applying, harvesting and grading.

efficient than using a conveyor system to carry watermelons from the digital weighing section to the grading table.

Conclusion

The most important sector that needs more focus is agriculture as without it all other activities would be adversely affected. It is imperative that AR4.0 be developed appropriately by swiftly integrating IR4.0 technology to facilitate agricultural endeavours and help realise two of the Sustainable Development Goals of the United Nations, namely, the eradication of hunger and poverty. Agricultural productivity can be increased and worker scarcity can be addressed by utilising advanced robotic and other AI-enabled smart systems to carry out tasks such as planting, crop monitoring, pesticide applying, harvesting and grading. It would then be simple to scale up and introduce these developed technologies to the general public, improving the reputation of agriculture as a “dirty, tough, and hazardous” field. This way more young people may be encouraged to pursue careers in it. Food security will be preserved for the world’s rapidly expanding population as a result. ■

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UAV-based Remote Sensing for Precision Agriculture in Rice Farming

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The average rice self-sufficiency level in Malaysia was around 62.5% for the years 2019–2022 with an average yield of 3.528 metric tonnes per hectare [1]. Malaysia's rice production is currently facing challenges due to declining or stagnating productivity, climate change, water scarcity, rising cost of fertilisers, herbicides and pesticides, and labour shortage [2]. Transformation of traditional agriculture to modern agriculture is needed to boost the paddy and rice industry and improve food security.

Precision Agriculture (PA) technologies have a significant potential to increase farm productivity, profitability and environmental sustainability through targeted application of inputs [3]. PA is farm management that involves identifying and managing on-farm variability. Remote Sensing (RS) is generally considered one of the most important technologies for PA. RS allows obtaining and interpreting information from a distance using sensors that are not in physical contact with the object being observed [4]. RS has been widely used to monitor many crops and vegetation parameters through images at various wavelengths. In the past, RS was often based on satellite images to monitor vegetation status at specific growth stages. However, satellite imagery is limited to the low spatial and temporal resolutions of images acquired and hampered by environmental restrictions such as cloud cover.

The development of Unmanned Aerial Vehicle (UAV)-based remote sensing systems has taken RS and PA one step further in the application of

modern precision farming technology. To date, UAV-based remote sensing has been successfully employed in a variety of applications for PA in rice farm management, such as land preparation, water management, plant population density monitoring, fertiliser management, pest, disease and weed management and yield prediction. Thus, this review focuses on applications of UAV-based remote sensing systems for precision agriculture in rice production for the above-mentioned rice farm management.

LAND PREPARATION

Precision land levelling facilitates application efficiency through the even distribution of water and increased water-use efficiency that results in uniform seed germination, improved crop establishment, improved crop nutrient uptake and increased crop yield [5, 6]. Traditional land levelling is performed by the operator to modify the land topography through land cut and fill works using implements mounted on a tractor.

Assessment of soil unevenness after land levelling is an important step to ensure that the rice field is ready for planting. A UAV equipped with a digital camera can be used to map ground elevations for assessment of soil unevenness. *Enciso et al.* (2018) [7] reported that UAV-based remote sensing could be an efficient method for determining terrain elevation with a 0.3% error and an observed value of $R^2 = 0.93$ between



A UAV equipped with a digital camera

estimated and measured data. Therefore, it can be used to assess the performance of land levelling in paddy fields.

WATER MANAGEMENT

Currently, the largest amount of water consumed in the world is in the irrigation of crops [8]. Rice seeding under flooding requires a large amount of water (15,000–20,000 m³/ha) [9]. The availability of water for irrigation is becoming scarce due to climate change and competition with the other sectors. Therefore, it is essential to use irrigation water more efficiently and effectively [10].

Previous studies demonstrated that precision irrigation techniques can improve the efficiency of water use by proper monitoring of the water body distribution in the field. UAV-based remote sensing data can be used for a fast and reliable identification of the water body extent at a local scale with an average kappa coefficient of the water body identification above 0.9 [11]. This information can be processed into multi-temporal

high-resolution water movement pattern maps highlighting the status of the flooded areas by image processing techniques. These maps provide essential information to help irrigation managers enhance decision-making in the management and operation of the irrigation system.

PLANT POPULATION DENSITY MONITORING

Rice tiller numbers are a key indicator in plant population density monitoring. They provide information on the status of the crop as well as potential yield. This information can be used to calculate the amount of fertiliser and pesticide to be applied in the field [12].

Ground-based sampling methods have been used to count the tiller numbers for determining plant populations in rice fields [13,14]. The sampling method is performed by randomly choosing several different locations within a plot to perform tiller counting in a 25 cm x 25 cm square frame. However, this method is usually

performed by manually counting the total number of rice plant tillers in the square frame. This sampling technique is time-consuming, labour intensive and costly [13]. To solve this problem, *Teoh et al.* (2008) [14] introduced an automatic counting plant tiller method using an image processing technique. Digital images of rice plants in the square frame were captured and classified into plant and non-plant regions using an image classification method. Linear regression analysis results indicated that a good correlation coefficient value of 0.8328 existed between the plant tiller count and the area of the plant region. Verification results also showed that the linear model is capable of estimating tiller numbers with 92.17% average accuracy. However, both methods are only applicable for tiller counting on the ground in small fields [13,14].

To solve the problem, a UAV equipped with a camera has been used for counting rice plants [15]. The results revealed that the correlation of the rice plant count between the remote sensing method and ground counting method is $R^2 = 0.893$. Hence, UAV-based remote sensing is capable of tallying plant numbers for generating a plant population density map.

FERTILISER MANAGEMENT

Variable-rate nitrogen (N) management is one of the most important activities in PA for minimising fertiliser input and maximising yield. Traditional N application methods such as blanket or package fertiliser recommendations over large areas are not efficient because indigenous nutrient supply varies widely in rice fields [16, 17]. According to *Peng et al.* (1996) [18] and *Balasubramanian et al.* (1999) [19], a SPAD chlorophyll meter can be used to monitor plant N status *in situ* in the field and determine the right time for N topdressing in rice. However, field manual measurement of plant N content using the SPAD chlorophyll meter is time-consuming and tedious.

To overcome the problem, low-altitude remote sensing using a camera attached to a UAV was applied to improve the manual measurement of plant N status in a larger paddy field. For example, Vegetation Indices (VIs) have been used in remote sensing applications for monitoring the crop N

status in paddy fields [20 - 23]. The dark green colour index (DGCI) derived from aerial images was used to assess the N concentrations in the field [20]. It was found that DGCI values predicted the N concentrations with $R^2 = 0.672$. The band ratio Red/(Red+Green+Blue) and Normalised Difference Vegetation Index (NDVI) were used to estimate SPAD values [21, 22]. The results demonstrated that the Red/(Red+Green+Blue) and NDVI produced highly accurate SPAD estimations with $r^2 = -0.97$ and $R^2 = 0.76$, respectively. According to *Zheng et al.* (2018) [23], the Red Edge Vegetation Indices (REVI) calculated from multispectral images produced high estimation accuracy for leaf nitrogen accumulation (range of R^2 : 0.79 - 0.81) and plant nitrogen accumulation (range of R^2 : 0.81 - 0.84). The results documented in previous reports indicated that the UAV-based N status monitoring system is capable of providing useful information for near real-time decision-making on variable-rate N management in paddy fields [20-23].

PEST, DISEASE AND WEED MANAGEMENT

Pest, disease and weed (P&D&W) are very important factors that can cause significant economic loss due to reduced yield and quality. Crops should be monitored constantly to detect the P&D&W in time and avoid spreading problems. Traditionally, monitoring and blanket spraying of chemical tasks are performed manually in the field. However, this can be very time-consuming, labour intensive and costly.

To overcome the problems, precision agriculture adopts a variable rate technology (VRT) that has been used for controlling the P&D&W in the paddy field. VRT refers to the spatially variable application of chemicals according to site-specific requirements. P&D&W distribution maps are important in VRT for precise spraying of chemicals. Applications of UAV-based remote sensing technologies for P&D&W monitoring and mapping in the paddy fields have been reported by *Yue et al.* (2012) [24], *Zhang et al.* (2018) [25], *Huang et al.* (2018) [26] and *Stropping et al.* (2018) [27], respectively. A distributional map of crop pest status has been generated and classified into healthy,



Agriculture drone spraying fertiliser on the rice fields.

slight damage, severe damage and dead crops [24]. The correlation between image-extracted NDVI and sheath blight disease severity was $R^2 = 0.627$ and the accuracy to quantify different levels of the disease in the plots was 63% [25]. The accuracy for weed recognition was 0.883 as documented by *Huang et al.* (2018) [26] and the overall accuracy of weed maps obtained from NDVI was higher than 91% as reported by *Stropping et al.* (2018) [27]. Therefore, UAV-based mapping techniques can gather images and derive data to generate precise P&D&W distribution maps depicting the spots where chemicals are needed.

The P&D&W distribution maps can be used by the spraying drone to apply precise chemical volumes to the spot areas in the field. The use of the Global Positioning System (GPS) for measuring distances allows spraying drones to follow the spraying flight paths and flying heights have been programmed according to the P&D&W distribution maps. This map-based variable rate application of chemicals is useful to reduce chemical and labour costs and improve the ability to apply chemicals with greater precision and on a timely basis.

YIELD PREDICTION

The capability to predict crop yield before harvesting is also an important factor, as it enables farm managers to change farming practices throughout the growing season to maximise profit and yield while minimising costs. Recently, remote sensing technology has been widely used for crop yield prediction. NDVI has been widely used in remote sensing applications for monitoring crop conditions in qualitative and quantitative vegetation analysis [28]. Regression methods have been used to predict crop yields such as generating a regression model to develop direct empirical relationships between the NDVI measurements and crop yield. A UAV equipped with a camera has been used to predict rice crop yields [29, 30]. The results indicated that NDVI values and rice yields showed a good correlation with $r^2 = 0.75$ [29] and $R^2 = 0.75$ [30]. Hence, the yield estimation regression model using NDVI values was capable of predicting rice yields with high accuracy.

CONCLUSION

It can be said that UAV-based remote sensing systems have the potential to revolutionise PA and improve the current rice production system. The application of UAVs offers great possibilities to acquire field data in an easy, fast and cost-effective way compared to space satellite-based remote sensing. UAVs can fly at low altitudes and acquire high spatial resolution images of the crops. This significantly improves the performance of the present PA for rice production. Furthermore, UAV-based remote sensing systems also provide high temporal resolution images for enhancing current PA crop monitoring systems. ■

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SMART AGRICULTURE: Modernising the Agricultural Industry

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Agriculture is one of the most significant components of the National Key Economic Areas (NKEA) because of its ability to boost economic growth by producing more jobs and improving farmers' income. As the population of Malaysia is projected to increase to more than 45 million by 2050, there will be an increase in food demand and consumption. Smart agriculture leverages modern technologies to enhance the efficiency, productivity, and sustainability of farming practices. By integrating various innovative technologies, smart agriculture aims to address the challenges of traditional farming, such as resource management, climate change, and food security to increase productivity while protecting the environment.

Enabling Technologies

The enabling technologies in modernising agriculture during this Industrial Revolution 4.0 (IR4.0) era include Robotics, 3D printing, the

Internet of Things, Big Data, Artificial Intelligence and Blockchain.

Robotics

Robotics is an interdisciplinary and multidisciplinary field that combines advanced systems related to mechanical, electrical and electronic hardware and software. The use of robotics in the agriculture industry can vary from simple repetitive tasks to complex processes.

Three-dimensional (3D) printing

3D printing technology uses digital data to create various types of solid and semi-solid products. The application of 3D printing has gained enormous interest in many agricultural sectors. It can be used to replace parts for equipment and the day-to-day tools and fixtures required by farmers.

Internet of Things (IoT)

IoT is a system that connects devices through a network, allowing the exchange of data. It has the potential to create intelligent environments of

powerful tools in many agriculture and livestock areas, enabling operators to create, modify, and share information.

Big Data

Big Data refers to extremely large and complex data sets that cannot be analysed or processed using traditional methods. It requires advanced analytical tools and techniques to process these massive data sets.

Artificial Intelligence (AI)

AI is a computational technology used to mimic human abilities to perceive their environment, learn, and make decisions. AI techniques play a key role in automation in the smart agriculture and food processing industry and can help accelerate the transition towards sustainable food systems. Generally, AI-based technologies can be used in real-time monitoring and decision-making processes.

Blockchain

Blockchain technology can be defined as cryptographically secure distributed ledgers where the ledgers are distributed in a peer-to-peer format among the entities, making it a decentralised system. Decentralised solutions are needed due to single points of failure, product irregularities, quality compromises, and loss of data present in conventional food supply chains. The adoption of blockchain in the agriculture and food supply chain, especially when combined with other technologies such as IoT, enables data interoperability, cost reduction, transparency, auditability, integrity and authenticity.

Imaging Technology for Smart Agriculture

There are still barriers and limitations to IR4.0 adoption in agriculture, such as not fully understanding the limitations of relevant technologies and data sources. Visual data is useful for AI model deployment where it can show important signs of plant or animal health and growth, such as by analysing its size and shape, biomass accumulation, photosynthetic activity, physiological status, water content and use, stress

response, and biochemical composition. All this information can be obtained by using different types of images.

RGB images

RGB images are obtained using a standard digital camera to capture images in red, green, and blue channels. This allows the capture of high-resolution images of objects to assess traits like height, area, and growth patterns and also analyse colour-based traits such as colouration features, which can indicate health and stress levels. Together with deep learning, it has been used to automatically detect planthoppers in the paddy field and then classify them into four classes (see Figure 1).

Hyperspectral image

A hyperspectral image provides comprehensive data across a wide range of wavelengths, allowing for the detection of subtle differences in object composition and physiology. It is normally used in food safety, disease diagnosis, grading, classification, quality and composition analysis of animal products. As shown in Figure 2, it can detect oil palm seedlings infected by disease at a very early stage i.e. in asymptomatic conditions.

Multispectral image

A multispectral image is captured at specific wavelengths across the electromagnetic spectrum. Unlike RGB image, which captures only three bands, multispectral imaging collects data in typically three to 15 bands. This allows multispectral systems to provide valuable and affordable spectral information. Furthermore, it can be used to create a vegetation index. Figure 3 shows an example of the use of thermal images and vegetation index for disease detection.

3D image and Laser Scanning (LiDAR)

Laser Scanning (LiDAR) uses laser pulses to create detailed 3D models of object structures. Meanwhile, Photogrammetry combines multiple 2D images taken from different angles to reconstruct 3D structures. The 3D image can be used to analyse complex traits like object architecture, biomass, and object structure (Figure 4).

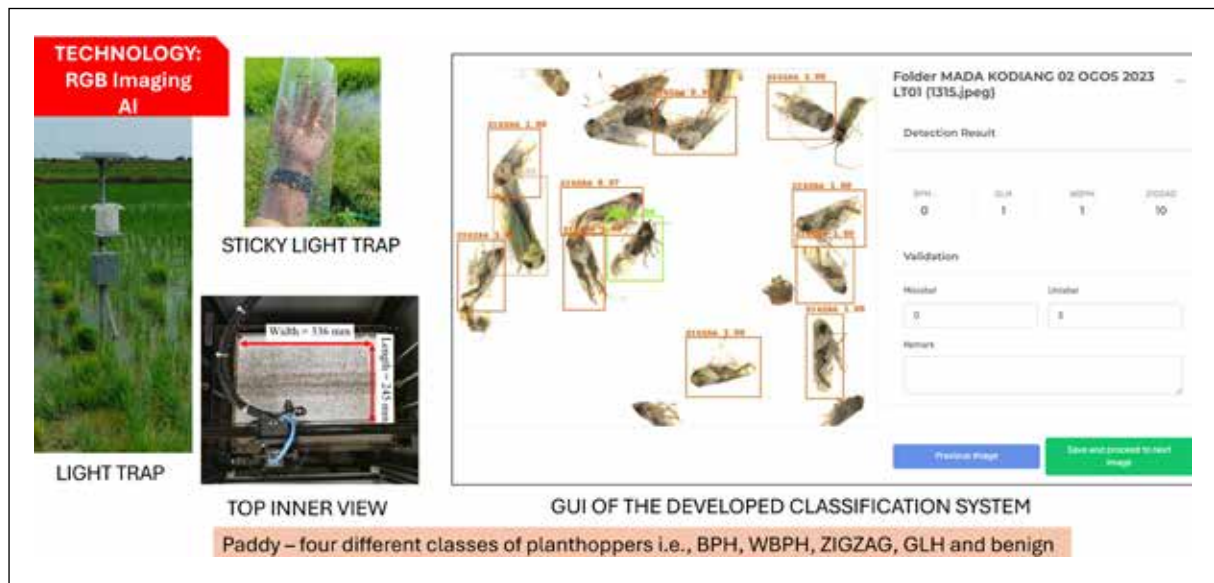


Figure 1: Automatic planthoppers detection, classification and counting using RGB images and deep learning [1].

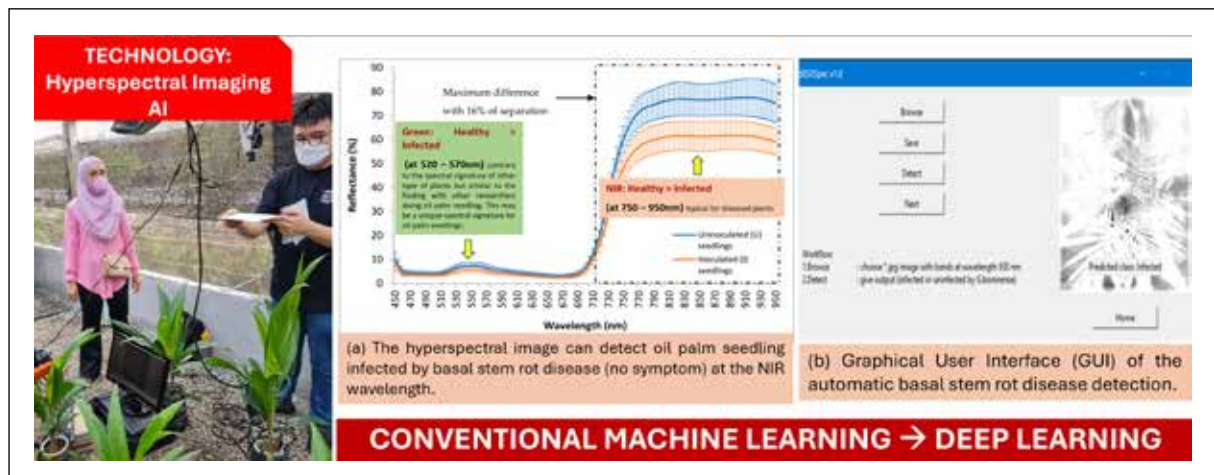


Figure 2: Automatic detection of basal stem rot disease at a very early stage i.e., in asymptomatic condition [2,3].

The role of the Institute of Plantation Studies in Modernising Agriculture

Smart agriculture is one of the eight high-impact industries outlined in the Twelfth Malaysia Plan (RMK12). The Institute of Plantation Studies (IKP) in UPM actively conducts research and produces innovations related to smart agriculture approaches where farmers use exact amounts of required inputs such as water, fertiliser and

pesticides at specific times and locations, allowing farms to become more profitable, efficient, safe and environmentally friendly. Innovations related to the remote crop management concept have also been developed by IKP (see Figure 5). This is done by using various types of technologies such as sensing technology, IoT, positioning technology, machines, robots, drones, communication systems and application software. To provide holistic solutions for the plantation crop industry, IKP fully

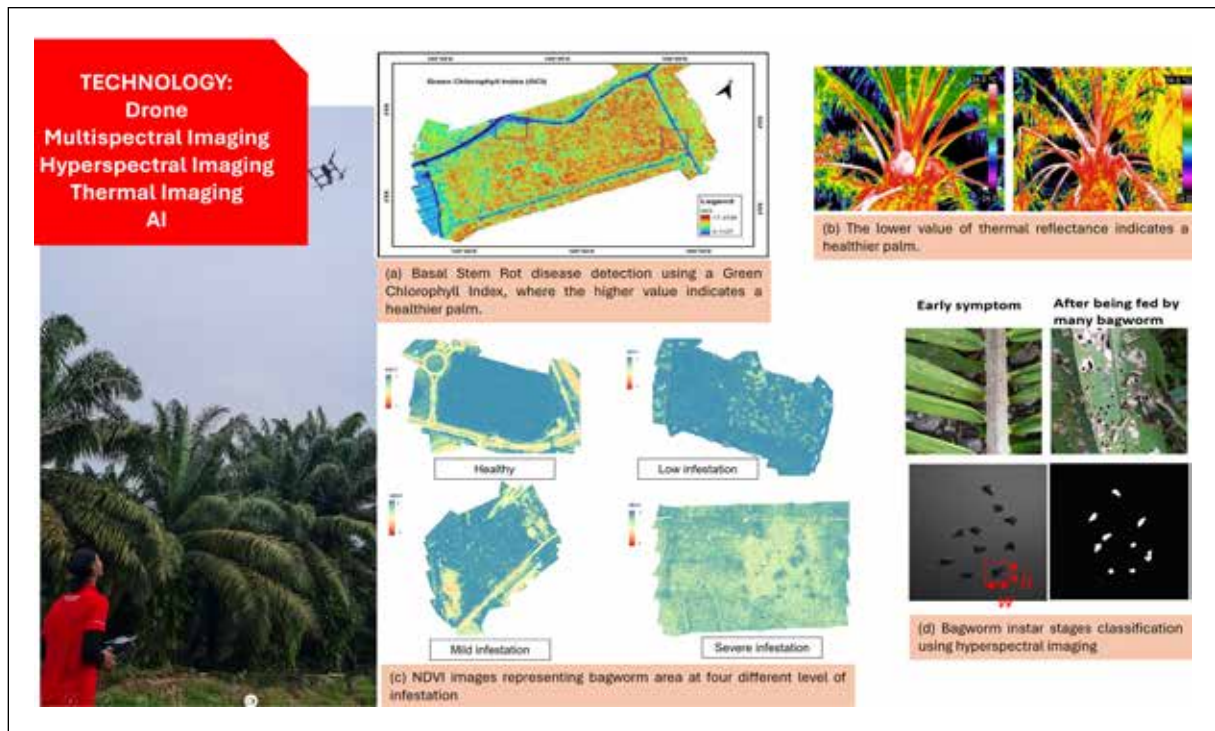


Figure 3: Automatic pest and disease management using imaging technology [4-6].

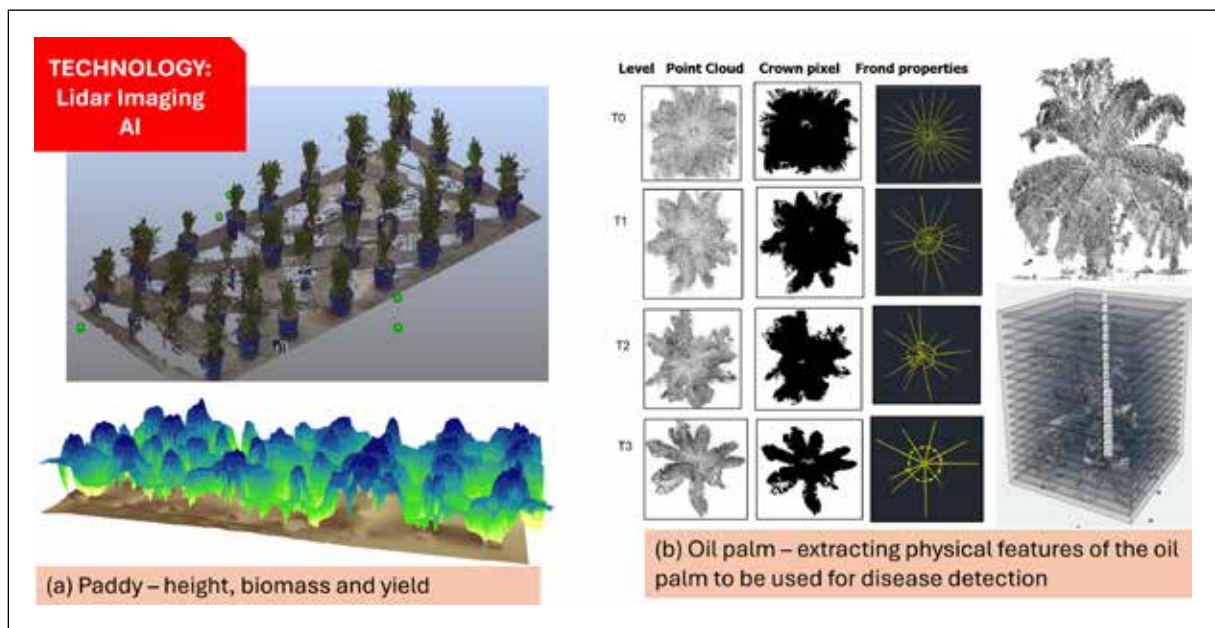


Figure 4: Application of LiDAR imaging for plant growth and disease management [7-9].



Figure 5: Remote management of oil palm seedlings at nursery using soil sensor, IoT and AI [10].

supports national policies such as the National Agricommodity Policy (2021-2030), the National Food Security Policy (2021-2025), the National Agrofood Policy (2021-2030), the 10-10MySTIE Framework and the National Biomass Action Plan (2023-2030).

Changes in the workforce environment as a result of modern technological advances have driven the need to secure human capital with relevant and adequate skills in the agricultural value chain. Therefore, IKP also plays a role in producing professional agricultural engineers and scholars who are equipped with the necessary skills through graduate programmes at the Master's and PhD levels.

It is clear here that IKP plays a big role in the agricultural industry by helping the agricultural sector transition to become more competitive by using various science and technology drivers to create core innovations that can increase return

on value. For example, a high return value on palm oil will increase the country's economic activity when the society, including small palm oil farmers, has greater purchasing power.

Conclusion

Sensing technologies, Robotics, 3D Printing, the Internet of Things, Big Data, Artificial Intelligence and Blockchain are the push factors that influence how much technology adaptation and integration can be used for Smart Agriculture. These technologies can help achieve higher yield, better crop quality, less labour, remote monitoring, reduced crop loss, and reduced usage of fertilisers and pesticides.

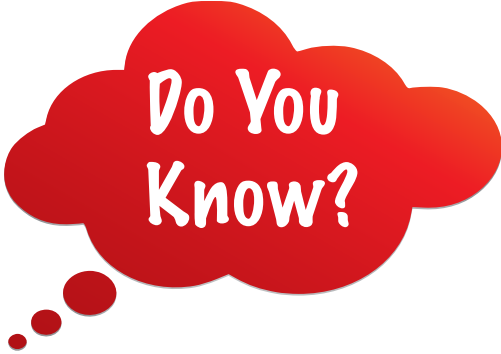
Modernising the agricultural industry can create more highly-skilled jobs in the agriculture sector, addressing the issue of the high

unemployment rate and attracting young people to the industry. It could have a big impact on the country due to its role as an important generator of economic wealth and employment, and give rise to other socioeconomic drivers.

However, several challenges need to be addressed. These include the lack of digital infrastructure and connectivity in many rural areas, making it difficult for farmers to access and utilise the new technologies. Additionally, the high cost of implementing these new technologies, especially for small and medium-sized enterprises, poses a significant challenge. Another key issue is the need for skilled employees who can operate in the industry and effectively implement these new technologies. Data privacy and cybersecurity concerns are also important, as the increasing use of connected devices and data analytics raises the risk of sensitive data being compromised. To address these challenges, greater collaboration and co-ordination among supply chain stakeholders is necessary to ensure that the new technologies are effectively integrated into existing systems. ■

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Do You Know?

Agricultural Engineering

By Pang Soo Mooi

When Malaysia launched the National Food Security Policy Action Plan 2021-2025, the first core action plan among the five core actions plan is to expand the usage of technology in the agriculture industry. The focus in agriculture engineering is well defined as the specific action plan is to strengthen national food securities, taking into account issues and challenges along the food supply chain ranging from agricultural inputs to food waste. The National Food Security Policy (DSMN Action Plan) 2021-2025 covering five core strategies, 15 strategies and 96 initiatives will ensure the sustainability of the country's food supply at all times, especially in the face of unexpected situations.

The unveiling of a new hybrid high quality pineapple known as MS 16 developed by MARDI in January 2024 signified another milestone of agriculture R&D achievement which involves agriculture engineering. This new hybrid was the result of MARFI germplasm exchange in 1993 with Maroochy Horticultural Station in Nambour, Queensland, Australia.

INTERNATIONAL BODIES RELATED TO AGRICULTURAL ENGINEERING

1. *International Commission of Agricultural and Biosystems Engineering (CIGR):*

Focus: Promotes the development of agricultural and biosystems engineering globally.

Activities: Research, publications, conferences, and technical reports.

2. *American Society of Agricultural and Biological Engineers (ASABE):*

Focus: An international organisation dedicated to the advancement of engineering applicable to agricultural, food, and biological systems.

Activities: Publications, conferences, and development of engineering standards.

3. *European Society of Agricultural Engineers (EurAgEng):*

Focus: Represents the interests of engineers and technologists in agricultural and biosystems engineering in Europe.

Activities: Conferences, technical groups, and publications.

4. *Asian Association for Agricultural Engineering (AAAE):*

Focus: Enhances co-operation among agricultural engineers in Asia and the Pacific.

Activities: Conferences, workshops, and collaborative projects.

INTERNATIONAL BODIES RELATED TO THE AGRICULTURE INDUSTRY

1. *Food and Agriculture Organisation of the United Nations (FAO):*

Focus: Leads international efforts to defeat hunger and improve agricultural productivity.

Activities: Research, policy advice, technical assistance, and data collection.

2. *International Fund for Agricultural Development (IFAD):*

Focus: Provides financial support and development programmes to eradicate rural poverty and promote agricultural development.

Activities: Funding projects, research, and partnerships.

3. International Food Policy Research Institute (IFPRI):

Focus: Provides research-based policy solutions to sustainably reduce poverty and end hunger.

Activities: Research, publications, policy analysis, and capacity building.

4. World Food Programme (WFP):

Focus: Provides food assistance to tackle hunger and promote food security.

Activities: Emergency assistance, development aid, and logistics support.

5. Consultative Group on International Agricultural Research (CGIAR):

Focus: A global research partnership for a food-secure future.

Activities: Research programmes, partnerships, and development initiatives.

6. International Federation of Organic Agriculture Movements (IFOAM):

Focus: Promotes organic agriculture through advocacy, education, and standards development.

Activities: Advocacy, standards development, and certification support.

7. Global Forum on Agricultural Research and Innovation (GFAR):

Focus: Enhances agricultural research and innovation through global collaboration.

Activities: Advocacy, networking, and capacity building.

HISTORY OF AGRICULTURAL ENGINEERING

Agricultural engineering has evolved from simple mechanical innovations to a sophisticated, inter-disciplinary field that integrates advanced technology, sustainability, and global collaboration. Its history reflects the continuous quest to improve agricultural productivity and efficiency while addressing the challenges of a growing global population and environmental sustainability.

1. Ancient and Early Developments: Ancient Civilisations (circa 10,000 BCE – 1,000 CE) and Medieval Period (500 – 1500 CE)

The early agricultural societies in Mesopotamia, Egypt, the Indus Valley, and China developed irrigation systems,

plows, and other basic agricultural tools. The Roman Empire made advancements in water management, including aqueducts and drainage systems, which were crucial for agriculture. The development of the heavy plow in Europe enabled the cultivation of heavier soils. Innovations like the three-field system improved crop rotation and soil fertility.

2. Renaissance to the Industrial Revolution (1500 - 1800 CE)

During the Renaissance (14th - 17th century), improved understanding of mechanics and hydraulics led to better water management and milling technologies. Agricultural treatises and manuals began to be written, spreading knowledge about farming techniques.

3. 17th - 18th Century

This period witnessed the Agricultural Revolution in Britain with significant changes, including selective breeding of livestock, crop rotation, and the introduction of new crops like turnips and clover. Jethro Tull invented the seed drill (1701), which improved the efficiency of planting seeds.

4. 19th Century: Birth of Agricultural Engineering - Mechanisation of Agriculture

The Industrial Revolution brought about the mechanisation of agriculture with inventions like the mechanical reaper by Cyrus McCormick (1831) and the steel plow by John Deere (1837). Steam-powered tractors and threshing machines began to appear, drastically increasing agricultural productivity.

The term “agricultural engineering” began to be used, and the first formal programmes and departments were established in universities.

The American Society of Agricultural Engineers (ASAE, now ASABE) was founded in 1907 to promote the profession and standardise practices.

5. 20th Century: Growth and Expansion Technological Advancements

The development of gasoline-powered tractors in the early 20th century revolutionised farming, leading to increased mechanisation and efficiency. Advances in irrigation technology, such as the centre pivot irrigation system, improved water management and crop yields.

Post-War Era

The Green Revolution (1940s-1960s) introduced high-yielding crop varieties, chemical fertilisers, pesticides, and advanced irrigation techniques, transforming global agriculture. Agricultural engineering expanded to include food processing, storage, and environmental management.

Computerisation and Automation

The advent of computers and digital technology in the latter half of the 20th century brought precision agriculture, utilising GPS, GIS, and remote sensing to optimise farming practices. Automation and robotics began to be used in tasks such as planting, harvesting, and processing.

6. **21st Century: Modern Agricultural Engineering**

Sustainability and Environmental Focus

The focus shifted towards sustainable agriculture, aiming to balance productivity with environmental stewardship. Renewable energy sources, such as solar and wind power, began to be integrated into agricultural practices.

Biotechnology and Genomics

Advances in biotechnology led to the development of genetically modified crops with improved resistance to pests, diseases, and environmental stresses.

Genomics and precision breeding techniques enhanced the development of crop and livestock varieties.

Global Collaboration and Innovation

International collaboration through organisations like the Food and Agriculture Organisation (FAO) and the Consultative Group on International Agricultural Research (CGIAR) helped spread agricultural engineering innovations worldwide.

The rise of smart farming and the Internet of Things (IoT) enabled real-time monitoring and management of agricultural systems

INTERNATIONAL STANDARDS FOR AGRICULTURE PRODUCE AND PRODUCTS

There are several international standards for agricultural produce and agri-products that ensure quality, safety, and sustainability in the global food supply chain. These standards are developed and maintained by various international organisations and standard-setting bodies. Here's a list of some notable international standards:

1. **Codex Alimentarius**

Developed by Food and Agriculture Organization (FAO) and World Health Organization (WHO) and focus on food safety, quality, and fair trade practices. The key standards are on General Standards for Food Additives, Pesticide Residue Limits and Contaminants and Toxins in Food and Feed.

2. **GlobalGAP (Good Agricultural Practices)**

Developed by FoodPLUS GmbH, these focus on Certification for safe and sustainable agricultural production. The standards used are Integrated Farm Assurance (IFA), Crops Standard, Livestock Standard and Aquaculture Standard.

3. **ISO Standards (International Organization for Standardization)**

Developed by International Organization for Standardization (ISO), these focus on various aspects of food safety, quality management, and environmental sustainability. The standards used are ISO 22000: Food Safety Management Systems, Environmental Management Systems, Quality Management Systems and Social Responsibility.

4. **HACCP (Hazard Analysis and Critical Control Points)**

Developed by Codex Alimentarius Commission, these focus on a preventative approach to food safety. The key elements involved are: Conduct hazard analysis; Determine critical control points; Establish critical limits; Monitor procedures; and Corrective actions.

5. **Organic Standards**

Developed by various national and international bodies, these focus on certification of organic agricultural products. The key standards are on EU Organic Regulation, USDA Organic

(United States Department of Agriculture), JAS (Japanese Agricultural Standards) and IFOAM Standards (International Federation of Organic Agriculture Movements).

6. Fair Trade Standards

Developed by Fairtrade International (FLO), these focus on fair wages, good working conditions, and sustainable practices. The key standards are Fairtrade Standard for Small-scale Producer Organisations, Fairtrade Standard for Hired Labour and Fairtrade Standard for Climate Projects.

7. Global Food Safety Initiative (Gfsi)

Developed by Consumer Goods Forum, it focuses on Benchmarks for food safety standards. The key standards are on BRC Global Standard for Food Safety, FSSC 22000 (Food Safety System Certification), IFS (International Featured Standards) and SQF (Safe Quality Food).

8. Sustainable Agriculture Initiative Platform (SAI Platform)

Developed by Industry-led initiative, it focuses on sustainable agricultural practices. The key standard is Farm Sustainability Assessment (FSA).

MALAYSIA'S BIRD'S NEST

Malaysia is one of the leading producers and exporters of edible bird's nests, particularly those harvested from swiftlet farms. The country has established specific standards and export requirements to ensure the safety, quality, and traceability of bird's nests. Here's an overview of Malaysia's bird's nest standards and export requirements:

MALAYSIAN BIRD'S NEST STANDARDS

1. Good Animal Husbandry Practice (GAHP) Guidelines for Swiftlet Farming / Birdhouse:

These guidelines issued by the Department of Veterinary Services (DVS), Ministry of Agriculture and Agro-Based Industry serves to ensure that swiftlet farms adhere to practices that promote the health and welfare of the birds while ensuring the safety and quality of the nests.

2. Malaysian Standard MS 2334:2011 (Edible Bird's Nest Specification):

This standard specifies the quality requirements for raw, cleaned, and processed edible bird's nests as follow:

Quality Criteria: Includes parameters such as moisture content, cleanliness, microbial limits, and chemical residues.

Labelling Requirements: Proper labelling for traceability and authenticity, including information on the origin and processing methods.

3. Good Manufacturing Practices (GMP):

Swiftlet house operators and processors must comply with GMP to ensure hygiene and quality during the processing of bird's nests. It is regulated by the Ministry of Health (MOH), Malaysia.

4. Hazard Analysis and Critical Control Points (HACCP):

HACCP principles must be applied in the processing of bird's nests to control potential hazards and ensure food safety.

EXPORT REQUIREMENTS FOR MALAYSIAN BIRD'S NESTS

1. Registration and Licensing:

- Swiftlet Farms: Must be registered with the DVS.
- Processing Facilities: Must be licensed and comply with the regulations set by the MOH and the DVS.

2. Traceability System:

- Record Keeping: Detailed records of production, processing, and distribution must be maintained to ensure traceability.
- Batch Identification: Each batch of bird's nests must be identifiable through a traceability system.

3. Health and Safety Certification:

- Health Certificate: Issued by the DVS certifying that the bird's nests meet the health and safety standards required by the importing country.
- Free from Contaminants: The nests must be tested and certified free from harmful contaminants, including heavy metals and nitrites.

4. **Export Documentation:**

- **Export Permit:** Required for each consignment, issued by the Malaysian Quarantine and Inspection Services (MAQIS).
- **Certificate of Origin:** To verify that the bird's nests are produced in Malaysia.

5. **Compliance with Importing Country Requirements:**

- **China:** One of the largest markets for Malaysian bird's nests, requires compliance with specific standards, including testing for nitrite levels and certification by the General Administration of Customs China (GACC).
- **Other Countries:** Exporters must comply with the specific import requirements of each destination country, which may include additional certifications and inspections.

6. **Quality Assurance and Testing:**

- **Laboratory Testing:** Bird's nests must be tested by accredited laboratories to ensure they meet the required quality and safety standards.
- **Third-Party Certification:** Some markets may require third-party certification to validate compliance with their standards.

USE OF ISOTOPES FOR SEED MODIFICATION

Isotope techniques in seed modification, particularly through the use of radiation, are employed to induce genetic mutations. These mutations can lead to the development of new plant varieties with desirable traits such as improved yield, disease resistance, or better nutritional quality. The process is often referred to as mutagenesis and involves the following steps:

PROCESS OF ISOTOPE-INDUCED MUTAGENESIS

1. **Selection of Isotope:**

Commonly used isotopes for inducing mutations include gamma rays (from Cobalt-60 or Cesium-137) and X-rays. These

isotopes emit radiation that can penetrate plant tissues and alter DNA.

2. **Exposure:**

Seeds or plant tissues are exposed to controlled doses of radiation. The duration and intensity of exposure are critical to achieving the desired mutation rate without causing excessive damage to the plants.

3. **Mutation Induction:**

The radiation causes random changes or mutations in the DNA of the seeds. These mutations can occur in various forms, such as point mutations, deletions, insertions, or chromosomal rearrangements.

4. **Selection and Breeding:**

After irradiation, the seeds are planted, and the resulting plants are screened for desirable traits. Plants exhibiting beneficial characteristics are selected and further bred to stabilise these traits over successive generations.

5. **Field Testing and Commercialisation:**

Selected mutant varieties undergo rigorous field testing to evaluate their performance under different environmental conditions. Successful varieties are then multiplied and released for commercial cultivation.

The benefits of this technology is yield improvement, drought tolerance, pest and disease resistance, and enhance nutritional profiles. Since mutagenesis involves inducing natural mutations rather than introducing foreign genes, the resulting plants are not considered genetically modified organisms (GMOs) in many regulatory frameworks.

Isotope techniques for seed modification, particularly through radiation-induced mutagenesis, provide a powerful tool for developing new plant varieties with desirable traits. Bioengineering enhances this process by offering precise genetic manipulation methods, such as CRISPR, and accelerating breeding programmes through marker-assisted selection. Together, these approaches contribute significantly to the advancement of modern agriculture, enabling the creation of high-yield, resilient, and nutritionally superior crops. ■

Nurturing Community Involvement In Agricultural Engineering Projects

By **Muhammad Hazwan Hamzah, Nur Azuan Husin, Diyana Jamaludin, Hasfalina Che Man, Mahirah Jahari**
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Community involvement is an important part of student and academic life at Malaysian higher learning institutions. Experience with complex engineering and technology problems, including knowledge of design systems, components, and sustainable environmental processes, can be obtained by students either individually (final year projects), collectively in a group (integrated design projects), or through Service-Learning Malaysia-University for Society (SULAM). In the engineering academic programme, students are expected to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the subsequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. In addition to these, technical know-how is used to solve agricultural engineering-related issues in the community. The major disciplines of agricultural engineering involve mechanisation and automation, soil and water resources, postharvest and environment, and agricultural informatics.

Currently, the global agro-food sector is confronted with several issues, including natural resource scarcity, agricultural productivity and innovation, changing demographics and nutritional trends, food waste and loss, and climate change. The National Agro-Food Policy 2.0 (NAP 2.0) 2021–2030 was introduced by the Malaysian Government to increase the competitiveness of the

agro-food industry through the use of advanced agricultural technology, promote economic growth, and ensure environmental sustainability following the Sustainable Development Goals (SDG) 2030. In line with the Universiti Putra Malaysia (UPM) Strategic Plan 2021–2025, which aims to preserve the industrial network ecosystem and society by utilising expertise per national demands, the Department of Biological and Agricultural Engineering (DBAE), UPM initiated several community programmes involving department staff and students.

AquaBAE Project with Suria Residences

AquaBAE with Suria Residences, Pajam consisted of 14 students and three lecturers. This project is part of the engineering course Engineers and Society (ECV 3011), which included the application of engineering knowledge through joint activities with the community. This project is in line with UPM's mission and goal to make a meaningful contribution to the formation of wealth and national development as well as global progress through the exploration and dissemination of knowledge between the university and the community.

Aquaculture is increasingly recognised as a sustainable alternative to traditional farming. It requires less land and water, produces lower

greenhouse gas emissions, and can be integrated into urban environments. Residential complexes could utilise engineering principles to create self-sustaining ecosystems that benefit both residents and the environment.

Several visits to the project site were conducted between April 2023 and May 2023 to take measurements and design the aquaculture system.

The AquaBAE system was designed to be efficient, sustainable, and easy to maintain, ensuring long-term viability. This project used recirculating aquaculture systems, where the systems continuously filter and recycle water, maintaining optimal conditions for fish growth while minimising water usage (Figure 1). Advanced filtration units remove waste and toxins, ensuring a clean and healthy environment for the fish. The integrated aquaponics systems also combine aquaculture with hydroponics and use fish waste as a natural fertiliser for growing plants. The plants, in turn, help to purify the water, creating a symbiotic relationship that maximises resource use and minimises waste.



Figure 1: AquaBAE system installed at the Kebun Komuniti Suria Residences.

Through this AquaBAE programme, good relationships were established between the community at Suria Residences, Pajam and the UPM students and staff (see Figure 2). In addition, the involvement of the students in making this project a success improved their soft skills such as teamwork and entrepreneurship. By initiating these types of agriculture projects, communities can produce fresh, nutritious food on-site and provide residents with access to healthy, locally-grown food, promoting better nutrition and overall well-being. The social interactions and

collaborative efforts throughout this project also enhance community spirit and cohesion.

Part of this project was funded by the Seremban City Council, and, remarkably, Kebun Komuniti Suria Residences won the Diamond Award under category 7: Urban Farming at the Malaysian Institute of Planners (MIP) MyPlace Awards in 2023. The success of AquaBAE at Suria Residences serves as an inspiring model for other urban communities. It demonstrates how innovative engineering solutions can be harnessed to create sustainable, self-sufficient ecosystems within residential complexes. As more communities adopt similar initiatives, the collective impact on urban sustainability and food security could be profound.



Figure 2: The AquaBAE programme ended with a photoshoot of participants, students and lecturers.

BAEGROW Project at Taman Suria Tropika

BAEGROW is a community programme implemented under the course ECV3011, aimed at developing urban agriculture in Taman Suria Tropika, Selangor. This innovative project ran from May 6 to June 10, 2023, involving active participation from students, lecturers, and assistant engineers. BAEGROW epitomises the collaboration between DBAE's students and the Taman Suria Tropika community, working together to integrate natural elements into urban agriculture and foster sustainable farming practices in urban settings.

The primary objectives of BAEGROW include enhancing the existing hydroponic system and incorporating advanced technological solutions to improve urban agriculture. The programme leverages the engineering skills



Figure 3: Installation of solar power system.

and knowledge acquired by participants to create a more systematic and efficient planting system. Three major projects were planned to achieve these goals: improving the hydroponic system; implementing a solar power system; and constructing a protective shed for the hydroponic setup.

One of the critical advantages of hydroponics is its water efficiency. Traditional soil-based agriculture often experiences significant water wastage due to drainage or evaporation. In contrast, hydroponic systems recirculate water, significantly reducing water consumption. This environmentally friendly approach makes hydroponics a sustainable solution for growing plants, especially in water-scarce regions. Additionally, hydroponic systems promote accelerated growth and higher yields by providing plants with an optimised nutrient solution, balanced pH level, and controlled environmental factors such as temperature and lighting.

In this project, the BAEGROW team undertook the task of remodelling and improving an existing hydroponic system. The objective was to enhance the structure and functionality of the system to optimise plant growth and overall performance. Through careful analysis and planning, significant upgrades were made to the hydroponic setup. The

improvements focused on enhancing the system's design, optimising nutrient circulation, and improving water and nutrient management. These enhancements aimed to create a more efficient and productive hydroponic system capable of meeting the community's needs.

One of the major challenges faced during the project was the absence of readily available electricity to power the hydroponic system's pump. To address this issue, the decision was made to integrate a solar panel system, providing a sustainable and renewable power source (see Figure 3). The installation of the solar panel system allowed the hydroponic setup to operate independently of the local electrical grid, harnessing clean energy from the sun. Additionally, a housing structure was constructed to protect and support the solar panel, ensuring its longevity and functionality. This integration not only solved the power supply issue but also promoted the use of environmentally friendly agriculture practices.

By incorporating modern techniques and technologies, such as automation and solar power, the BAEGROW project successfully created a more efficient and sustainable hydroponic system. The remodelling efforts aimed to maximise space utilisation, increase yields, and promote healthier plant growth. The project's outcomes demonstrated the potential of hydroponic systems to revolutionise urban agriculture and contribute to sustainable farming practices.

The BAEGROW initiative underscores the importance of collaboration and innovation in addressing contemporary agricultural challenges. By bringing together students, lecturers, and assistant engineers, the programme fostered a spirit of teamwork and learning, enabling participants to apply their theoretical knowledge to practical, real-world problems (see Figure 4).



Figure 4: Photo session with hydroponics system developed in Taman Suria Tropika.

The success of BAEGROW serves as a model for similar initiatives, highlighting the potential of hydroponic systems and renewable energy solutions to enhance urban agriculture and promote sustainability.

Modification of Water Treatment System and Aquaponics Integration at Fishlegs Farm

This knowledge transfer programme was held on January 6 and 7, 2024, at Fishlegs Farm in Batu Pahat, Johor, as part of the EAB 4947 Agricultural and Biosystem Engineering Design Project course. There were 11 participants in the programme, which was funded under the Knowledge Transfer Grant Scheme (KTGS) @ PTJ, UPM.

The programme focused on the modification of the water treatment system and aquaponics installation. The system had been fabricated a few weeks earlier at the Faculty of Engineering, UPM and installed at the farm. During this session, students meticulously inspected the system for potential issues post-installation, such as leaks, water pressure inconsistencies, and water flow rates. Inspection ensured that the system was functioning optimally before being fully operational. The water treatment process was modified to utilise fly ash, a natural carbon source, and a sponge instead of charcoal and lime. It was observed that the system successfully neutralised the pH of the ditch water used for the fish farm, raising it from pH 4 to pH 6.8. This outcome indicated that the system effectively addressed the primary issue faced by Fishlegs Farm, which was the presence of acidic water sources. The successful neutralisation of water pH was a significant milestone, demonstrating the system's efficacy and potential for broader application in the aquaculture industry. In addition, the aquaponic system was installed on the farm utilising the recirculating aquaculture system concept.

On the second day, activities commenced with a pre-programme survey for the participants to assess their current knowledge of water treatment and aquaponic systems. A brief sharing session about the aquaponic system installed and the modification of the water treatment system on Day One (see Figure 5) was also conducted. During this



Figure 5.:Brief sharing session about the aquaponic system installed and modification of the water treatment system

session, the design and operational mechanisms of the system were explained to the community. This initiative aimed to empower the community with practical knowledge that could be applied to their aquaculture practices.

The programme continued with an insightful expert talk by Dr. Muhamad Saufi Mohd Kassim. He shared detailed insights about his aquaponic system, including its design and operational mechanisms. The session introduced new ideas and inspired the community to consider developing their systems, fostering a spirit of innovation and adaptation. The next session featured a sharing session by members of the community, where they discussed their experiences and challenges with their aquaculture businesses.



Figure 6: The programme ended with a photoshoot of participants and lecturers.

Solar Drying Racks for Sustainable Fish Feed Production for Fish Farmers

This project aims to utilise water hyacinth and giant salvinia as alternative sources of additional feed for aquaculture farming and to utilise a self-constructed multi-layer solar pellet drying system.



Figure 7: Handover session of the solar dryer rack.

It involves the preparation of feed formulations, the construction of drying racks, and the provision of education and demonstration to farmers. In this project, pellet formulation involved the use of Water Hyacinth and Giant Salvinia as the main ingredients with the addition of commercial pellets at an optimised ratio. This formulation process is crucial as it ensures that additional pellets produced will have the necessary nutrient content required by the fish. The developed solar drying racks were handed over to the fish farming community at Lake Tok Uban, Kelantan (see Figure 7).

The programme also provided education and demonstration to the farmers on how to use the solar drying racks. The farmers were given detailed training on how to operate and maintain the drying racks. They were provided with practical guidance on the usage and upkeep of the drying racks to ensure their proper functioning. Additionally, they were also briefed on the benefits of using solar drying racks to improve the efficiency of drying fish feed pellets.

Previously, farmers attempted to manually produce dry pellets from chicken intestines,



Figure 8: Photo session with all involved parties during the Solar Dryer Rack Handover Programme.

but this process was ineffective and attracted flies. The assessment study during the drying rack handover programme indicated that most farmers had never been exposed to solar drying racks before, and they were looking forward to applying this new concept. Participants also requested the development of cheaper drying equipment. Overall, the study showed interest and need for technology that could enhance the drying process in fish farming, as well as a desire for greater support and education in the use of this new technology. This programme also served as a platform for farmers to exchange opinions and experiences regarding the use of this new technology. Farmers not only received equipment but also received support and guidance to integrate this new technology into their daily processes. This ensures that the solar drying racks are not just unused tools but truly valuable assets in their efforts to improve sustainable and efficient fish feed production.

Urban Agrischool Programme: ‘Agricilik Pertanian Bandaran’

An Urban Agrischool programme, ‘Agricilik Pertanian Bandaran’, was held on May 7, 2024, at Taski ABIM Saidatina Fatimah Sri Serdang, Selangor. A total of 33 students and five teachers of Taski ABIM were introduced to hydroponics by five lecturers and six undergraduate students from UPM.



Figure 9: Colouring activity during the programme



Figure 10: Taski ABIM's students with hydroponic pot.

In this programme, Taski ABIM students learned the concept of hydroponics through leisure activities such as games and colouring (see Figure 9). Every student and teacher of Taski ABIM was also given a hydroponic pot kit with pak choy seeds (see Figure 10). In addition, the University Community Transformation Centre (UCTC) UPM also co-operated by providing a bus equipped with an exhibition related to agriculture and science that attracted the attention of Taski ABIM students.

According to the Project Leader, Dr Diyana Jamaludin, "In general, students' interest in agriculture is relatively low compared to other fields. Therefore, this programme is conducted to introduce the concept of urban agriculture to students as early as pre-school level to instil an interest in the field of agriculture as well as encourage co-operation between the university and the community. In addition, to improve students' cognitive knowledge about plant science and agricultural engineering, this programme can also help to improve students' affective and psychomotor skills by cultivating a responsible attitude when nurturing their hydroponic plants".

Taski ABIM Saidatina Fatimah Sri Serdang is one of the pre-school organisations in Sri Serdang which is close to UPM. This programme, which was funded by a KTGS grant to increase exposure to hydroponics, could be expanded to other Taski ABIMs in the Serdang area.

CONCLUSION

To address specific issues related to societal needs, particularly on the use of modernisation in the agro-food sector, close collaboration between academia, Government, industry, and community-based organisations would boost demand-driven research and development, facilities, joint programmes and community outreach in a dynamic education ecosystem. In general, higher education students need to be equipped with the knowledge and skills needed to advance agricultural engineering and technology to produce a competent labour force, ensure career sustainability, and nurture and contribute back to the community in the future. ■



Basha Miao cultural performance for visitors at the village square



Basha Miao Village's Unique Architecture, Building Construction and Culture

By Dato' Ir. Fong Tian Yong

Basha Miao Village, often referred to simply as Basha Village, has a population of 2,200 villagers, mostly of the Miao tribe. It is situated in Congjiang County, a part of the Qiandongnan Miao and Dong Autonomous Prefecture southeast of Guizhou Province, PR China.

The village is nestled in a mountainous area surrounded by lush forests and terraced fields. The natural beauty of the region is a significant aspect of its charm and appeal to visitors.

The village is known for its well-preserved Miao buildings, culture and traditions. It is one of the few places where the ancient customs—including their unique architecture, traditional dress, and cultural practices—of the Miao people are still actively practised and maintained. It is also the only village which allows the possession of guns as it is part of the Basha Miao tradition for local folks to carry guns and knives.

The Miao people, also known as the Hmong in some regions, are an ethnic minority group primarily located in southern China, particularly in the provinces of Guizhou, Yunnan, Hunan, and Guangxi.

Their traditional houses, known as “Diaojiaolou” or “Diaolou,” which means hanging or stilt houses, are distinctive in design and construction, reflecting the unique cultural and environmental characteristics of the region.



Photo 1: Typical of most ethnic minorities, most of the Miao villages are located in a mountainous region away from the township.



Photo 2: Miao houses are built on stilts on hill slopes. Materials used are mainly local fir timber and clay or timber shingle roofs with masonry foundations.



Photo 3: Basha Miao villagers are the only people in China permitted to carry guns. Notice the pouches worn by them to contain gunpowder and sickle. No bullets are used in the guns; instead, gunpowder is used to create sounds and smoke to entertain tourists.



Photo 4: A typical diaojiaolou or stilt house with part of the building extended over the lower slope to gain space instead of constructing an expensive retaining wall.



Photo 5: Another typical Miao house construction nestled on a slope.



Photo 6: A Miao double-storey house with local fir wood and clay tiles. Notice the ventilation opening at the roof gable.



Photo 7: Locally available stones are used as the building's foundation as well as retaining wall.



Photo 8: Open plan layout of a Miao house's interior to allow flexibility and multi-use of internal space.

Miao architecture and design

- **Elevated Houses:** Miao houses are often built on stilts or elevated platforms with one part of the building sitting on the land cut out from the slope and protruding outwards over the lower slope for more space. This serves to protect against flooding, pests, and humidity. The elevation also provides ventilation and helps to keep the interior cool during hot summers.
- **Wooden Structures:** Houses are typically constructed using wood, bamboo, and other locally available materials. The framework is usually made of timber, while bamboo is used for walls, floors, and roofs.
- **Overhanging Roofs:** The roofs of Miao houses have broad overhangs to provide shade and protection from rain. They are often covered with thatch, wooden shingles, or tiles made from local materials.
- **Open-Plan Layout:** Traditional Miao houses have an open-plan layout without internal walls, allowing for flexible use of space and airflow. Different areas may be designated for sleeping, cooking, and socialising.

Construction Techniques

- **Interlocking Joinery:** Miao houses are constructed using traditional joinery techniques, with wooden beams and columns fitted together without nails

or metal fasteners. This interlocking construction method enhances the structural integrity of the building.

- **Thatch and Bamboo Walls:** Bamboo strips are woven together to create walls, which are then plastered with mud or covered with thatch for insulation and weatherproofing. This allows for natural ventilation and regulates indoor temperature.
- **Handcrafted Details:** Miao houses often feature intricate carvings, paintings, and decorative motifs on beams, door frames, and eaves, showcasing the craftsmanship and cultural heritage of the community.

Miao Beliefs and Their Cultural Significance

Feng Shui:

Miao architecture is often influenced by feng shui principles, with houses positioned to optimise energy flow and harmony with the surrounding environment. Certain design elements, such as the orientation of the house and the placement of doorways, may have symbolic significance.

Ancestral Worship:

Miao people may incorporate religious and spiritual beliefs into the design and construction of their homes, including rituals to bless the house and ensure the well-being of its occupants. Ancestral altars and sacred objects may be housed within the home.



Photo 9: A Miao house being built using traditional methods of construction.



Photo 10: The traditional joinery techniques, without the use of nails, are commonly used by local craftsmen in house construction.



*Photo 11:
Typical Miao
granary stores
that store
grains on the
top level with
the ground
floor used to
store farming
tools.*



Photo 12: A typical grain drying rack with wooden columns wrapped with metal sheets to prevent creatures from climbing up.

Granary store and grain drying poles

With agriculture as the mainstay of their economy and livelihood in ancient times, granary stores were important for the villagers not just for normal use but also for emergencies in times of drought or tribal conflict.

Granary stores are still used as common storage for the villages as a whole although with improved infrastructure and modern lifestyle changes, their function has been reduced to some extent.

Granary stores are now built in smaller units and spaced further apart to prevent the spread of fire. Each building consists of two levels with the top level, with better ventilation to prevent dampness and better security against theft, used for storing grains. These stores are situated away from flood and landslide-prone areas. Supporting wooden columns are wrapped with metal sheets to prevent rats, lizards or any other creatures from climbing up to the stores.

Before the harvested grains are stored, they have to be dried at drying racks built with two vertical poles attached to a few horizontal racks.

The poles are also wrapped with metal sheets to prevent creatures from climbing up and consuming the grains.

Under ancient Miao village rules, anyone caught stealing the grains will be punished with a 'Three 120' penalty—120 katis of meat, 120 katis of rice and 120 katis of wine to be shared by all villagers.

Miao villages as tourist destinations

With China's rapid economic development, young villagers began to move to towns and cities for employment from the 1980s onwards as the limited agricultural land in these mountainous areas offered less opportunity for gainful employment compared with the urban economic zones.

However, with Miao's unique village features and local culture, Miao villages have been transformed into tourist destinations with special performances by local elderly folks and local girls. Visitors will be entertained by a welcoming ceremony right at the entrance to the village with performances of gun shooting and Miao traditional dances at the village square.

Worship of trees

Miao's tradition of tree worship is still faithfully followed. The Miao believe trees have protected them since ancient times from external attack.

The villagers still observe the strict rule that trees in the Miao village cannot be cut unless necessary and with the village committee's consent.

The Miao culture of tree worship can be summarised as follows:

a) Tree of life

When a Miao child is born, a tree will be planted dedicated solely to him.

b) Protector tree

When a child reaches 15 years old, he will be taken to a selected mature tree as his protector tree to protect his safety in the next phase of his life. This protector tree can be shared with others.

c) Evergreen tree

When the person finally dies, the tree that the parent planted for him at birth will be cut to make his coffin for his burial. There will be no tombstone but a small tree, called 'Evergreen Tree', will be planted in its place to signify new life.



Photo 13: Basha Miao villagers welcoming ceremony at the entrance to the village



Photo 14: A 'Tree of Life' planted in Basha Village when a person was born.

Conclusion

Miao tribal houses are a reflection of the cultural heritage, environmental adaptation, and craftsmanship of the Miao people. Through their distinctive architecture, construction techniques, and the use of natural materials, Miao houses embody the rich cultural traditions and spiritual beliefs of this ethnic minority group in southern China. ■

First Generation Factory Pre-cut Site Assembly Modular System for Public Housing in Sabah in 1970s

By Cheo Hong Keyong

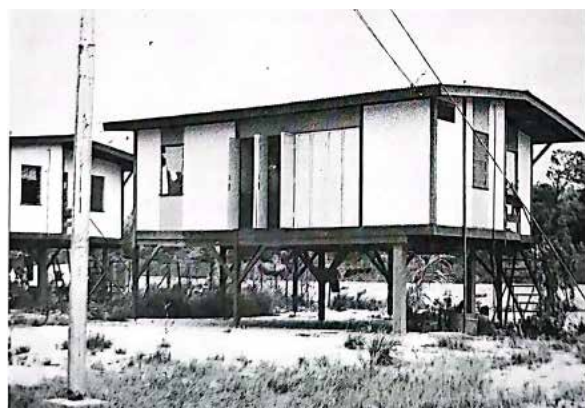


Photo 1: "Factory pre-cut for site assembly modular system" house assembled at Likas Bay, Kota Kinabalu in the 1970s as part of a low-cost housing scheme.

In the 1970s, Sabah's public housing policy aimed to address the severe housing needs of its population, particularly focusing on the lower-income groups. The state's policy was driven by the necessity to provide affordable and adequate housing to ensure the overall well-being of its citizens.

The key objectives of the policy were:

- a) **Affordable Housing for All:** The primary objective was to ensure that every citizen, especially those from lower-income brackets, could access affordable housing. This was crucial in a less-developed state like Sabah where economic disparities were prominent.

- b) **Urban and Rural Focus:** The policy aimed to balance housing development between urban and rural areas to prevent overcrowding in cities and to promote rural development.

- c) **Improving Living Standards:** By providing better housing, the Government sought to improve the overall living standards, health, and well-being of its population.

The mid-term review of the Second Malaysia Plan (1971-1975) tried to address the provision of low-cost housing and aimed at improving the living conditions of the urban poor who lived in the fringe areas of urban centres. These residents relied on urban centres for employment.

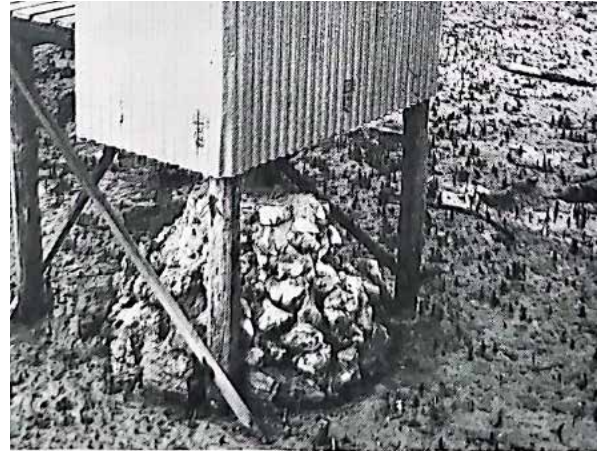


Photo 2: "Factory pre-cut for site assembly modular system" house assembled on the seashore near Tanjong Aru, Kota Kinabalu, Sabah.

Notice that waste materials are discharged from the water closet onto a cone built from sea corals that function by allowing the micro-creatures within it to do the work.

The Sabah State Housing Commission wanted to provide low-cost housing that replicated rural settings so owners could enjoy relatively unrestricted space where they could carry out backyard industries and farming and at the same time enjoy employment in, and the facilities of, urban centres.

For this purpose, 'Factory pre-cut for site assembly modular system' was introduced. The first model was built in Likas Bay on the northern outskirts of Kota Kinabalu and another near Tanjong Aru.

In view of the lack of most building materials and skilled or semi-skilled construction workers in Sabah, these houses were designed to keep packaging and shipment space to a minimum. All components were factory pre-cut and shaped either in Singapore or Malaysia. The construction design utilised stud framing of 3.75 by 1.75in of finished timber. All floor beams and stilts were 6 by 4in while floor joists were 5 by 2in timber. All stilts sit on precast concrete blocks. The floors were made of tongue and groove boarding except the verandah which was constructed with timber slats with space in-between to help reduce moisture retention.

The cost of construction varied from RM5,000 to RM8,000 depending on the size of the building. Considering that all the building materials had to be imported, the cost was considered appropriate for the Sabah scenario.

The timber construction methods of the 1970s in Sabah reflected a practical and resourceful approach to addressing housing needs, combining traditional techniques with available resources to create functional and affordable homes.

The 1970s public housing policy in Sabah was a crucial step towards improving the living conditions of its lower-income population. The policy focused on providing affordable housing through major land schemes and systematic implementation. Despite facing significant challenges such as geographical constraints, limited resources, and logistical issues, the Government made substantial progress in housing development. These efforts not only provided better homes for many families but also contributed to the overall well-being and development of the state. The achievements of this era laid a foundation for future housing policies and developments in Sabah. ■

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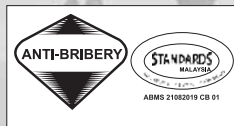
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