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Unleashing the potential of UAVs in agriculture: ASEAN and Thailand's rice production industry improvements: Review article

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Abstract Agriculture is vital for economic sustainability and structural transformation in ASEAN. This paper explores the agricultural landscape in ASEAN, focusing on Thailand as a prominent rice producer. Challenges such as rural-urban migration, the ageing population employed in agriculture, and need to implement innovative solutions to strengthen regional food security are discussed. The primary focus is the innovative use of unmanned aerial vehicles (UAVs) in ASEAN agriculture. UAVs revolutionize data collection through aerial photography, providing real-time insights into terrain, vegetation health, and soil composition. They enable informed decisions, optimize resource allocation, and streamline processes, resulting in cost savings. Equipped with sensors, UAVs precisely monitor crop health, irrigation efficiency, and early pest detection. Integration of advanced software and geographical information systems enhances data analysis and visualization. UAVs facilitate high-resolution mapping, offering detailed information on crop density, weed infestation, and disease outbreaks. This enables targeted interventions, reducing input costs and optimizing resource allocation. Multispectral or hyperspectral sensors provide insights into plant health, chlorophyll content, and water stress, enabling site-specific management strategies for improved sustainability. UAVs are affordable, versatile, and continuously advancing. They can potentially improve productivity, efficiency, and resource management in agriculture. In rice production, UAVs offer benefits like crop monitoring, precise spraying, and uniform seed spreading. They provide real-time information on crop health and pest infestations, enabling optimized management. Spray drones accurately apply pesticides, while seed-spreading drones enhance crop growth and save costs. UAV drones offer significant advantages in ASEAN agriculture, addressing workforce challenges and enhancing productivity. Supportive measures will lead to efficient UAV integration, enhancing sustainability and farmer livelihoods.

Keywords: Unmanned aerial vehicles (UAVs), Precision farming, Remote sensing, Data analysis, Resource management

Introduction

Undoubtedly, agriculture holds immense significance when it comes to ensuring the sustainability of any economy. It plays a pivotal role in

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fostering long-term economic growth and facilitating structural transformation. However, it's important to note that agriculture can exhibit substantial variations across different countries. In the past, agricultural activities were primarily focused on food and crop production (Mizik *et al.*, 2020). Nonetheless, in several nations, it has evolved into encompassing the marketing and distribution of both crops and livestock products. At present, agricultural endeavors not only serve as a vital source of livelihood, but they also contribute significantly to the GDP, act as a driving force behind national trade, mitigate unemployment, provide essential raw materials for other industries, and contribute to overall economic development (Hoang, 2020; Khan *et al*., 2021).

The very foundation of sustaining the population within a state lies in the land, which encompasses not only the physical territory but also its associated factors such as climatic conditions and inherent potential. The agricultural sector serves as the foremost driver in the economic advancement of a nation. The efficient utilization of land and the presence of well-developed infrastructure are pivotal in determining the wealth derived from this sector.

Agriculture in the ASEAN

Thailand is a member of the Association of Southeast Asian Nations (ASEAN), a regional organization with ten member countries. ASEAN is well-known for its diverse agricultural sector, which plays an important role in sustaining member economies and maintaining food security (Khan *et al*., 2021; Panpluem *et al*., 2019). Thailand stands out among ASEAN countries as a major agricultural producer in Southeast Asia.

Because of its diverse climate, fertile soils, and geographical variances, the ASEAN region produces a wide range of agricultural products. The unmanned aerial vehicles (UAVs) is experienced application for organic rice production in Thailand (Figure 1). Rice, maize, sugarcane, fruits, vegetables, palm oil, coffee, tea, rubber, and spices are among the crops grown by member countries (Hoang, 2020). Furthermore, cattle production, aquaculture, and forestry all contribute considerably to the ASEAN agricultural industry.

Thailand, in particular, is often referred to as the "Rice Bowl of Asia" due to its extensive rice output. The country is a major supplier of rice and excels in farming jasmine and glutinous rice varieties. Thailand excels in the production of other major crops such as sugarcane, maize, rubber, cassava, palm oil, and diverse fruits such as durian, mango, and pineapple, in addition to rice (Hoang, 2020; Panpluem *et al*., 2019). Thailand also has well-developed poultry and livestock sector, which includes poultry, swine, and cow production. Aquaculture, notably shrimp and fish farming, is extremely important in the country.

Figure 1. The unmanned aerial vehicles (UAVs) is experienced application for organic rice production in Thailand

Nonetheless, traditional farming methods, particularly small-scale family farming, continue to dominate in most ASEAN countries. However, with the use of technology and machinery, there is a growing trend toward modern agricultural practices. Organic farming and precision agriculture are prominent sustainable farming strategies that promote environmentally friendly approaches and reduce the usage of pesticides (Mizik *et al.*, 2020). Furthermore, ASEAN countries have improved irrigation systems, supported research and development, and improved farmers' access to loans and markets.

Despite the immense agricultural potential in the region, ASEAN countries face various challenges. These challenges include the impacts of climate change, land degradation, water scarcity, pests and diseases, rural-urban migration, and the need for agricultural modernization. However, these challenges also present opportunities for innovation and collaboration among member countries (Ruiz Salvago *et al.*, 2019). ASEAN nations are working together to enhance agricultural productivity, boost trade and investment, promote sustainable practices, and strengthen regional food security.

Naturally, ASEAN has established the ASEAN Economic Community (AEC) with the aim of fostering regional economic integration and cooperation. The AEC endeavors to facilitate the freer movement of goods, services, investment, and skilled labor, all of which benefit the

agricultural sector. Through initiatives such as the ASEAN Integrated Food Security Framework, ASEAN Plus Three (APT), and the ASEAN Plus Six (APT+6), member countries collaborate to address common agricultural challenges and explore opportunities for trade and development (Puriwat and Tripopsakul, 2020).

Issues in the ASEAN agriculture

The ASEAN agricultural industry faces a number of common difficulties that demand collective attention and coordinated efforts. These difficulties have an impact on farmer livelihoods, agricultural system resilience, and overall food security in ASEAN countries.

The impact of climate change and natural disasters is one of the most important challenges. Rising temperatures, irregular rainfall patterns, and an increase in the frequency of extreme weather events endanger crop harvests, livestock production, and food security (Muraru *et al*., 2019). The region is particularly prone to natural disasters such as floods, droughts, and storms, which increase the agricultural sector's issues.

Many ASEAN countries are concerned about land degradation and deforestation. Soil erosion, nitrogen depletion, and salinization reduce agricultural land quality, while deforestation for agricultural expansion and other purposes threatens biodiversity and essential ecosystem services (Ruiz Salvago *et al*., 2019). These concerns necessitate sustainable land management strategies as well as conservation and restoration activities for forest resources.

Water management is critical for agricultural output, especially in water-intensive industries like rice agriculture. Water scarcity, pollution, poor irrigation practices, and insufficient water storage and distribution facilities, on the other hand, are barriers to sustainable agricultural development. Key priorities include encouraging responsible water usage, investing in water infrastructure, and implementing effective water management systems.

Pests, diseases, and invasive species pose significant threats to crops, livestock, and fisheries. Outbreaks of these biological threats, such as the autumn armyworm, rice blast, foot-and-mouth disease, and shrimp illnesses, can result in significant crop losses and financial hardship for farmers (Khan *et al*., 2021). To mitigate these hazards, it is critical to strengthen pest and disease management systems, promote integrated pest management approaches, and improve disease surveillance.

Smallholder farming and rural poverty continue to be chronic issues in ASEAN countries. Many smallholder farmers lack credit, technical knowledge, new agricultural technologies, and market prospects (Panpluem *et al*., 2019). This, together with rural poverty, inadequate infrastructure, and economic inequality, impedes farmers' development and well-being.

Capacity building, access to finance and markets, and the promotion of sustainable farming techniques are all critical for decreasing poverty and improving rural livelihoods.

Bridging the technology and innovation gap is critical for the ASEAN agricultural sector's progress. Many farmers continue to struggle with access to contemporary agricultural technologies, research, development, and innovation (Ruiz Salvago *et al.*, 2019). Promoting modern farming techniques, precision agriculture, and agri-tech advances can increase production, efficiency, and sustainability. This necessitates investments in R&D, technology transfer, and knowledge exchange platforms to allow farmers to reap the benefits of cutting-edge agricultural practices (Ruiz Salvago *et al*., 2019).

Furthermore, the aging population and a shortage of younger people entering the agriculture industry pose major obstacles. This is a global trend that affects agricultural sectors all around the world, including ASEAN countries. The retirement or reduced physical capabilities of older farmers, along with a lack of younger people entering the business, results in a shrinking workforce (Ruiz Salvago *et al.*, 2019). Labor shortages impede agricultural output and operations while putting precious expertise gathered over generations at risk. Encouragement of younger generations to enter the agricultural industry, as well as assistance for their education and training, and promotion of the use of contemporary agricultural technologies, can help alleviate the labor shortage and ensure the transfer of knowledge and competence to the next generation (Puriwat and Tripopsakul, 2020). Younger people, who are often more tech-savvy and open to new ideas, can play an important role in driving the adoption of advanced farming practices, precision agriculture, and agri-tech solutions, improving overall efficiency, productivity, and sustainability in the ASEAN agricultural sector.

UAV as an innovational solution for ASEAN agriculture

Revolutionizing agriculture with UAV data collection

Rapid technological breakthroughs and the ever-evolving capabilities of monitoring systems have heralded a new era of possibilities for the agriculture economy. The field has undergone substantial change, with numerous ways for gathering critical information now available. Among these technologies, unmanned aerial vehicles (UAVs) have emerged as a game changer, allowing data collecting via aerial photography (Muraru *et al.*, 2019). Farmers and agricultural professionals may access high-resolution images and videos that provide real-time insights into numerous areas of their operations, such as topography analysis, vegetation health, and soil composition, by using the power of drones.

The incorporation of drones into the agricultural landscape has enabled complete analysis and decision-making. These adaptable gadgets can be operated manually, allowing users to analyze important circumstances and obtain personal visual information from a remote location. Alternatively, they can be designed to automatically analyze data and create thorough reports (Sharma *et al.,* 2023). This level of monitoring and evaluation enables farmers to make informed decisions, improve resource allocation, and streamline operations, resulting in significant cost savings.

Empowering farmers with affordable UAV technology for informed decision-making and efficiency

One of the most appealing characteristics of using drones in agriculture is their low cost in comparison to traditional aerial vehicles such as planes and helicopters. Ready-made drone solutions for farmers' different needs are widely available in both domestic and foreign markets (Kagita *et al.,* 2022; Sharma *et al.,* 2023). Whether farmers rent or buy drones entirely, the financial burden is substantially less than that of acquiring specialist planes. This cost-effective alternative not only makes drone technology available to a greater range of agricultural stakeholders, but it also tackles the issues related with low productivity and inefficiency that are frequently encountered with ground-based equipment.

Drones have excellent payload capacity and coverage area capabilities. Even the most basic variants can transport up to 10 kg of liquid chemicals in a single trip, making them appropriate for crop spraying or fertilizing. Furthermore, these mobile machines can cover large regions, with the ability to treat up to 4 hectares of land efficiently (Kagita *et al.,* 2022). This exceptional efficiency and productivity improve farming operations, allowing farmers to obtain larger yields while reducing resource waste.

Drones have changed remote sensing techniques in agriculture, in addition to their utility. Remote sensing is the collection of data from many sources utilizing sensors and geospatial analysis tools. Drones are an attractive platform for collecting useful remote sensing data due to their adjustable spatial and spectral resolution capabilities. They outperform standard remote sensing platforms by delivering more detailed and adaptable data on soil parameters, crop classification, water stress detection, agricultural disease monitoring, and crop yield mapping. This plethora of data enables farmers and agricultural businesses to make data-driven decisions, optimize farming operations, and increase output.

Transforming Agricultural Remote Sensing with UAV Technology

For example, with the help of drones, we can determine the presence of weeds in the field (Figure 2).

Figure 2. Map of the distribution of weeds in the field

The capacity of unmanned aerial vehicles (UAVs) to record high-resolution imagery with resolutions as low as one centimeter allows for detailed mapping and monitoring of agricultural fields. UAVs may generate orthomosaic maps and 3D models using photogrammetry techniques, providing a full perspective of the environment and crop health (Bogue, 2021). Farmers can estimate crop density precisely, identify regions of nutrient deficit or weed infestation, and detect anomalies or disease outbreaks that may not be visible at ground level. Such specific data enables focused interventions, lowering input costs and optimizing resource allocation.

For example, with the help of drones, it is possible to map the differentiated application of bio-fertilizers or chemical fertilizers. This will reduce the cost of fertilizers up to 90%, as well as the stress of growth due to the excess amount of applied substances (Figures 2, 3).

Combining UAVs with multispectral or hyperspectral sensors expands the possibilities for agricultural applications even more. These sensors collect data at a variety of wavelengths, allowing for the detection of minute changes in plant health, chlorophyll concentration, and water stress (Bogue, 2021, Thompson and Puntel, 2020). Farmers can utilize this data to conduct site-specific management tactics, such as providing fertilizer, irrigation, and crop protection items precisely where they are needed. This focused approach reduces environmental impact while

increasing resource use efficiency, resulting in increased crop yields and greater sustainability.

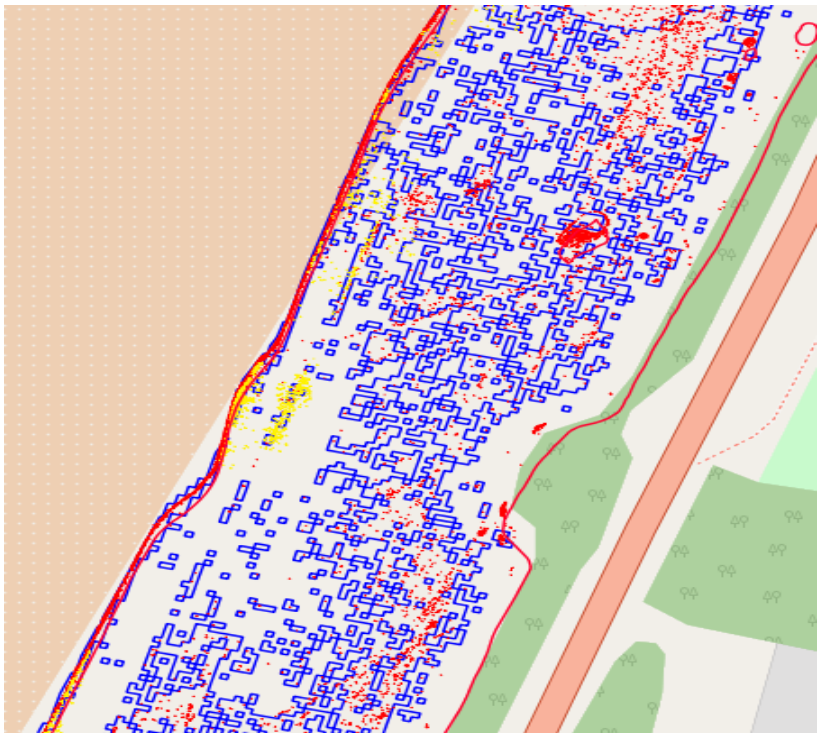

Figure 3. Variable application map

Furthermore, UAVs fitted with thermal cameras can provide valuable insights into crop temperature distribution and indicate stress or disease areas. Thermal imaging can help detect early signs of plant stress caused by things like water scarcity, pests, or fungal infections. Farmers can limit damage and prevent crop losses by spotting these concerns early, boosting overall crop health and output.

UAVs' ease and efficiency extend beyond the data collection phase. Once the aerial data has been obtained, advanced software platforms allow for rapid processing, analysis, and visualization of the data (Triantafyllou *et al.*, 2019). These platforms provide farmers with user-friendly interfaces that enable them to access data in a meaningful and easily interpretable fashion. The use of geographic information systems (GIS) improves the capabilities of UAV data by allowing more exact georeferencing, spatial analysis, and data integration with other agricultural management tools.

Enhancing precision agriculture and resource management with UAVs

Remote sensing applications go beyond simple data collecting. Remote sensing pictures are commonly used for land cover classification,

which allows for change detection monitoring, effective agricultural management, precise green vegetation classification, and informed land use and urban planning (Triantafyllou *et al.,* 2019). Farmers acquire a comprehensive view of their fields by using the power of remote sensing imagery and drone technology, allowing them to change their plans based on accurate and up-to-date information.

Drones have transformed the agriculture industry, providing numerous advantages such as real-time data collecting, cost-effectiveness, better efficiency, and improved decision-making capabilities. Drones have revolutionized remote sensing techniques and provided significant support to farmers and agricultural enterprises due to their ability to collect high-resolution photos, carry large payloads, and cover large areas (Sharma *et al.,* 2023). Drones are poised to play an ever more major role in creating the future of agriculture, promoting innovation, and assisting the industry in addressing difficulties.

Many factors contribute to the growing use of unmanned aerial vehicles (UAVs), making them highly appealing and flexible instruments in a variety of industries. UAVs were initially popular for recreational and military purposes, but their applications have extended to include scientific study, surveillance, cinematography, and agriculture. The use of unmanned aerial vehicles (UAVs) for scientific data gathering and applications, particularly small multi-rotor UAVs, has acquired substantial traction and acceptance among scientists and researchers all over the world.

The simplicity of use of UAVs, particularly in agriculture, is one of the primary reasons for their appeal. These portable devices are user-friendly, allowing farmers and academics to swiftly comprehend their operations and harness their potential. UAVs provide a seamless piloting experience that does not require substantial training or specialist knowledge, thanks to straightforward controls and streamlined interfaces (Yaqot and Menezes, 2021). Because of this, UAVs have become appealing to individuals looking to incorporate sophisticated technologies into their farming methods.

Aside from their ease of use, UAVs are very adaptable equipment that may adapt to a wide range of agricultural applications. They are great for navigating complicated, limited locations like as dense crop fields or orchards due to their compact size and mobility (Liu *et al.,* 2020). Farmers can use UAVs to acquire high-resolution aerial images or films, which can provide significant insights regarding vegetation, soil conditions, and crop health overall. Farmers can use this real-time data to make data-driven decisions, improve resource allocation, and take appropriate action to mitigate possible risks or obstacles.

Another appealing feature of UAVs in agriculture is their risk-free piloting. UAVs, unlike manned aircraft or helicopters, do not require human operators to be physically present in the aircraft. This considerably

decreases the risks of flying, such as accidents or injuries (Liu *et al.*, 2020). Farmers can safely control UAVs remotely, protecting their safety while collecting critical data from the air. UAVs also have improved collision avoidance systems and intelligent flight modes, which improve their safety and reliability.

UAVs have developed as particularly appealing precision agriculture instruments, with the goal of optimizing farming operations and resource management for optimum efficiency and yield. These flying vehicles can be outfitted with a variety of sensors, such as multispectral or thermal cameras, allowing valuable data collecting beyond what the human eye can see (Liu *et al*., 2020; Javaid *et al.,* 2022). This new information can be processed and analyzed using modern algorithms to detect crop stress, diagnose nutrient deficiencies, monitor irrigation efficiency, and forecast yield potential. Farmers may make informed judgments about irrigation schedules, fertilization programs, pest management techniques, and general crop health management with such exact and detailed information.

The low cost of UAVs contributes to their attractiveness in agriculture. UAVs, as opposed to traditional manned aircraft or satellite photography, present a cost-effective method for obtaining high-resolution aerial data (Javaid *et al*., 2022). They are substantially less expensive to purchase and operate, making them suitable for farmers with limited resources or small-scale businesses. Because UAV technology is now more affordable, farmers of all sizes can benefit from the insights and efficiencies afforded by airborne data collection.

Furthermore, UAV technology is continuously evolving, with continuous improvements in battery life, flying duration, payload capacity, and data processing capabilities (Negash *et al.,* 2019). These developments broaden the potential applications of unmanned aerial vehicles in agriculture and pave the way for future innovation. UAVs are predicted to play an increasingly important role in determining the future of agriculture, enhancing productivity, sustainability, and resource management as technology advances.

Driving innovation in agriculture with advanced UAV technology and data integration

Drones' innovative work includes four critical stages: preliminary photogrammetric processing, deep learning-based object detection, complete data analysis, and outcome evaluation. Let us look at each phase in detail to comprehend their relevance and allure. The method begins with preliminary photogrammetric processing of UAV photos using cutting-edge digital tools. This preliminary stage guarantees that the collected images have been refined and are ready for future processing.

The power of deep learning algorithms is then put to use. These sophisticated algorithms recognize diverse land cover types and identify diseases connected with them. The algorithms efficiently split the region covered by the main crop and detect individual crops on the orthomosaic using pattern-matching approaches. This discovery enables accurate crop monitoring and disease detection. After methodically gathering the data, it is thoroughly analyzed using cutting-edge geoprocessing technologies. Based on drone data, these technologies enable agricultural professionals to extract useful insights and make informed decisions. Professionals can check crop health, detect pests, and estimate potential yield implications thanks to the combination of advanced technology and data analysis. Furthermore, detection accuracy is pivotal in determining the threshold, ensuring precise identification of pests affecting field crops (Maddikunta *et al.,* 2021). By analyzing field samples, experts can assess the impact of pests on crops, aiding in the development of effective mitigation strategies.

It is essential to highlight the crucial role of topographic maps in agricultural and vegetation mapping. Along with aerial triangulation, drones collect essential data that is later orthorectified and georeferenced using control points (Maddikunta *et al.,* 2021). This data integration ensures accurate representation and analysis of various vegetation types, accounting for factors such as altitude restrictions.

Monitoring crop growth at critical stages is paramount for estimating yields and addressing potential issues promptly. Drones equipped with multispectral, infrared, and hyperspectral sensors offer one of the most effective methods for detecting stressed plants and distinguishing between crop types and growth stages (Yinka-Banjo and Ajayi, 2019). The data collected by these sensors enables agricultural professionals to analyze soil and crop conditions accurately. Vital information regarding crop health is obtained by utilizing field maps and additional indices like the Crop Water Stress Index (CWSI) and the Crop Map Crop Chlorophyll Content Index (CCCI) (Yinka-Banjo and Ajayi, 2019).

In addition to facilitating precision farming, UAVs also play a crucial role in assessing soil health, irrigation scheduling, evaluating yield data, and optimizing fertilizer application. Furthermore, they provide valuable data for weather analysis, ensuring that agricultural professionals have the necessary information to make informed decisions.

Consequently, when combined with other data sources and analytical solutions, the spatial data collected by drones offer valuable information for agricultural professionals. This integration of technologies not only supports precision farming practices and helps optimize soil health, improve irrigation strategies, enhance crop yields, and contributes to sustainable agricultural practices (Figure 4).

Figure 4. Field data collection with UAV and multispectral camera

UAV potential

UAVs are becoming increasingly popular in agriculture due to their ease of use, versatility, risk-free flying, precision capabilities, and cost (Sharma *et al.,* 2023). These portable and agile equipment let farmers and researchers to collect high-resolution aerial data, allowing them to make informed decisions and enhance agricultural methods. UAVs are poised to change the agricultural industry as technology advances. The incorporation of artificial intelligence and machine learning algorithms into UAVs has the potential to significantly improve their capabilities. These intelligent systems are capable of processing massive volumes of data acquired by UAVs and giving real-time insights and predictive analytics for optimal crop management. In addition to crop monitoring and management, UAVs play an important role in optimizing other agricultural tasks. UAVs, for example, can be used for field levelling inspections, assisting farmers in identifying areas that require land grading or soil preparation (Sharma *et al.*, 2023). They can also help track the progress of agricultural infrastructure projects, providing real-time updates and supporting effective project management.

Overall, deploying UAVs in agriculture provides a clear and appealing solution to farmers' modern-day concerns. They are crucial for enhancing resource management, increasing production, and supporting sustainable agriculture practices due to their ease of operation, adaptability, risk-free piloting, precision capabilities, and affordability. As technology advances and UAV adoption spreads, the agricultural industry is ready to see major improvements in efficiency leading to greater profitability.

Drones have emerged as significant instruments for increasing efficiency and output in rice cultivation. They provide a variety of

applications that assist farmers in monitoring crops, spraying pesticides, and even seed distribution. Surveillance drones, spray drones, and seed spreading systems are three notable types of drones used in agriculture, primarily rice cultivation in ASEAN countries in general and Thailand in particular.

Surveillance drones

Drone surveillance is critical in rice production since it provides farmers with detailed and real-time information on their fields. These drones, which are outfitted with high-resolution cameras and sensors, record airborne photographs and collect data on crop health, growth patterns, and insect infestations. Farmers can discover possible difficulties such as nutrient deficits or disease outbreaks early on by analyzing collected data, allowing them to take immediate action to mitigate crop harm (Figure 5). Drone surveillance is especially useful in huge rice fields where manual monitoring would be time-consuming and impractical.

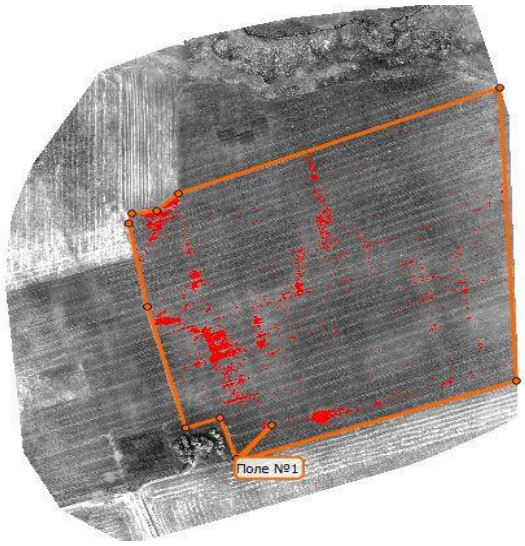

Figure 5. Map of diseases in the field

Spray drones

Pest control with spray drones has transformed rice production. With their precision spraying capabilities, these drones can apply insecticides, herbicides, and fertilizers to rice fields in an accurate and efficient manner. Spray drones can accurately target specific locations using specialized spraying systems and GPS technology, decreasing chemical waste and environmental impact. Farmers may save time and money by automating the spraying process while still maintaining effective pest control. Spray

drones also reduce the need for farmers to be exposed to potentially hazardous chemicals, boosting agricultural safety.

Seed spreading systems

Drone-based seed-spreading methods have grown in popularity in rice cultivation, particularly in places with difficult terrain or big fields. Drones equipped with seed dispensers can accurately scatter rice seeds across the field with these systems. GPS guidance and superior mapping technology are used by the drones to ensure uniform seed dispersal, resulting in more consistent crop growth and higher yields. Seed-spreading drones are also more efficient than traditional human methods, requiring less time and labor to sow. They can also visit isolated or inaccessible regions, making them especially helpful in difficult terrain.

Tradition vs. innovation

UAV drones have the ability to aid ASEAN farmers by increasing efficiency, lowering costs, and promoting sustainable agriculture methods. However, solving adoption, knowledge transfer, and infrastructural constraints is critical to fully leveraging the promise of drones in ASEAN's diverse agricultural terrain. Drones can contribute to the expansion and development of the region's agriculture sector with supportive policies and investments. Drones have the ability to greatly improve efficiency in the rice producing business. They can be outfitted with a variety of sensors and imaging technologies in order to monitor crop health, detect illnesses, and check field water levels (Khan *et al*., 2021). Drones, with their capacity to cover huge areas fast and offer real-time data, can assist farmers in immediately identifying and addressing concerns, resulting in more efficient crop management and higher yields. Farmers, on the other hand, make judgments based on their expertise and knowledge, which can be time-consuming and inaccurate when compared to the data-driven insights supplied by drones. However, let us suppose a 5000 square meter space. This region will be covered in about 5 minutes by one drone. In comparison, the region would require 50 field workers to do the same operation in 25 minutes using manual labor. As a result, not only is the UAV drone faster, but it is also considerably cheaper to take advantage of its advantages.

As previously said, drones can provide cost advantages in the rice production industry. Investing in drones and the necessary equipment may appear pricey at first. However, they can be cost-effective in the long run (Khan *et al.,* 2021). Drones cut labor expenses by eliminating the need for manual labor in operations such as crop scouting. Drones can also improve the use of inputs like fertilizer and pesticides by targeting regions that need treatment, reducing waste and expenses. Farmers, on the other hand, rely

significantly on human labor, which can be pricey and scarce. Nonetheless, the population working in ASEAN agriculture industries is aging, with most younger people preferring other employment and leaving the land. As a result, the agriculture industry is dealing with an aging population.

The rice farming business faces challenges due to an aging population and a decrease in the number of trained farmers. Drones can help with this problem by lowering physical labor requirements and providing remote crop monitoring and management. This allows senior farmers to be involved in the sector and share their knowledge without putting in too much physical work. Drones can be an effective tool for information transfer, allowing new farmers to learn from more experienced farmers.

Conclusion

UAV drones have the ability to change rice production in ASEAN countries by providing farmers with several benefits. Drones can help the region's agriculture sector expand and flourish by increasing efficiency, lowering costs, and promoting sustainable agricultural methods. However, in order to fully realize the promise of drones, it is critical to solve issues such as adoption, knowledge transfer, and infrastructure.

Drones equipped with modern sensors and imaging technology may monitor crop health, diagnose illnesses, and measure field water levels, resulting in better agricultural management and higher yields. Drones' real-time data allows farmers to quickly detect and fix concerns, allowing them to make informed decisions based on data-driven insights. In comparison to manual labor, drones can cover enormous regions swiftly and effectively, saving time and money.

While the initial investment in drones may appear to be high, they are ultimately cost-effective. Drones save labor expenses by removing the need for manual labor in operations such as crop scouting. Furthermore, drones optimize inputs such as fertilizers and insecticides, reducing waste and costs. Given the agriculture industry's aging population and a shortage of skilled farmers, drones provide a solution by lowering physical labor requirements and enabling remote crop monitoring and management. This allows senior farmers to be involved in the sector and share their knowledge without putting in too much physical work.

To fully realize the benefits of drones in ASEAN's diversified agricultural terrain, supportive policies and investments are required. Governments and organizations must promote and incentivise the use of drone technology, as well as provide farmers with training and instruction and develop infrastructure to enable drone operations. By tackling these issues, ASEAN countries will be able to realize the full potential of UAV drones, improving agricultural productivity, sustainability, and the livelihoods of farmers throughout the region.

References

Bogue, R. (2021). Robots poised to transform agriculture. Industrial Robot: the international journal of robotics research and application, 48:637-642.

Hoang, V. V. (2020). Investigating the agricultural competitiveness of ASEAN countries. Journal of Economic Studies, 47:307-332.

Javaid, M., Haleem, A., Singh, R. P. and Suman, R. (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. International Journal of Intelligent Networks, 3:150-164.

Kagita, M. K., Kaosar, M. and Thilakarathne, N. (2022). Survey on AI-based IoT and drone-equipped smart agriculture. Artificial Intelligence of Things in Smart Environments, Applications in Transportation and Logistics, pp.101-114.

Khan, D., Nouman, M., Popp, J., Khan, M. A., Ur Rehman, F. and Oláh, J. (2021). Link between technically derived energy efficiency and ecological footprint: Empirical evidence from the ASEAN region. Energies, 14: 3923.

Liu, Y., Ma, X., Shu, L., Hancke, G. P. and Abu-Mahfouz, A. M. (2020). From Industry 4.0 to Agriculture 4.0: Current status, enabling technologies, and research challenges. IEEE Transactions on Industrial Informatics, 17:4322-4334.

Maddikunta, P. K. R., Hakak, S., Alazab, M., Bhattacharya, S., Gadekallu, T. R., Khan, W. Z. and Pham, Q. V. (2021). Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges. IEEE Sensors Journal, 21:17608-17619.

Mizik, T., Szerletics, Á. and Jámbor, A. (2020). Agri-food export competitiveness of the asean countries. Sustainability, 12:9860.

Muraru, S. L., Cardei, P., Muraru, V., Sfîru, R. and Condruz, P. (2019). Researches regarding the use of drones in agriculture. International Multidisciplinary Scientific GeoConference: SGEM, 19:683-690.

Negash, L., Kim, H. Y. and Choi, H. L. (2019, November). Emerging UAV applications in agriculture. In 2019 7th International Conference on Robot Intelligence Technology and Applications (RiTA) (pp. 254-257). IEEE.

Panpluem, N., Mustafa, A., Huang, X., Wang, S. and Yin, C. (2019). Measuring the technical efficiency of certified organic rice producing farms in Yasothon province: Northeast Thailand. Sustainability, 11:6974.

Puriwat, W. and Tripopsakul, S. (2020). Preparing for Industry 4.0--Will Youths Have Enough Essential Skills?: An Evidence from Thailand. International Journal of Instruction, 13:89-104.

Ruiz Salvago, M., Phiboon, K., Faysse, N. and Nguyen, T. P. L. (2019). Young people's willingness to farm under present and improved conditions in Thailand. Outlook on Agriculture, 48:282-291.

Sharma, S., Verma, K. and Hardaha, P. (2023). Implementation of artificial intelligence in agriculture. Journal of Computational and Cognitive Engineering, 2:155-162.

Thompson, L. J. and Puntel, L. A. (2020). Transforming unmanned aerial vehicle (UAV) and multispectral sensor into a practical decision support system for precision nitrogen management in corn. Remote Sensing, 12:1597.

Triantafyllou, A., Sarigiannidis, P. and Bibi, S. (2019). Precision agriculture: A remote sensing monitoring system architecture. Information, 10:348.

Yaqot, M. and Menezes, B. C. (2021). Unmanned aerial vehicle (UAV) in precision agriculture: business information technology towards farming as a service. In 2021 1st International Conference on Emerging Smart Technologies and Applications (eSmarTA) (pp. 1-7). IEEE.

Yinka-Banjo, C. and Ajayi, O. (2019). Sky-farmers: Applications of unmanned aerial vehicles (UAV) in agriculture. Autonomous vehicles, 107-128.

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