

RECENT DRONE APPLICATIONS IN MALAYSIA: AN OVERVIEW

Adel Gohari¹, Anuar bin Ahmad¹, Olakunle O. Oloruntobi²

¹Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

²Department of Maritime Operation, Faculty of Maritime Studies, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia.

Commission IV, WG 7

KEY WORDS: Drones, Applications, Review, Documents, Journals, Conferences, Malaysia.

ABSTRACT:

This study aims on an exploration of recent applications of drones in the Malaysian context. More specifically, to investigate the drone's application status and application areas. To search the academic literature and identify the included documents, we have followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. We conducted an overview study of the total number of 54 documents (out of 202) published since 2018, which were extracted from the Scopus database. The results of the bibliometric analysis of the included documents showed that drones in Malaysia are applied in different disciplines, including agriculture, mapping, forestry, river monitoring, transportation, construction, coastal management, flood management, and other applications. Among these, agriculture and mapping are the main application areas. MDPI published the most journal articles, and IGRSM conferences published the highest number of conference papers. Furthermore, scholars from the Universiti Teknologi Malaysia have the highest contribution among others.

1. INTRODUCTION

The vast applications of drones, which are known as small-sized Unmanned Aerial Vehicles (UAVs), have gained huge interest nowadays and have become central to the functions of various businesses and governmental organizations in countries around the globe. It could be due to the high potential of drones to offer countless benefits to the current industries in different sectors by providing innovative products and solutions. Increasing work efficiency and productivity, decreasing workload and production costs, improving accuracy, refining service and customer relations, and resolving security issues on a vast scale are a few of the top uses drones offer industries globally. Drones can perform indoor and outdoor activities and enable us to collect data in large and difficult-to-access areas in a short time while reducing human intervention and manpower requirements (Gohari et al., 2022).

To the best of our knowledge, there is a lack of literature regarding a review study on drone applications in the Malaysian context. In this regard, Ab Rahman et al. (2019) attempted to explore drone applications in Malaysia. However, this research has not been conducted in a systematic method. A systematic review of the literature allows for a detailed analysis of recent research. The aim of this review is to investigate the application of drones in Malaysia through bibliometric analysis of academic literature and seek to answer the following research questions: What is the application status of drones in the Malaysian context? What application areas of drones have been presented in the literature in the Malaysian context?

The remainder of this study is presented as follows. In the next section, we discuss the methodology used to extract the relevant research works from the academic literature. In the finding and results section, we demonstrate the outcome of the bibliometric analysis, which includes statistics about annual published documents, the contribution of journal outlets and conferences,

the author's affiliations, and the categorization of the included documents. The conclusion is given in the last section.

2. METHODOLOGY

The methodology of this systematic review is based on the PRISMA guidelines to extract the relevant documents. The flowchart process of this study is presented in Figure 1. To collect relevant academic papers in the identification stage, the Scopus database was searched on August 07, 2022. We used an advanced search tool and the search string in their title, abstract, and keywords. The complete used search string was ("*drone*" OR "*UAV*" OR "*UAS*" OR "*unmanned aerial vehicle*" OR "*unmanned aerial system*") AND ("*Malaysia*"). The result of this query showed 202 documents since 1993. However, since this study focuses on the most recent researches, we picked the papers published in the last 5 years (2018 onwards). We also limited the search results based on the different criteria including document type (article and conference paper), source type (journal and conference proceeding), publication stage (final), keyword ("unmanned aerial vehicles (UAV)", "drones", "UAV", "unmanned aerial vehicle", and "drone"), and language (English). These limitations caused a reduction of the search results to 77 documents, which were extracted for further processing in the next stages. Checking these documents showed no duplication. In the screening stage, we checked the titles and abstracts of all the 77 documents and found that 11 documents records were irrelevant to this study. Therefore, a total of 66 documents remained. In the eligibility stage, the authors carefully screened the full text of all 66 documents. Among them, 12 documents addressed different technical and non-technical issues (drone operations, performance, optimization, and review), which are out of the scope of this review. Ultimately, a total of 54 documents were included in the current review.

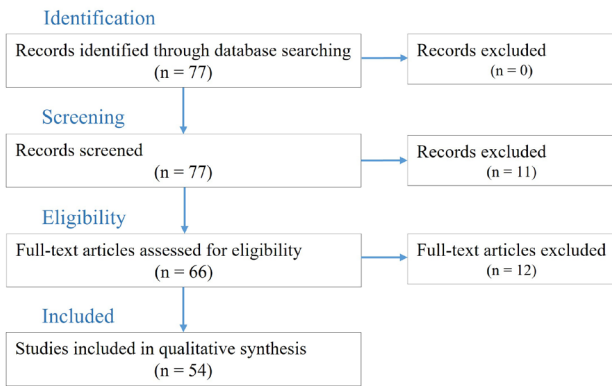


Figure 1. Flowchart process of the current review.

3. FINDINGS AND RESULTS

The bibliometric analysis of all included articles was performed to investigate the current applications of drones in Malaysia in terms of the number of documents yearly published, conference and journal papers, publishers, affiliation of authors, and categorization of the included documents. The annual number of documents was distributed between 2018 (14 documents), 2019 (11 documents), 2020 (13 documents), 2021 (10 documents), and 2022 (6 documents), which is shown in Figure 2.

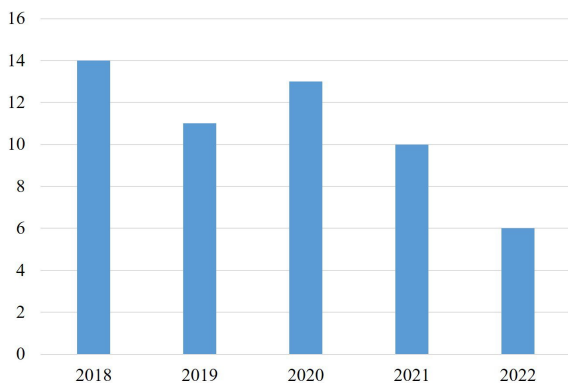


Figure 2. The annual number of published documents.

The 54 documents consist of 28 journal articles and 26 conference papers. The only journal with more than 1 published article (2 articles) is the "Remote Sensing" journal. The list of involved journals is presented in Table 1. The highest number of articles were published by MDPI (7 articles) and Elsevier (2 articles) outlets, while the remaining articles were published by 19 different publishers (1 each), which is illustrated in Figure 3.

	Journal	Number of articles
1	International Journal of Architectural Computing	1
2	International Journal of Civil Engineering	1
3	Journal of Theoretical and Applied Information Technology	1
4	Journal of Tropical Forest Science	1
5	Journal of Advanced Research in Fluid Mechanics and Thermal Sciences	1
6	Forests	1
7	BMC Health Services Research	1

8	Physics and Chemistry of the Earth	1
9	Sustainability	1
10	Journal of Mines, Metals and Fuels	1
11	Estuarine, Coastal and Shelf Science	1
12	Computers, Materials and Continua	1
13	Applied Artificial Intelligence	1
14	Journal of Oil Palm Research	1
15	Remote Sensing	2
16	Journal of Sustainability Science and Management	1
17	ISPRS International Journal of Geo-Information	1
18	International Journal of Remote Sensing	1
19	Sensors	1
20	International Journal of Innovative Technology and Exploring Engineering	1
21	Drones	1
22	Journal of Sustainability Science and Management	1
23	Journal of Advanced Manufacturing Technology	1
24	International Journal of Supply Chain Management	1
25	Forest Ecology and Management	1
26	International Journal of Supply Chain Management	1
27	International Journal of Integrated Engineering	1

Table 1. The list of journals.

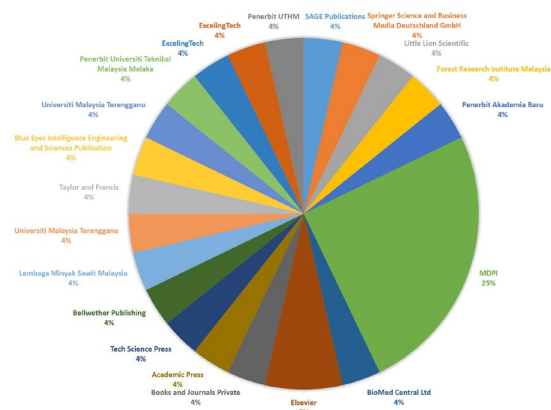


Figure 3. Contribution of the publishers.

The greatest number of conference papers (seven out of 26) were belonged to the Institution of Geospatial and Remote Sensing Malaysia (IGRSM) conferences in 2018 and 2020, followed by the Asian Conference on Remote Sensing (ACRS) conferences (total of six papers) in 2018, 2019, and 2020, and the International Conference on System Engineering and Technology (ICSET) in 2020 (2 papers). The remaining conference papers belong to 11 different conferences. The contribution of involved conferences regarding published papers is illustrated in Figure 4.

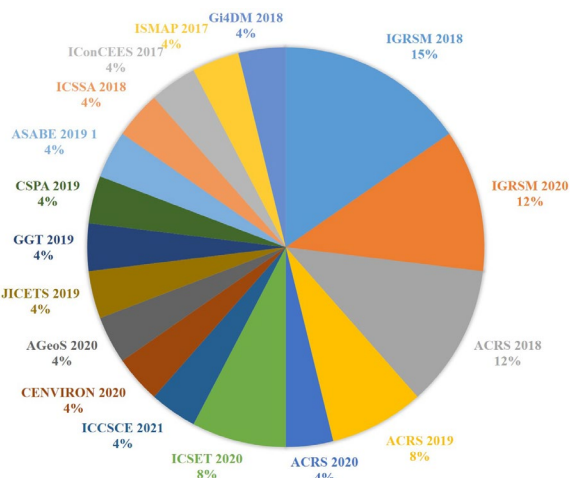


Figure 4. Contribution of conferences.

The results of the author's affiliation indicated that a total of 51 local and international universities and organizations have been involved, which consists of local universities (16), international universities (18), local organizations (15), and international organizations (2). Local universities have shown the maximum number of affiliations (107), followed by international universities (27), local organizations (20), and international organizations (2). Consequently, a total number of 156 affiliations has resulted. Among local universities, the top two most prominent affiliations belong to Universiti Teknologi Malaysia (24) and Universiti Teknologi MARA, Malaysia (18). Among international universities, Université Libre de Bruxelles in Belgium, Kennesaw State University in the United States, and Hokkaido University in Japan have the most affiliations (3 each). In terms of local organizations, the Forest Research Institute Malaysia has highest affiliations (3), followed by the Department of Agriculture in Sarawak, Malaysia, the Ministry of Health (MOH), Malaysia, the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) (2 each). The National Institute for Environmental Studies, Japan, and Vlaamse Instelling Voor Technologisch Onderzoek (VITO) Research Organisation, Belgium, were involved international organizations. The affiliation appearance of local and international universities is shown in Figure 5 and Figure 6, respectively.

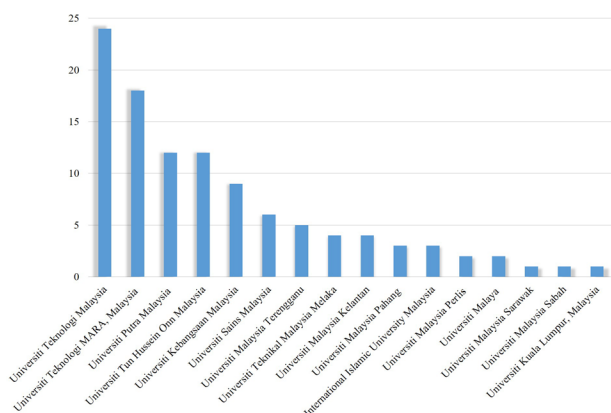


Figure 5. Affiliation appearance of local universities.

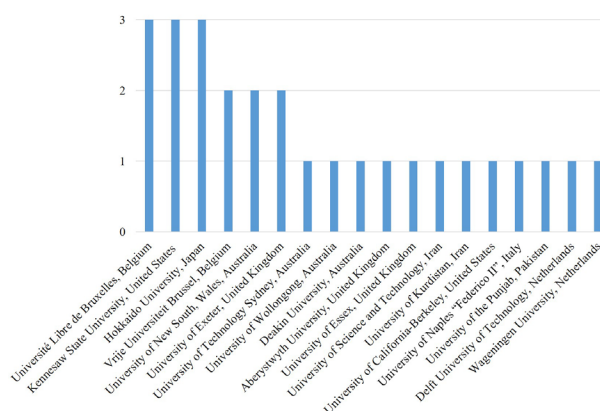


Figure 6. Affiliation appearance of international universities.

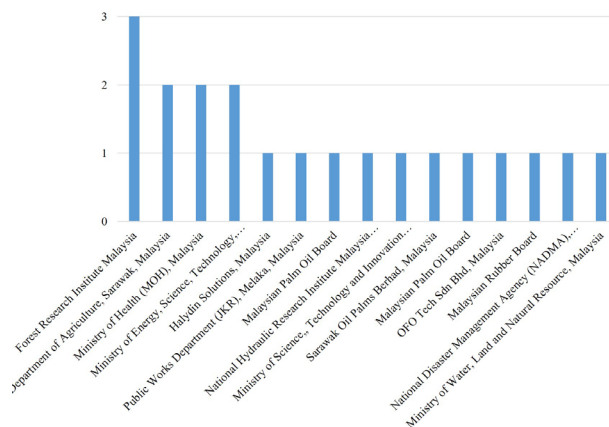


Figure 7. Affiliation appearance of local organizations.

In recent years, the application of drones in Malaysia has been addressed in different disciplines. The authors of this review categorized the 54 included documents into nine distinct groups, including construction, agriculture, transportation, forestry, mapping, coastal management, flood management, river monitoring, and others, which is shown in Figure 8. Note that applications that have been addressed by one document are placed in the "others" group. Based on the categorization results, almost one quarter of the documents have addressed the application of drones related to agriculture (13), followed by mapping (10), forestry (6), and river monitoring (5). Transportation, construction, and coastal management groups have shared an equal number of documents (4 each). A few studies addressed drone applications in flood management (2).

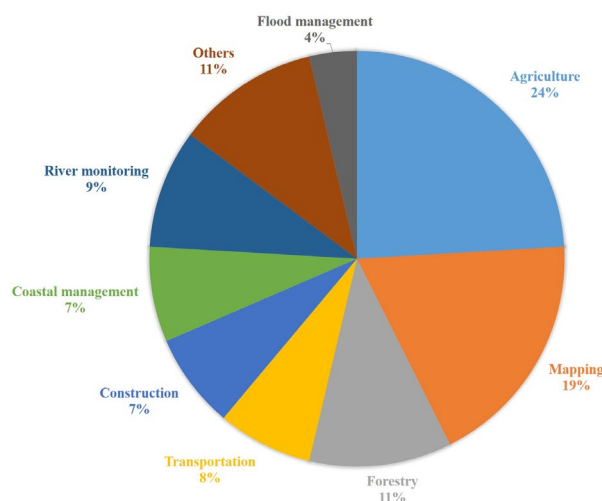


Figure 8. Application areas of drones in Malaysia.

The associated references to each group are presented in Table 2. The Agriculture group covers estimation of Nitrogen (N) status in MD2 pineapple (*Ananas comosus* var. MD2) crop on mineral soil, durian orchards monitoring, automatic oil palm detection, detection of palm oil health condition, detection of ganoderma disease in oil palm, extraction of biophysical parameters of young oil palm, durian plantation management, estimation of leaf area index, oil palm (*Elaeis guineensis*) canopy segmentation and height estimation, chemical spraying, rubber-tree clones leaf diseases determination, and rice crop monitoring. The mapping group focuses on slope, 2D, 3D, land use, landslides, terrain, and topographic (large scale) map production. The forestry group includes different topics: determination of emission factor from selective logging activities; detecting and mapping post-selective logging impacts; mangrove tree height measurement; tree stump height estimation; deforestation and forest degradation; and forest inventory. River monitoring applications include water level changes, riverine plastic debris quantification, sustainability monitoring, and quantifying variations in river surface flow areas and vegetation growth. Transport-related applications are blood products delivery, road image segmentation, effectiveness analysis of transverse rumble strips, and shipping container counting. Applications related to construction include construction site visualization and mapping; progress monitoring; information fusion for 3D modelling of cultural heritage; and housing renovation identification. Coastal management studies addressed the effects of erosion and accretion on beach profile, volume measurement, shoreline evolution, and reef-island shoreline change assessment. The flood management group represents studies on real-time and intelligent flood forecasting and flood assessment. The other groups include rockfall trajectory and back analysis, detecting Bornean orang-utans, elevation data acquisition for geophysical survey alignments, monitoring trawler activities, suspected unregulated dumping site detection and verification, and eutrophication process monitoring.

Application	References
Agriculture	(Hasni et al., 2022); (Yusof et al., 2022); (Liu et al., 2021); (Rafezall et al., 2020); (Izzuddin et al., 2020); (Avtar et al., 2020); (Syafiqah et al., 2020); (Abdullah et al., 2020); (Fawcett et al., 2019); (Suab et al., 2019); (Ismail et al., 2019); (Ali et al., 2018); (Norasma et al., 2018)
Mapping	(Zolkepli et al., 2021); (Chaudhry et al., 2020); (Noor et al., 2020); (Kaamin et al., 2020); (Udin et al., 2019); (Yazid et al., 2019); (Ahmad et al., 2018a); (Abdullah et al., 2018); (Yusoff et al., 2018); (Ahmad et al., 2018b)
Forestry	(Siti-Nor-Maizah et al., 2022); (Kamarulzaman et al., 2022); (Saliu et al., 2021); (Maizah Saad et al., 2020); (Otero et al., 2018); (Nadia Zainol et al., 2018)
River monitoring	(Ansari et al., 2021); (Mohamad et al., 2019); (Geraeds et al., 2019); (Elijah et al., 2018a); (Elijah et al., 2018b)
Transportation	(Zailani et al., 2021); (Mahmud et al., 2021); (Sanik et al., 2019); (Abdullah et al., 2019)

Construction	(Keyvanfar et al., 2022a); (Keyvanfar et al., 2022b); (Mohd Noor et al., 2020); (Mustaffa et al., 2018)
Coastal management	(Narashid et al., 2021); (Yusoff et al., 2020); (Zulfakar et al., 2020); (Lowe et al., 2019)
Others	(Sheng et al., 2021); (Nagendran and Ismail, 2021); (Azmi et al., 2020); (Mutalib et al., 2019); (Ismail et al., 2018); (Suteris et al., 2018)
Flood management	(Goudarzi et al., 2021); (Sharom et al., 2018)

Table 2. References associated with each group.

4. CONCLUSION

This study contributes to the body of literature by providing bibliometric analysis of published documents regarding drone applications in the Malaysian context. We found that this topic of research is growing since a variety of local universities and governmental organizations are involved. MDPI and IGRSM are, respectively, the main publisher and conference organizer that publish most of the journal articles and conference papers. The highest number of authors' affiliations in terms of local universities and organizations is assigned to the Universiti Teknologi Malaysia and Forest Research Institute Malaysia, respectively. The involvement of a number of international universities and a few international organizations also appeared. Drones in Malaysia are applied in different disciplines, including agriculture, mapping, forestry, river monitoring, transportation, construction, coastal management, flood management, and other applications. Among these, agriculture and mapping are the main application areas. However, it should be noted that the outcomes drawn from this study are based on some limitations which are explained in the methodology section. Thus, we suggest conducting the study by considering other scholarly databases such as the Web of Science. Also, by investigating the integration of different technologies with drones to perform flight operations and data collection, further studies can be conducted.

ACKNOWLEDGEMENTS

The authors wish to extend their appreciation to UTM Iconic research grant no Q.J130000.4352.09G75 for sponsoring this study and making it successful. Special thanks to Faculty Built Environment & Surveying, UTM for supporting this work.

REFERENCES

- Abdullah, A.A.A., Noor, N.M., Abdullah, A., 2018: Drone 3D mapping in identifying Malay urban form: case study of Kota Bharu. *IOP Conference Series: Earth and Environmental Science. 9th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM), 24–25 April 2018, Kuala Lumpur, Malaysia*, 169(1), p. 012084. IOP Publishing.
- Abdullah, A.N.H., Muharam, F.M., Zulkafli, Z.D., Nurulhuda, K., Hashim, M.F.C., Zad, S.N.M., Ismail, M.R., 2020: Estimation of leaf area index from UAV multispectral indices and machine learning models. *The 40th Asian Conference on Remote Sensing, 14 – 18 October 2019, Daejeon, South Korea*, 1, 145-151, Korean Society of Remote Sensing (KSRS).

- Abdullah, A., Jaafar, J., Tahar, K.N., Mohamed, W., 2019: Unmanned aerial vehicle (UAV) and ArcGIS for shipping container counting. *International Journal of Supply Chain Management* 8(3), 565.
- Ab Rahman, A.A., Wan Shafrina, W.M.J., Khairul Nizam, A.M., Norazilawati, M.N., Midhun, M., Adrian, C., Carlos Alberto, S., Nik Norasma, C., Nasrul Ikhwan, N., 2019. Applications of drones in emerging economies: A case study of Malaysia. *6th International Conference on Space Science and Communication (IconSpace)*, 28-30 July 2019, Johor Bahru, Malaysia, 35-40, IEEE.
- Ahmad, M.J., Ahmad, A., Kanniah, K.D., 2018a: Large scale topographic mapping based on unmanned aerial vehicle and aerial photogrammetric technique. *IOP Conference Series: Earth and Environmental Science. 9th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM), 24–25 April 2018, Kuala Lumpur, Malaysia*, 169(1), p. 012077, IOP Publishing.
- Ahmad, M.J., Ahmad, A., Suhaimi, H.M. 2018b: Production of large scale topographic map using fixed-wing unmanned aerial vehicle. *Proceedings - 39th Asian Conference on Remote Sensing (ACRS 2018): Remote Sensing Enabling Prosperity*, 15-19 October, Kuala Lumpur, Malaysia, 3, 1427-1437, Asian Association on Remote Sensing (AARS).
- Ali, H.M., Abd Hamid, N.R., Abd Ghani, Z., Mahsuri, I., Yusoff, A.R.M., Zainon, O., Idris, K.M., Dollah, R., 2018: Determination of rubber-tree clones leaf diseases spectral using unmanned aerial vehicle compact sensor. *IOP Conference Series: Earth and Environmental Science, 9th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM), 24–25 April 2018, Kuala Lumpur, Malaysia*, 169(1), p. 012059. IOP Publishing.
- Ansari, E., Akhtar, M.N., Abdullah, M.N., Othman, W.A.F.W., Bakar, E.A., Hawary, A.F., Alhady, S.S.N., 2021: Image processing of UAV imagery for river feature recognition of Kerian River, Malaysia. *Sustainability* 13(17), 9568.
- Avtar, R., Suab, S.A., Syukur, M.S., Korom, A., Umarhadi, D.A., Yunus, A.P., 2020: Assessing the influence of UAV altitude on extracted biophysical parameters of young oil palm. *Remote Sensing* 12(18), 3030.
- Azmi, M.Z.M., Mohamad Sharom, M.A.A., Md Zin, S.M., Numpang, W., Sipit, C.A.R., 2020: Suspected unregulated dumping site detection and verification using high resolution satellite images and drone full motion video (FMV) data. *41st Asian Conference on Remote Sensing (ACRS)*, 9-11 November 2020, Deqing, China, Code 169013.
- Chaudhry, M.H., Ahmad, A., Gulzar, Q., 2020: A comparative study of modern UAV platform for topographic mapping. *IOP Conference Series: Earth and Environmental Science, 10th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing 20-21 October 2020, Kuala Lumpur, Malaysia*, 540(1), p. 012019, IOP Publishing.
- Elijah, O., Rahman, T.A., Yeen, H.C., Leow, C.Y., Sarijari, M.A., Aris, A., Salleh, J., Han, C.T., 2018a: Application of UAV and low power wide area communication technology for monitoring of river water quality. *2nd International Conference on Smart Sensors and Application (ICSSA)*, 105-110. IEEE.
- Elijah, O., Rahman, T. A., Leow, C. Y., Yeen, H. C., Sarijari, M. A., Aris, A., Salleh, J., Chua, T.H., (2018b): A concept paper on smart river monitoring system for sustainability in river. *International Journal of Integrated Engineering* 10(7).
- Fawcett, D., Azlan, B., Hill, T.C., Kho, L.K., Bennie, J., Anderson, K., 2019: Unmanned aerial vehicle (UAV) derived structure-from-motion photogrammetry point clouds for oil palm (*Elaeis Guineensis*) canopy segmentation and height estimation. *International Journal of Remote Sensing* 40(19), 7538-7560.
- Geraeds, M., Van Emmerik, T., De Vries, R., Bin Ab Razak, M.S., 2019: Riverine plastic litter monitoring using unmanned aerial vehicles (UAVs). *Remote Sensing* 11(17), 2045.
- Gohari, A., Ahmad, A.B., Rahim, R.B.A., Supa'at, A.S.M., Abd Razak, S., Gismalla, M.S.M., 2022: Involvement of surveillance drones in smart cities: A systematic review. *IEEE Access* 10, 56611–56628.
- Goudarzi, S., Soleymani, S.A., Anisi, M.H., Ciunzo, D., Kama, N., Abdullah, S., Azgomi, M.A., Chaczko, Z., Azmi, A., 2021: Real-time and intelligent flood forecasting using UAV-assisted wireless sensor network. *Computers, Materials and Continua* 70(1), 715-738.
- Hasni, R., Hasmah, M., Mohd Yazid M.A.K., Azlina, N., Azilawati, B., Khairul, F.T., Radziah, J., Syahira, J., Ngabdollah S., 2022: Determining suitable spatial resolution to estimate nitrogen status in M2 pineapple crop cultivated on mineral soil. *Journal of Theoretical and Applied Information Technology* 100(3).
- Ismail, S.A., Yahya, A., Su, A.S.M., Asib, N., Mustafah, A.M., 2019: Chemical spraying using unmanned aerial system (UAS) in wetland rice cultivation in Malaysia. *2019 ASABE Annual International Meeting (p. 1)*, American Society of Agricultural and Biological Engineers.
- Ismail, M.A.M., Kumar, N.S., Abidin, M.H.Z., Madun, A., 2018: Systemic approach to elevation data acquisition for geophysical survey alignments in hilly terrains using UAVs. *Journal of Physics: Conference Series. International Seminar on Mathematics and Physics in Sciences and Technology 2017 (ISMAP), 28–29 October 2017, Hotel Katerina, Malaysia*, 995(1), p. 012104). IOP Publishing.
- Izzuddin, M.A., Hamzah, A., Nisfariza, M.N., Idris, A.S., 2020: Analysis of multispectral imagery from unmanned aerial vehicle (UAV) using object-based image analysis for detection of ganoderma disease in oil palm. *Journal Of Oil Palm Research* 32(3), 497-508.
- Kaamin, M., Mazuki, M.S., Madun, A., Ab Razak, S.N., Ngadiman, N., Nor, A.H.M., 2020: Visual slope inspection using unmanned aerial vehicle (UAV). *Journal of Physics: Conference Series, The 2nd Joint International Conference on Emerging Computing Technology and Sports (JICETS) 2019 25-27, November 2019, Bandung, Indonesia, 1529(3)*, p. 032102. IOP Publishing.
- Kamarulzaman, A.M.M., Wan Mohd Jaafar, W.S., Abdul Maulud, K.N., Saad, S.N.M., Omar, H., Mohan, M., 2022: Integrated segmentation approach with machine learning classifier in detecting and mapping post selective logging impacts using UAV imagery. *Forests* 13(1), 48.

- Keyvanfar, A., Shafaghat, A., Rosley, M.S., 2022a: Performance comparison analysis of 3D reconstruction modeling software in construction site visualization and mapping. *International Journal of Architectural Computing* 20(2), 453-475.
- Keyvanfar, A., Shafaghat, A., Awanghamat, M.A. 2022b: Optimization and trajectory analysis of drone's flying and environmental variables for 3D modelling the construction progress monitoring. *International Journal of Civil Engineering* 20(4), 363-388.
- Liu, X., Ghazali, K.H., Han, F., Mohamed, I.I., 2021: Automatic detection of oil palm tree from UAV images based on the deep learning method. *Applied Artificial Intelligence* 35(1), 13-24.
- Lowe, M.K., Adnan, F.A.F., Hamylton, S.M., Carvalho, R.C., Woodroffe, C.D., 2019: Assessing reef-island shoreline change using UAV-derived orthomosaics and digital surface models. *Drones* 3(2), 44.
- Mahmud, M.N., Osman, M.K., Ismail, A.P., Ahmad, F., Ahmad, K.A., Ibrahim, A., 2021: Road image segmentation using unmanned aerial vehicle images and DeepLab V3+ semantic segmentation model. *2021 11th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 27-28 August, 176-181. IEEE.
- Maizah Saad, S.N., Abdul Maulud, K.N., Mohd Jaafar, W.S.W., Muhmad Kamarulzaman, A.M., Omar, H., 2020: Tree stump height estimation using canopy height model at Tropical Forest in Ulu Jelai Forest Reserve, Pahang, Malaysia. *IOP Conference Series: Earth and Environmental Science, 10th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing, 20-21 October 2020, Kuala Lumpur, Malaysia*, 540(1) p. 012015. IOP Publishing.
- Mohamad, N., Abdul Khanan, M.F., Ahmad, A., Md Din, A.H., Shahabi, H., 2019: Evaluating water level changes at different tidal phases using UAV photogrammetry and GNSS vertical data. *Sensors* 19(17), 3778.
- Mohd Noor, N., Ibrahim, I., Abdullah, A., Abdullah, A.A.A., 2020: Information fusion for cultural heritage three-dimensional modeling of Malay cities. *ISPRS International Journal of Geo-Information* 9(3), 177.
- Mustaffa, A.A., Hasmori, M.F., Sarif, A.S., Ahmad, N.F., Zainun, N.Y. 2018: The use of UAV in housing renovation identification: A Case study at Taman Manis 2. *IOP Conference Series: Earth and Environmental Science. 4th International Conference on Civil and Environmental Engineering for Sustainability (IconCEES 2017), 4-5 December 2017, Langkawi, Malaysia*, 140(1), p. 012003. IOP Publishing.
- Mutalib, A.H.A., Ruppert, N., Akmar, S.A.L.N.I.Z.A., Kamaruszaman, F.F.J., Rosely, N.F.N., 2019: Feasibility of thermal imaging using unmanned aerial vehicles to detect Bornean orangutans. *Journal of Sustainability Science and Management* 14(5), 182-194.
- Nadia Zainol, K., Fairuz Fuazi, M., Jamil, H., Hamadi Shahid, M., Shukri Wan Abdul Rahman, W.A.H., Osman, R., 2018: Synergy between satellite and unmanned aerial vehicle (UAV) images for deforestation and forest degradation assessment. *39th Asian Conference on Remote Sensing (ACRS): Remote Sensing Enabling Prosperity*, 2, 908-916.
- Nagendran, S.K., Ismail, M.A.M., 2021: UAV photogrammetry application for rockfall trajectory and back analysis at Perak, Malaysia. *Journal of Mines, Metals and Fuels* 69(8), 185-192.
- Narashid, R.H., Zakaria, M.A., Mohd, F.A., Pa'suya, M.F., Talib, N., Ariffin, E.H., 2021: Effect of erosion and accretion on beach profile in Kuala Terengganu coastal areas. *IOP Conference Series: Earth and Environmental Science, Advanced Geospatial and Surveying Conference 7 October 2020, Perlis, Malaysia*, 620(1), p. 012008. IOP Publishing.
- Noor, N.M., Harun, N., Abdullah, A., 2020: The fixed wing UAV usage on land use mapping for gazetted royal land in Malaysia. *IOP Conference Series: Earth and Environmental Science, 10th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing, 20-21 October 2020, Kuala Lumpur, Malaysia*, 540(1), p. 012006. IOP Publishing.
- Norasma, C.Y.N., Abu Sari, M.Y., Fadzilah, M.A., Ismail, M.R., Omar, M.H., Zulkarami, B., Hassim, Y.M.M., Tarmidi, Z., 2018: Rice crop monitoring using multirotor UAV and RGB digital camera at early stage of growth. *IOP Conference Series: Earth and Environmental Science, 9th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM) 24-25 April 2018, Kuala Lumpur, Malaysia*, 169(1), p. 012095. IOP Publishing.
- Otero, V., Van De Kerchove, R., Satyanarayana, B., Martínez-Espinosa, C., Fisol, M.A.B., Ibrahim, M.R.B., Sulong, I., Mohd-Lokman, H., Lucas, R., Dahdouh-Guebas, F., 2018: Managing mangrove forests from the sky: Forest inventory using field data and Unmanned Aerial Vehicle (UAV) imagery in the Matang Mangrove Forest Reserve, peninsular Malaysia. *Forest Ecology and Management* 411, 35-45.
- Rafezall, C.M., Darwin, N., Ariff, M.F.M., Majid, Z., 2020: Detection of palm oil health through multispectral UAV platform. *10th International Conference on System Engineering and Technology (ICSET)*, 09-09 November 2020, Shah Alam, Malaysia, 240-244. IEEE.
- Saliu, I.S., Satyanarayana, B., Fisol, M.A.B., Wolswijk, G., Decannière, C., Lucas, R., Otero, V. and Dahdouh-Guebas, F., 2021: An accuracy analysis of mangrove tree height mensuration using forestry techniques, hypsometers and UAVs. *Estuarine, Coastal and Shelf Science* 248, 106971.
- Sanik, M.E., Nor, A.H.M., Hamid, N.B., 2019: Effectiveness analysis of transverse rumble strip using the image processing technique. *International Journal of Innovative Technology and Exploring Engineering* 8(9), Special issue 3, 1360-1365.
- Siti-Nor-Maizah, S., Wan-Shafrina, W.M.J., Khairul-Nizam, A.M., Aisyah-Marliza, M.K., Hamdan, O., 2022: Determination of emission factor from logging operations in Ulu Jelai Forest reserve, Pahang using the integration of UAV and high-resolution imageries. *Journal of Tropical Forest Science* 34(2), 247-257.
- Sharom, M.A.A.M., Fauzi, M.F.A., Samsudin, S., Azmi, M.Z.M., Rahman, M.H.A., Shahri, S., Fadzil, M.A., Jusoh, R.M., 2018: Monsoon flood assessment and mitigation through satellite imagery and drone full motion video (FMV). *39th*

- Asian Conference on Remote Sensing (ACRS): Remote Sensing Enabling Prosperity*, 15-19 October 2018, Kuala Lumpur; Malaysia, 3, 1419-1426, Code 149873.
- Sheng, L.Y., Azhari, A.W., Ibrahim, A.H., 2021: Unmanned aerial vehicle for eutrophication process monitoring in Timah Tasoh Dam, Perlis, Malaysia. *IOP Conference Series: Earth and Environmental Science, 3rd International Conference on Civil and Environmental Engineering 18 November 2020, Malaysia*, 646(1), p. 012057. IOP Publishing.
- Suab, S.A., Syukur, M.S., Avtar, R., Korom, A. 2019: Unmanned aerial vehicle (UAV) derived normalised difference vegetation index (NDVI) and crown projection area (CPA) to detect health conditions of young oil palm trees for precision agriculture. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 42*, 611-614.
- Suteris, M.S., Rahman, F.A., Ismail, A., 2018: Route schedule optimization method of unmanned aerial vehicle implementation for maritime surveillance in monitoring trawler activities in Kuala Kedah, Malaysia. *International Journal of Supply Chain Management 7*(5), 245-249.
- Syafiqah, N.F., Shariff, A.R., Che'Ya, N.N., Ya, C., 2020: GIS and UAV aerial imaging applications for durian plantation management. *40th Asian Conference on Remote Sensing*. 14-18 October 2019, Daejeon, South Korea, 11-18, Korean Society of Remote Sensing (KSRS).
- Udin, W.S., Norazami, N.A.S., Sulaiman, N., Zaudin, N.C., Ma'ail, S., Nor, A.M., 2019: UAV based multi-spectral imaging system for mapping landslide risk area along Jeli-Gerik highway, Jeli, Kelantan. *15th International Colloquium on Signal Processing & Its Applications (CSPA)*, 08-09 March 2019, Penang, Malaysia, 162-167, IEEE.
- Yazid, A.S.M., Wahid, R.A., Nazrin, K.M., Ahmad, A., Nasruddin, A.S., Rozilawati, D., Hamzah, M.A., Razak, M.Y.A., 2019: Terrain mapping from unmanned aerial vehicles. *Journal of Advanced Manufacturing Technology 13*(1), 1-16.
- Yusof, A.A., Nor, M.K.M., Azyze, N.L.A.M.S., Kassim, A.M., Shamsudin, S.A., Sulaiman, H., Hanafi, M.A., 2022: Land clearing, preparation and drone monitoring using red-green-blue (RGB) and thermal imagery for smart durian orchard management project. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 91*(1), 115-128.
- Yusoff, A.R., Darwin, N., Majid, Z., Ariff, M.F.M., Idris, K.M., 2018: Comprehensive analysis of flying altitude for high resolution slope mapping using UAV technology. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 42*(3/W4), 583-589.
- Yusoff, A.R., Darwin, N., Majid, Z., Razali, A.F., Ariff, M.F.M., 2020: Beach volume measurement on variation of UAV altitude mapping. *10th International Conference on System Engineering and Technology (ICSET)*, 09-09 November 2020, Shah Alam, Malaysia, 145-149, IEEE.
- Zailani, M.A., Azma, R.Z., Aniza, I., Rahana, A.R., Ismail, M.S., Shahnaz, I.S., Chan, K.S., Jamaludin, M., Mahdy, Z.A., 2021: Drone versus ambulance for blood products transportation: an economic evaluation study. *BMC health services research 21*(1), 1-10.
- Zolkepli, M.F., Ishak, M.F., Yunus, M.Y.M., Zaini, M.S.I., Wahap, M.S., Yasin, A.M., Sidik, M.H., Hezmi, M.A., 2021: Application of unmanned aerial vehicle (UAV) for slope mapping at Pahang Matriculation College, Malaysia. *Physics and Chemistry of the Earth, Parts A/B/C 123*, 103003.
- Zulfakar, M.S.Z., Akhir, M.F., Ariffin, E.H., Awang, N.A., Yaacob, M.A.M., Chong, W.S., Muslim, A.M., 2020: The effect of coastal protections on the shoreline evolution at Kuala Nerus, Terengganu (Malaysia). *Journal of Sustainability Science and Management 15*(3), 71-85.