Available Online at www.e-iph.co.uk
Indexed in Clarivate Analytics WoS

E-B
Environment - Behaviour
Proceedings Journal

AcE-Bs2025Bangkok

e-IPH
e-International Publishing House Ltd., United Kingdom

https://www.amerabra.org/
13th ASIAN Conference on Environment-Behaviour Studies
Al Meroz Hotel, Bangkok, Thailand, 04-06 Apr 2025

Utilizing Tree Risk Assessment (TRA) and Unmanned Aerial Vehicle (UAV) as a Pre-determine Tree Hazard Identification

Masbiha Mat Isa[1*], Muhammad Hafiz Zainal[1], Muhammad Adam Zakaria[1], Khairulnizam Tahar[1], Qianda Zhuang[2]
**Corresponding Author*

[1] Faculty of Built Environment, Universiti Teknologi MARA, Shah Alam, 40450, Malaysia
[2]College of Agriculture and Forestry, Linyi University, Linyi 276000, China

masbiha125@uitm.edu.my, hafizzainal@uitm.edu.my, adamzakaria@ uitm.edu.my, khairul0127@uitm.edu.my, zhuangqianda@lyu.edu.cn
Tel: +60 12-291 9151

Abstract
Trees carry a lot of benefits to urban areas but may also become huge threats. This study aims to integrate on-ground inspection data using TRA with UAV-based hyperspectral imagery data as pre-determined tree risk hazard levels on selected hot spots in Kuala Lumpur. Green Leaf Index (GLI) is used as a vegetation health indicator. The findings demonstrate that GLI analysis aligns significantly with tree hazard classifications, offering a reliable method for identifying hazardous trees in Malaysia's urban environments. The results indicate that this approach would specifically benefit the local authorities to accurately identify hazardous urban trees and mitigate potential threats.

Keywords: Tree risk; UAV; tree hazard

DOI: https://doi.org/10.21834/e-bpj.v10i32.6634

1.0 Introduction

Trees bring numerous positive externality advantages to urban environments, including making them more resilient, safer, and more sustainable. The physical and biological characteristics of urban trees provide important Ecosystem Services (ES) with a significant positive impact that increases the quality of life within cities such as purifying air quality by absorbing carbon emission (De Manuel et al., 2021) and removing particulate pollutants (Palliwoda et al., 2020). Nowadays, it's concerning how trees, initially planted for various advantages, are turning into hazards, falling and causing damage to properties and vehicles, and even injuring or, in extreme cases, killing people. Kuala Lumpur has surpassed all other areas in Klang Valley in terms of the number of complaints about uprooted trees, especially during storms (Bernama, 2023). In Malaysia, Tree Risk Assessment (TRA) is not commonly practiced by most local authorities, as it is not integrated into routine or scheduled activities. In current practice, ground-data collection involves tree inventory and hazard assessment based on criteria established by the International Society of Arboriculture (ISA). The assessment format follows guidelines from the "A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas" handbook, which suggests collecting various data on the physical characteristics of trees, including hazard ratings. As part of this process, site factors and tree coordinates are recorded to ensure comprehensive data collection.

However, collecting such data for numerous trees across a wide area is labour-intensive and time-consuming. Assessing the health and physical condition of tall trees from the ground can be challenging, with accuracy relying on visual observation, despite tools like binoculars. Furthermore, despite these efforts, the data collected on the ground lacks important information on tree health, such as defects and potential hazards. The single method is ineffective in increasing the dependability for tree maintenance and hazard prevention purposes. Precise attributes are crucial for effective monitoring, saving resources like time and money. Therefore, enhancing tree care monitoring, particularly in risk assessment methods, is essential due to uncertainties in decision-making caused by irrelevant tree hazard data.

Consequently, it is seen fit to include the usage of the mapping technology of hyperspectral Unmanned Aerial Vehicle (UAV) to provide a faster, energy-efficient, cost-effective (Guimarães et. al., 2020), bendable, and potentially more accurate option in collecting the data (Chen et al., 2019). Photogrammetric and remote sensing techniques in UAV-based hyperspectral would help in providing quick species identification, health and physical data of a tree – thus enabling a quick first level of tree assessment to be done so that the relevant parties can do further, detailed inspection on the targeted trees that may become a threat. The objective of the study is to integrate on-ground TRA practices with UAV-based imagery to improve the accuracy, efficiency, and applicability of urban tree hazard assessments. With the merging of the data collected manually on the ground, better accuracy in data collection could be very helpful in formulating the tree assessment model for urban areas which can be adapted to local authorities in Malaysia.

2.0 Literature review

Urban trees have been defined as perceived major contributors to human well-being (Jones, 2021). According to Breslow et al. (2016), the concept of human well-being is achieved when human needs are met and when individuals and communities enjoy a quality of life, which means a state of being with others and the environment. In mental and physical health, Gerstenberg & Hofmann (2016), Kabisch et al. (2021), and Nilsson et al. (2011) professed that a group of urban trees could enhance human mental and physical health by providing comfortable outdoor environments for activities.

Liability trees are defined as hazardous trees that deteriorate the safety and security of potential targets including properties, infrastructure, and people (M. M. Isa et.al., 2012). Hazardous trees are the ones with structural defects on their parts such as the root, stem, and branch. Other than that, the indicators that are usually associated with defects are branch deterioration, weak branch unions, cracks, root damage, and disease. This defective part is a weak point that is incapable of being exposed to certain challenging environmental pressures as these could become the root of tree failures (overturning trees, breaking stems). Tree failures are caused by several physical and biochemical aspects, which include rough climate conditions (climatological factor), fungi, vigour and decay (biological factor), structural defects like codominant branches, mechanical factors like leaning and frail branch union, and other factors such the site's condition (Van Haaften et al., 2021).

To aid professionals through the tree inspection process, a variety of risk assessment approaches have been created. The Basic TRA method was developed in conjunction with the International Society of Arboriculture's (ISA) Tree Risk Assessment Best Management Practice (BMP) Manual (Smiley et al., 2017). Depending on the extent of the assessment, this tree risk assessment is divided into three levels; Level 1 involves a limited visual inspection, quickly conducted to gather basic information and identify high-risk trees, often with uncertainties due to restricted access, Level 2 assessment entails a more comprehensive ground-level inspection, utilizing simple tools to examine the crown, trunk, roots, and site conditions, often employing the ISA Basic TRA form, and Level 3 assessment further enhances data collection with climbing and diagnostic equipment, incorporating specialist instruments for detailed evaluations such as aerial inspections and quantitative assessments for decay, health, wind load, and static load.

Generally, the TRA programs in Malaysia have been implemented by local several authorities. However, the TRA task is implemented on an ad-hoc basis due to logistic and technical constraints, such as lack of finance and staff, as well as expertise. In the year 2009, the National Landscape Department took proactive steps in its tree care monitoring programs by implementing the tree inventory and assessment in selected local authorities. According to the National Landscape Department (2019), 26 local authorities were involved in this program, and a total of 6,300 selected urban trees were assessed in the year 2009 to 2010. The tree inventory and assessments were conducted in 26 local authorities selected areas, and data was generated based on the physical conditions of the trees, the hazard status, and the economic values of the trees. Data was collected through conventional field assessment by certified arborists within level 1 and level 2 tree risk assessment. The National Landscape Department presented the outcome of the assessment report, specifically for reducing the hazardous trees through abatement suggestions for actions to be taken, such as pruning or removing the trees. However, it was not unimplemented anymore because of the uneconomical due to the long period of implementation and incomprehensiveness other than the uncertainty of the data obtained (human error).

Based on the current scenario, the establishment of a model based on TRA of Level 1 which employs advanced technologies such as UAVs and Level 2 which addresses biotic and abiotic attributes in tree assessment is in line with innovative research to address concerns in the well-being of urbanites in Malaysia. Alternatively, imagery taken by a UAV has emerged as a cost-effective method to successfully identify tree attributes (Kaneko & Nohara, 2014). The use of UAV technology is almost in line with other advanced technology and has become a new advanced technology with more cost-effective, particularly for aerial mapping technology (Mweresa et al., 2017). Previous researchers mentioned that UAV has been used rapidly, in terms of controllable and achievable to obtain high-resolution results, real-time, weather independent and efficiently produce very high-resolution of the earth's surface in 3D (Hackney & Clayton, 2015; Lim et al., 2015; Tuominen et al., 2015). Moreover, this technology also can replace the terrestrial method for image acquisition in small area coverage, is more economical to use compared to conventional aircraft, and requires less maintenance and flexibility for take-off and landing areas (Tuominen et al., 2015; Uysal et al., 2015). This research study attempts to assess the capability of UAV technology for the TRA task in assisting efficient urban tree hazard status determination.

3.0 Material and Methods

3.1 Study area

The study covers two parliament areas with the highest cumulative number of trees falling cases from January to June 2023 which are Kepong and Seputeh in Kuala Lumpur. The cases were gathered from the list of complaints on tree falling emergencies prepared by Unit Pengurusan Pokok Rendang under Kuala Lumpur City Hall (DBKL). Among all cases, two primary roads have been selected to be inventoried which are Jalan Seri Bintang, Taman Sri Bintang, Kepong (3.186226°N latitude and 101.644169°E longitude) and Jalan Awan Besar Klang Lama, Seputeh (3.073055°N latitude, 101.670946°E longitude) (Figure 1). The area's dense urban environment in the city centre makes it a suitable case study for evaluating tree risk and management strategies.

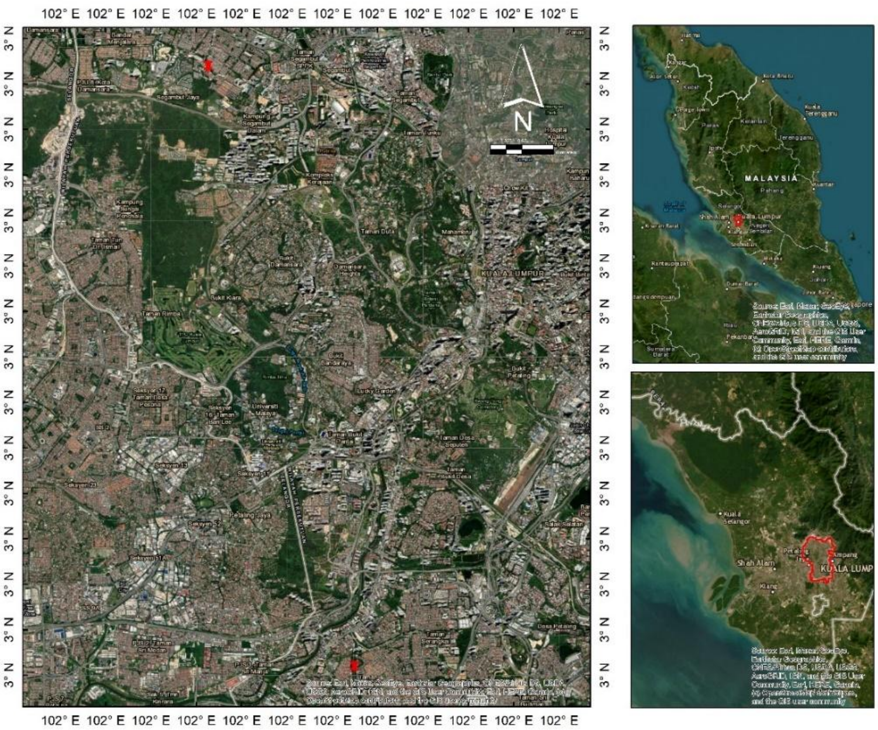


Fig. 1: Location of Jalan Seri Bintang, Taman Sri Bintang, Kepong, and Jalan Awan Besar Klang Lama, Seputeh, Kuala Lumpur as the two case studies
(Source: Google Earth)

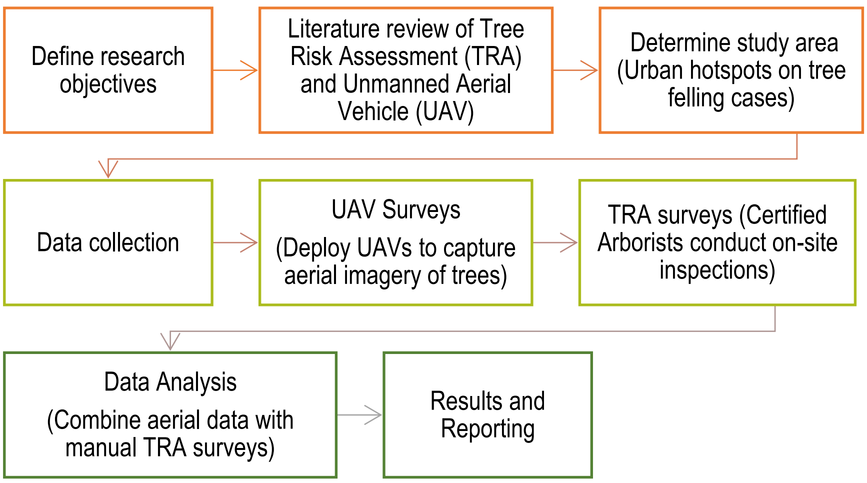


Fig. 2: Methodological flowchart
(Source: Author)

This study employs a structured methodological approach integrating UAV technology and TRA to evaluate urban trees along selected roads. The interpretation involves multiple stages, including detecting thematic tree groups, recognizing individual trees, analyzing their images, classifying their condition, and mapping their spatial distribution. UAV surveys capture high-resolution aerial imagery, complementing on-site inspections by certified arborists to ensure a comprehensive assessment. Photogrammetric methods facilitate the extraction of spatial data on urban tree health, enabling precise identification of hazardous trees, delineation of risk-prone areas through geo-referenced orthorectified images, and visualization in a GIS environment. The collected data is synthesized by integrating aerial and manual assessments, enhancing accuracy in detecting structural vulnerabilities. Findings are analyzed to formulate conclusions on tree characteristics and health, providing critical insights into spatial risk patterns and informing urban tree management and hazard mitigation strategies. Figure 2 shows the overall methodological process of the study.

3.2 UAV Data Collection

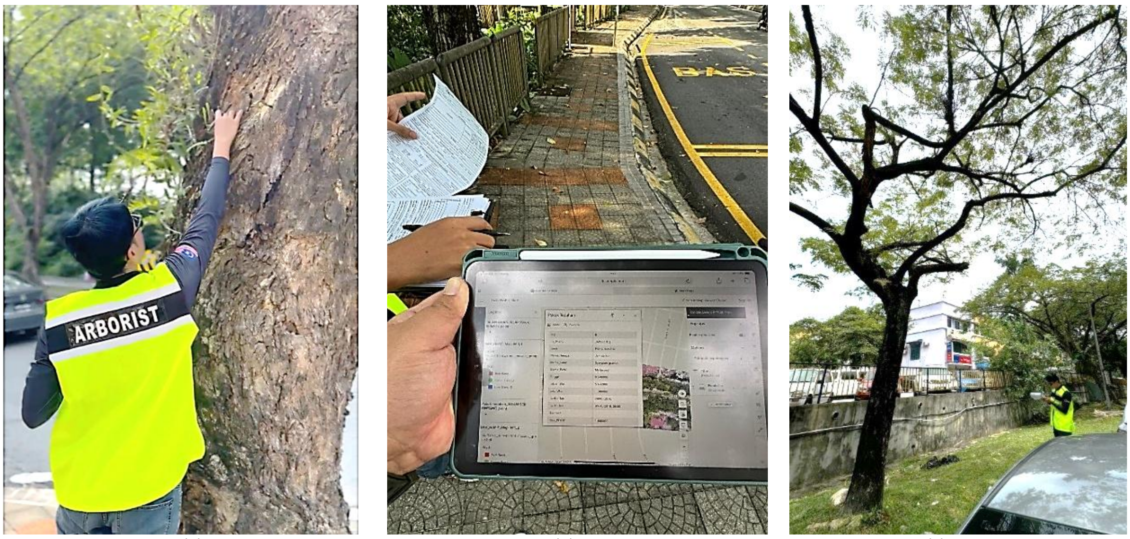
For UAV data collection, the flight plans were done by the Drone Deploy free software with 120 meters of flight height. The picture overlay is 80% on the front overlap and 60% on the side lap. Expanding UAV applications for photogrammetric surveying and research of urban tree areas will provide ease of data capture and data transfer (images, orthorectified images - 2D mosaics, 3D models, real-time video); efficiency and speed combined with precision commensurate with manned aviation system; suit for surveying relatively small areas and sites; and the ability to assess the condition of urban trees. The identified areas were scanned and mapped using the Phantom 4 Pro UAV model that weighs 1,388 kg with a one-inch 20 MP CMOS sensor (Figure 3). The camera lens is optimized for aerial imaging, with an aperture range from F2.8 to F11 and a 24mm equivalent focal length. It's equipped with a mechanical shutter and adjustable aperture range, with auto focus support.

(a) (b)

Fig. 3. UAV Field work, (a) UAV ground station; (b) hovering UAV

(Source: Author)

3.3 TRA Data Collection



(a) (b) (c)

Fig. 4. TRA Field work, (a) Arborist inspection; (b) recording tree data; (c) investigation of on-site condition

(Source: Author)

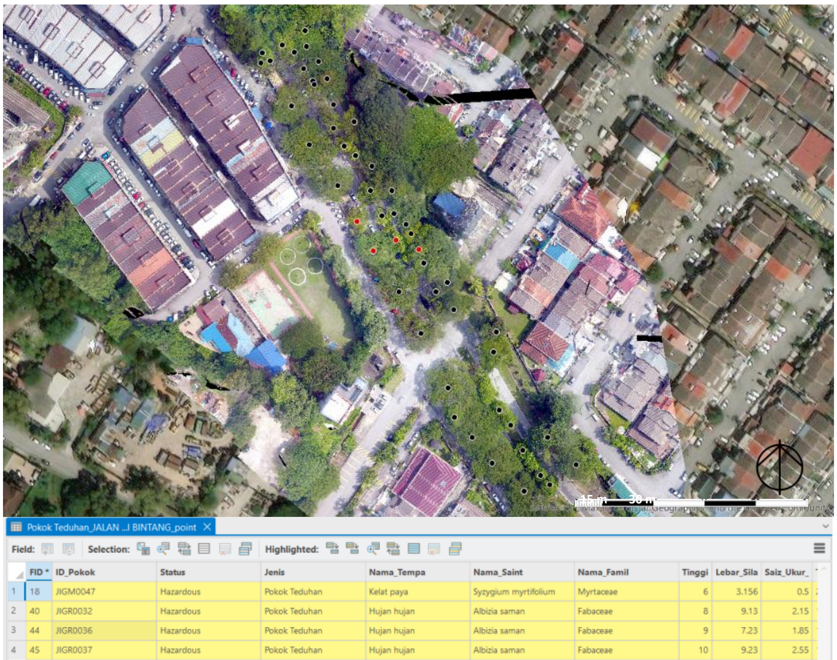
This phase included a manual, on-ground inspection, and tree assessment conducted by Certified Arborists using the TRA-suggested format (Appendix) by the ISA. The identified trees were individually inspected, with basic physical information recorded, including overall height, DBH, crown size, site conditions, and potential risks such as falling branches or tree toppling. Trees were assessed based on detected defects, such as branch decay, codominant branches, and root decay, and these findings were systematically documented. To ensure the reliability of the recorded on-ground data, the expertise of a Certified Arborist, preferably a Tree Risk Assessment Qualification (TRAQ) holder, was highly beneficial. As shown in Figure 4 (a), TRA fieldwork involved arborists inspecting trees as well as recording the tree location and attributes with the overlaying UAV images collected as in Figure 3, assessed in Quantum Geographic Information System (QGIS) open-source software as in Figure 4 (b) to ensure accurate documentation.

4.0 Result and Analysis

Studying urban trees with the UAVs' image capture activities requires it to be planned and executed according to a particular technological scheme. It involves photogrammetric processing (project planning, image acquisition, image processing, control data, data compilation, and presentation of the end products) and analytical interpretation of the resulting images. At the end of the technological process, thematic maps and table data of urban tree assessments are obtained. The analytical workflow integrates Green Leaf Index (GLI) analysis to assess tree health, alongside traditional photogrammetric outputs such as thematic maps and species recognition. The final assessment combines UAV-derived parameters with on-ground inspections by Certified Arborists to validate tree condition and structural risks. The reliability of UAV data is evaluated by comparing GLI-based health indicators with direct arborist assessments, ensuring an accurate and comprehensive approach to urban tree risk evaluation.

The UAV image overlayed on Google imagery presents a detailed aerial perspective, highlighting the distribution of hazardous trees along Jalan Seri Bintang, marked with red dots based on inspections conducted by a certified arborist. The UAV-captured imagery was processed and analyzed in both QGIS and ArcGIS Pro, where data from on-site TRA was systematically incorporated into the attribute table for enhanced spatial and attribute accuracy. This integration enables precise localization and evaluation of potentially hazardous trees.

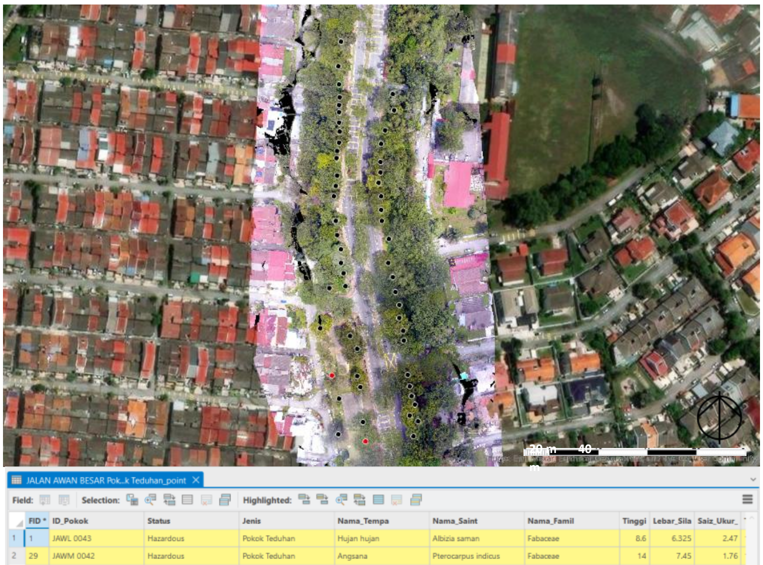
In the assessment, one individual tree from the species, *Syzygium myrtifolium,* along with three instances of *Albizia saman*, was classified as potentially hazardous due to poor structural and health conditions observed on-site (Figure 5). From the tree inspection shown in Figure 4 (c), *Albizia saman* has structural defects such as dead twigs/branches, poor branch attachment, unbalanced crown, and signs of damage from bad pruning history. Others show unbalanced crowns leaning towards the road, with codominant stems while the size of the trunk is also visibly smaller compared to the rest of the trees from the same species along the road. The trees were also detected as potential hazards from the UAV image, as their crown size is discernibly smaller and has discolouration. However, it is essential to note that UAV imagery, despite offering a comprehensive canopy view, does not provide sufficient detail to independently determine tree health. A face-to-face assessment remains necessary to accurately assess tree vitality, structural integrity, and potential hazards, as UAV imaging is limited in capturing nuanced indicators of health or decline visible only from ground-level observation.



	FID *	ID_Pokok	Status	Jenis	Nama_Tempa	Nama_Saint	Nama_Famil	Tinggi	Lebar_Sila	Saiz_Ukur_
1	18	JIGM0047	Hazardous	Pokok Teduhan	Kelat paya	Syzygium myrtifolium	Myrtaceae	6	3.156	0.5
2	40	JIGR0032	Hazardous	Pokok Teduhan	Hujan hujan	Albizia saman	Fabaceae	8	9.13	2.15
3	44	JIGR0036	Hazardous	Pokok Teduhan	Hujan hujan	Albizia saman	Fabaceae	9	7.23	1.85
4	45	JIGR0037	Hazardous	Pokok Teduhan	Hujan hujan	Albizia saman	Fabaceae	10	9.23	2.55

Fig. 5: Aerial overlay on Google imagery showing the distribution of hazardous trees along Jalan Seri Bintang
(Source: Author)

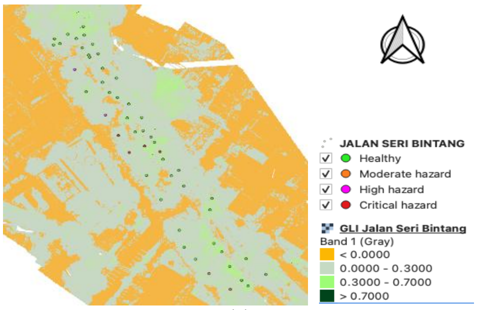
UAV imaging may provide aerial views of the tree crown's symmetry, density, discolouration, and dieback. Issues such as canopy asymmetry or excessive defoliation may be apparent from above, especially in dense urban environments. In the case of Jalan Awan Besar, two tree species, *Albizia saman* and *Pterocarpus indicus*, have been observed in deteriorating condition with poor branch stability, dieback/deadwood, visible canker, decay and cracks on their branches and/or trunks during on-site inspections, where a reduction in canopy density and colour variation is evident in UAV imagery. Such visual changes in canopy colour and coverage can serve as preliminary indicators of declining tree health, aligning with the on-site assessments of poor condition. However, while UAV imagery facilitates broader canopy observations, it is crucial to recognize its limitations in diagnosing health issues solely from aerial perspectives. The observed canopy reduction and discolouration, though indicative, would ideally be supplemented by ground-based assessments to confirm tree defects and conditions affecting the likelihood of failure, especially symptoms on the trunks and root collar which would not be able to be captured by the UAV imagery. In this context, UAV imagery serves as a valuable tool for identifying areas of concern but is best used in conjunction with on-the-ground evaluations for comprehensive tree health diagnostics.



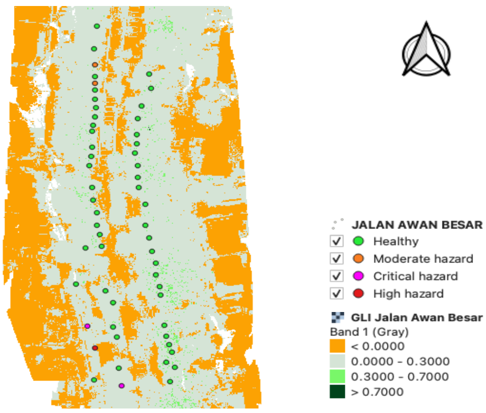
	FID *	ID_Pokok	Status	Jenis	Nama_Tempa	Nama_Saint	Nama_Famil	Tinggi	Lebar_Sila	Saiz_Ukur_
1	1	JAWL 0043	Hazardous	Pokok Teduhan	Hujan hujan	Albizia saman	Fabaceae	8.6	6.325	2.47
2	29	JAWM 0042	Hazardous	Pokok Teduhan	Angsana	Pterocarpus indicus	Fabaceae	14	7.45	1.76

Fig. 6: Aerial overlay on Google imagery showing the distribution of hazardous trees along Jalan Awan Besar
(Source: Author)

5.0 Green Leaf Index Analysis



(a)



(b)

Fig. 7. Superimposition of the Green Leaf Index and Tree Hazard Assessment, (a) Jalan Seri Bintang; (b) Jalan Awan Besar
(Source: Author)

The final stage of this study involves producing a comprehensive report documenting the processes, findings, and outcomes, alongside developing a modified TRA Model tailored for Malaysia's urban tree hazard identification. This study employed the Green Leaf Index (GLI), a vegetation index derived from RGB imagery, to assess tree health and identify hazardous and non-hazardous trees during site investigations. GLI values closer to 1 indicate healthy trees, while values near 0 or negative reflect low greenness, signaling poor health or stressed trees. Figure 7 illustrates the GLI results for Jalan Seri Bintang and Jalan Awan Besar. For Jalan Seri Bintang (Figure 7a), the TRA identified 43 healthy trees, 2 with moderate hazards, 2 with high hazards, and 4 with critical hazards. The GLI analysis revealed that 2 critical hazard trees and 2 high hazard trees fall under the GLI category of 0–0.3, representing areas with low greenness. This correlation indicates that the GLI accurately identifies poor tree health, aligning with the TRA by approximately 66%. For Jalan Awan Besar (Figure 7b), the TRA identified 56 healthy trees, 2 with moderate hazards, 1 with a high hazard, and 2 with critical hazards. The GLI analysis showed that the 2 critical hazard trees and 1 high hazard tree fall under the GLI category of <0, which reflects poor health and stress. Here, the GLI analysis aligns with the TRA with 100% accuracy.

The findings demonstrate the potential of the Green Leaf Index as a reliable method to support tree hazard assessments, particularly for urban environments. By integrating GLI analysis into tree management practices, local authorities, and urban planners can detect hazardous trees early, prioritize maintenance, and mitigate risks associated with tree failures. However, further refinement may be required to address environmental factors, such as lighting and shadow effects, that could influence GLI calculations. This study underscores the importance of combining advanced vegetation indices with field-based hazard assessments to enhance urban tree monitoring systems.

6.0 Conclusion

The tree assessment outcomes would be beneficial in aiding the local authorities by recognising the potential existing hazardous trees for better planning and management in the future. The quick identification of the specific trees to be further inspected by Certified Arborists is efficient in terms of time, cost, and labour. The study's outcomes also support DBKL's vision of becoming a World Class Sustainable Tropical City and its mission which is to develop a beautiful, neat, clean, and well-designed city landscape that provides satisfaction to city dwellers and tourists alike. The study's findings and outcomes are in line with objective one of the National Policy on the Environment (DASN) which is a clean environment, safe, healthy, and productive environment for present and future generations. This also complies with one of the eight themes of the National Physical Plan, which is the conservation of natural resources and the environment. This would also be aligned with the aspiration to make cities and human settlements inclusive, safe, resilient, and sustainable by pursuing green growth for sustainability and resilience using the latest technology thus primarily embracing SDG's goal number 11 addressing the Sustainable Cities and Communities. Indirectly the study also addressed the SDG's Goal 3 (Good Health and Well Being), and Goal 13 (Climate Action). Using UAVs is known to increase work efficiency, refining service and productivity. Ground technical work based on early detection by UAV will help landscape-related companies provide fast service, fast decisions, and cost-efficiency in tree management. This study demonstrates the effectiveness of GLI as a reliable tool for assessing urban tree health and identifying hazardous trees, with correlations of 66% and 100% observed at the sites studied. The integration of GLI analysis with traditional tree hazard assessment methods enhances the accuracy of identifying trees at risk, supporting proactive urban tree management practices. The GLI index categories from the TRA form align with the Risk Rating Matrix, where healthy trees correspond to low risk (unlikely to fail), moderate hazard trees to moderate risk (somewhat likely to fail), high hazard trees to high risk (likely to fail), and critical hazard trees to extreme risk (very likely to fail with severe consequences), helping prioritize tree management actions accordingly. These findings highlight the potential of the GLI-based TRA Model to be adapted for large-scale implementation in Malaysia's urban environments, ensuring safer and greener cities.

This study recommends expanding the application of the GLI to a broader range of urban environments and tree species across Malaysia to enhance the robustness and generalizability of the findings. Incorporating advanced remote sensing technologies, such as multispectral or hyperspectral imaging, can improve the accuracy of GLI measurements. A key limitation of this study is the potential variability in GLI accuracy due to environmental factors such as lighting conditions, shadows, and the presence of mixed vegetation, which may affect the consistency of UAV-based assessments across diverse urban settings. Additionally, integrating machine learning algorithms into the analysis process could automate tree hazard assessments and provide more precise predictions. Collaboration with local authorities and urban planners is crucial to translate these findings into actionable policies and strategies, enabling more effective and proactive urban tree management systems that prioritize public safety and environmental sustainability.

Acknowledgements

This study was funded by the MyRA Research Grant from the Research Management Centre (RMC), UiTM 600-RMC 5/3/GPM (059/2022).

Paper Contribution to Related Field of Study

Supports evidence-based decision-making for urban planners and arborists; and strengthens the application of remote sensing technologies in ecological risk assessment.

References

Bernama. (2023, January 10). Kuala Lumpur surpasses all areas in Klang Valley in tree uprooting complaints during storms. *The Star*.

Breslow, L., McGee, L., & Hall, J. (2016). Human well-being and the environment: Definitions and measurements. *Environmental Health Perspectives*, 124(2), 118-127.

Chen, X., Zhang, M., & Liu, J. (2019). Advances in UAV-based hyperspectral imaging for environmental applications: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 150, 27-41.

De Manuel, J. M., Sánchez, J. M., & Mendez, D. A. (2021). Urban trees and their role in mitigating climate change and improving air quality: A review. *Environmental Science and Pollution Research*, 28(5), 5851-5863.

Donovan, G. H., & Prestemon, J. P. (2012). The economic value of urban trees and their impact on community well-being. *Journal of Environmental Management*, 102, 93-101.

Gerstenberg, M., & Hofmann, D. (2016). The role of urban greenery in promoting mental and physical health: A systematic review. *Landscape and Urban Planning*, 148, 77-88.

Guimarães, G. S., Oliveira, D. M., & Silva, T. G. (2020). Hyperspectral unmanned aerial vehicle (UAV) for environmental monitoring: A cost-effective and efficient approach. *Journal of Remote Sensing*, 12(10), 3349.

Hackney, M., & Clayton, S. (2015). UAV-based imaging in urban tree monitoring: Technological advances and applications. *Environmental Monitoring and Assessment*, 187(9), 600.

Jones, R. (2021). Urban trees and the impact on community health and well-being. *Journal of Urban Health*, 98(1), 12-24.

Kaneko, M., & Nohara, M. (2014). Utilizing UAVs for tree attribute mapping and forest monitoring: A cost-effective approach for urban forestry. *International Journal of Forest Engineering*, 25(1), 19-29.

Kabisch, N., Qureshi, S., & Haase, D. (2021). Human well-being and urban trees: The importance of nature for mental and physical health. *Environmental Science & Policy*, 115, 54-62.

Koeser, A. K., Vogt, J. A., & Hall, D. (2016). Liability trees: Understanding hazardous trees and their impact on urban environments. *Arboriculture & Urban Forestry*, 42(4), 215-223.

Lim, S. S., Choi, J., & Kim, Y. (2015). High-resolution remote sensing data obtained from UAVs for urban tree management: Applications and future directions. *Journal of Urban Forestry*, 36(2), 203-210.

M. M. Isa, N. Othman & R. Ghazali. (2012) GIS in management of landscape trees: Determining, monitoring and implementing safety measures on potentially hazardous trees. *IEEE 8th International Colloquium on Signal Processing and its Applications, Malacca, Malaysia*, 2012, pp. 426-430, doi: 10.1109/CSPA.2012.6194762.

Mweresa, C. K., Karanja, F. K., & Muthama, N. (2017). Drone-based remote sensing for urban vegetation management: A cost-effective tool for urban forestry. *Journal of Environmental Management*, 202, 218-227.

Mortimer, N. D., & Kane, B. (2004). Assessing tree risk: A guide to evaluating hazardous trees in urban areas. *Urban Forestry & Urban Greening*, 3(1), 9-14.

National Landscape Department. (2019). *Tree inventory system program in authorities*. http://www.data.gov.my/data/en_US/dataset/program-sistem-inventori-pokok-di-bawah-peruntukan-jabatan-landskap-negara/resource/5bedafaf-f1d5-4dd9-92bb-4a813a93f1db

Nilsson, K., Sang, Å., & Paavola, J. (2011). Urban forests and human well-being: The psychological and social benefits of urban greenery. *Urban Forestry & Urban Greening*, 10(3), 127-138.

Palliwoda, J., Wagner, S., & Xie, S. (2020). Particulate matter removal efficiency of urban trees and shrubs in European cities. *Science of the Total Environment*, 705, 135474.

Smiley, E. L., Gilman, E. F., & Matheny, N. P. (2017). Tree Risk Assessment: Best Management Practices Manual. *International Society of Arboriculture.*

Tuominen, A., Vesterinen, E., & Harju, A. (2015). The use of UAVs in urban tree risk assessment: A comparison of methods and outcomes. *Urban Forestry & Urban Greening*, 14(1), 34-42.

Uysal, M., Jafari, M., & Nasir, R. (2015). UAV-based systems for monitoring and assessment of urban trees: Technological advancements and potential applications. *Remote Sensing of Environment*, 168, 99-107.

Van Haaften, J. H., Smiley, E. L., & Willis, R. A. (2021). Tree failures: The causes, indicators, and prevention of hazardous trees in urban environments. *Journal of Arboriculture*, 47(1), 35-46.

Yeo, L. H., & Mohtar, R. (2021). Flash floods, tree failures, and storm hazards: The implications for Malaysia's urban landscapes. *Urban Climate*, 38, 100787.