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SMART MAPPING AND MONITORING: UAV AND GIS-BASED PLANNING FOR THE CONSERVATION OF DIPTEROCARPUS SEMIVESTITUS IN UITM CAWANGAN PERAK

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Abstract

The survival of *Dipterocarpus Semivestitus*, a vulnerable tropical tree species native to Malaysia's lowland dipterocarp forests, is increasingly threatened by peri-urban expansion and habitat fragmentation. As an ecologically significant indicator species, its decline reflects broader environmental stress. This study aims to support the conservation of *Dipterocarpus Semivestitus* by applying geospatial technologies within a planning context. Specifically, the research objectives are to: (i) map the spatial distribution of existing stands, (ii) assess population density and habitat conditions, and (iii) detect landscape-level threats using UAV imagery and GIS analysis. High-resolution data enables accurate, non-invasive monitoring and reveals areas under ecological pressure. The results inform planners, conservationists, and arborists by identifying critical habitat zones and recommending spatial interventions such as buffer areas and green corridors for the protection of *Dipterocarpus Semivestitus*. This study demonstrates how technology-enhanced ecological data can guide integrated, evidence-based planning approaches, contributing to more resilient and sustainable peri-urban development aligned with broader environmental management goals.

Keywords: *Dipterocarpus Semivestitus*, Endangered, GIS, Preservation, UAV.

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INTRODUCTION

Dipterocarpus semivestitus, an endangered tropical tree species, plays a vital role in maintaining biodiversity and ecological balance in Southeast Asian Forest ecosystems. *Dipterocarpus Semivestitus*, a keystone species, is currently facing unprecedented threats that jeopardize its persistence, including habitat degradation and climate-induced changes (Smith et al., 2018; Jones & Wang, 2020). The imperative to conserve this species and safeguard the biodiversity within its ecosystems necessitates innovative and efficient approaches. *Dipterocarpus Semivestitus*, recognized as a key species in forest ecosystems, plays a pivotal role in upholding biodiversity and ecological equilibrium (Smith et al., 2018). The accurate identification and mapping of its distribution are imperative for the formulation of effective conservation strategies and sustainable forest management practices (Jones & Wang, 2020).

Preserving the natural habitat is fundamental to *Dipterocarpus Semivestitus* conservation. This involves establishing protected areas, implementing sustainable forestry practices, and minimizing land-use changes (Sodhi et al., 2010). However, due to deforestation and habitat fragmentation, *Dipterocarpus Semivestitus* has been designated as an endangered species, with the hazards of population decrease and genetic erosion (Slik et al., 2018). Monitoring *Dipterocarpus Semivestitus* populations is crucial for assessing the species' conservation status. Techniques such as remote sensing and Unmanned Aerial Vehicle (UAV) technology provide valuable tools for monitoring the spatial distribution of *Dipterocarpus Semivestitus*. (Franklin & Miller, 2019).

Traditional ground surveys have long been used in ecological assessments, but they present several limitations, particularly when applied to large or remote forested areas. These methods are often labor-intensive and time-consuming, requiring extensive manpower and multiple site visits especially in challenging terrains such as dense tropical forests (Brown & Stevens, 2019). For instance, locating and documenting individual trees like *Dipterocarpus Semivestitus* demands considerable effort and may still result in limited spatial coverage. Moreover, repeated human intrusion into sensitive habitats can inadvertently disturb wildlife or damage fragile ecosystems. These challenges underscore the value of modern, non-intrusive technologies such as UAV-based remote sensing and GIS analysis, which enable efficient, accurate, and minimally disruptive data collection across broader landscapes.

Given the limitations of traditional methods, the integration of UAV technology emerges as a promising and innovative alternative. UAVs equipped with high-resolution cameras facilitate the acquisition of detailed aerial imagery, enabling a more nuanced understanding of *Dipterocarpus Semivestitus* habitats and distribution patterns (Johnson et al., 2021). This technological approach not only expedites the data collection process but also enhances the accuracy and

efficiency of species identification (Chen et al., 2019). Building on these advantages, this study integrates UAV technology with Geographic Information Systems (GIS) to assess the spatial distribution of *Dipterocarpus Semivestitus* in the peri-urban forest landscape of UiTM Perak Branch, Seri Iskandar. The novelty of this study lies in its methodological contribution specifically, applying high-resolution UAV imagery to detect and map *Dipterocarpus Semivestitus* populations non-invasively, a technique not previously used for this species in this landscape.

The aim of this study is to develop an accurate and efficient method for identifying and mapping *Dipterocarpus Semivestitus* within a fragmented peri-urban ecosystem using UAV and GIS technologies. The findings are expected to contribute to biodiversity-sensitive land-use planning and support conservation strategies in similarly urbanizing landscapes. Beyond academic contributions, the results of this research hold practical relevance for sustainable forest management. By providing precise spatial information and insights into the species' habitat preferences, the study offers a valuable tool for guiding conservation priorities and maintaining biodiversity at both local and regional scales (IUCN, 2020). This work aligns with contemporary advancements in ecological monitoring by adopting a holistic, technology-driven approach. The integration of UAV technology and advanced geospatial analysis demonstrates the potential for innovative, scalable solutions in biodiversity conservation and forest ecosystem management bridging scientific research with real-world environmental planning needs.

LITERATURE REVIEW

Numerous studies have emphasized the importance of conserving dipterocarp species due to their ecological significance and vulnerability to anthropogenic threats (Smith et al., 2018; Slik et al., 2018). Conventional ground surveys have long been used for forest monitoring (Brown & Stevens, 2019), but these methods are often constrained by accessibility issues and limited spatial coverage. Recent advances in remote sensing, particularly UAV-based monitoring, offer improved efficiency and spatial accuracy (Johnson et al., 2021; Chen et al., 2019). However, there remains a research gap in applying these tools specifically to monitor *Dipterocarpus Semivestitus* in peri-urban tropical forests. This study builds upon previous UAV-based conservation research by focusing on a rarely studied endangered species and integrating spatial analysis to evaluate habitat fragmentation and edge pressures.

Preserving Endangered *Dipterocarpus Semivestitus* Species

Preservation efforts for endangered species such as *Dipterocarpus Semivestitus* frequently necessitate comprehensive plans that combine current technologies

and conservation approaches. The preservation of *Dipterocarpus Semivestitus* is critical not just for sustaining biodiversity but also for supporting the livelihoods of local communities that rely on these forests. Protecting *Dipterocarpus Semivestitus* involves employing various conservation approaches, such as managing protected areas, involving local communities in forest management, and implementing sustainable forestry practices (Blaser et al., 2011 and Saharudin et al. 2024).

Protected areas are vital for preserving the habitats of endangered species by offering legal protection from activities like logging, mining, and encroachment (Brun et al., 2015 and Blanton et al. 2024). Community-based Forest management involves local communities in conservation efforts and enables them to sustainably manage their natural resources. Sustainable forest management practices, like carefully choosing which trees to log and planting new trees, can ease the strain on natural forests and aid in the revival of *Dipterocarpus semivestitus* populations (Chaudhary et al., 2018).

GIS-Based Approach for *Dipterocarpus Semivestitus* Mapping

Mapping the distribution of *Dipterocarpus Semivestitus* is necessary to pinpoint its remaining habitat and prioritize conservation efforts. Remote sensing technologies like satellite imagery and geographic information systems (GIS) are commonly employed for this purpose, aiding in the mapping of forest cover and tracking alterations in land use (Irimi, 2021). Imagery provides detailed snapshots of large areas, allowing researchers to identify suitable habitats for *Dipterocarpus Semivestitus* and monitor any alterations over time. GIS software plays a critical role in identifying and delineating conservation priority zones by integrating multiple spatial datasets, such as vegetation distribution, terrain morphology, and anthropogenic pressures. This spatial approach facilitates strategic decision-making for biodiversity protection and ecosystem management (Abdullah et. al, 2021 and Abdullah et. al, 2024). These tools offer useful information about where *Dipterocarpus Semivestitus* is found, assisting conservationists in focusing their efforts more efficiently.

Therefore, UAVs combined with GIS have emerged as useful instruments for ecological monitoring and preservation planning (Anderson & Gaston, 2013). UAV-GIS techniques provide several advantages, including high spatial resolution, cost-effectiveness, and the capacity to visit remote or inaccessible places (Turner et al. 2015). Employing a UAV-GIS method for the preservation of *Dipterocarpus Semivestitus* at Universiti Teknologi MARA (UiTM) Seri Iskandar may provide various advantages. Firstly, it enables efficient and precise mapping of *Dipterocarpus Semivestitus* populations on campus and in the surrounding area. High-resolution photography obtained by

UAVs allows for the identification and monitoring of individual trees, facilitating population surveys and distribution evaluations (Lin et al., 2015).

In addition to conservation applications, GIS also supports species-specific ecological assessments. By overlaying variables such as topography, land cover, and soil characteristics, researchers can model the habitat suitability and ecological preferences of *Dipterocarpus Semivestitus*, aiding in the understanding of its spatial distribution and environmental dependencies (Lillesand et al., 2015). Furthermore, GIS technology supports habitat restoration efforts by identifying suitable sites for reforestation and ecological enhancement. By overlaying habitat suitability models with land use and land cover data, conservation practitioners can prioritize intervention areas and allocate resources more efficiently (Li et al., 2023).

MATERIAL AND METHOD

UiTM Perak Branch is one of the branches of Universiti Teknologi MARA established in Perak, Malaysia. It is administered by a Rector and is responsible for two UiTM campuses in Perak, namely Seri Iskandar and Tapah. The study area encompasses the forest area around UiTM Seri Iskandar, Perak. It covers an area of 25 hectares equivalent to 250,000 square meters located at latitude 4° 21' 30.98"N and longitude 100° 57' 9.70" E (Figure 1). This study's methodology is divided into three stages: data collection, data processing and the presentation of findings.

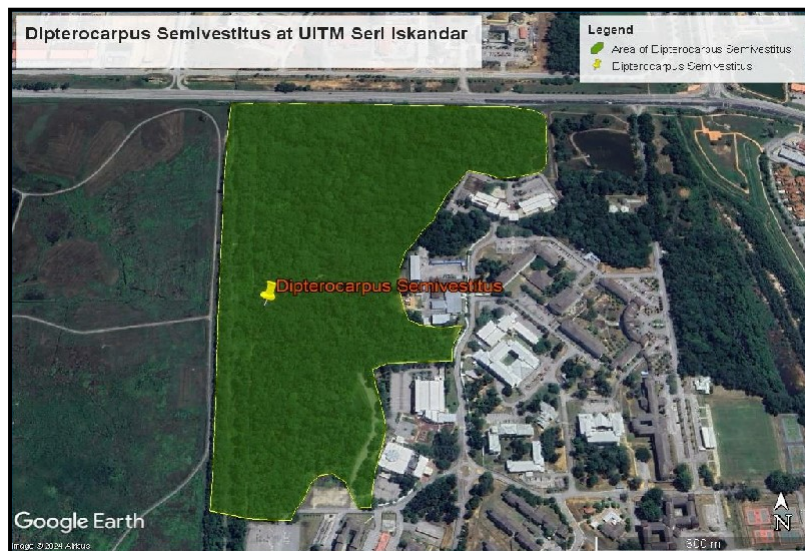


Figure 1: Study Area Located at UiTM Seri Iskandar, Perak
Sources: Google Earth Pro, 2024

UAV-Based (Aerial Imaging) Data Acquisition for *Dipterocarpus Semivestitus*

The data acquisition process using UAV for *Dipterocarpus Semivestitus* preservation at UiTM Seri Iskandar includes precisely scheduled flights to capture aerial photographs over the targeted locations. Mission planning for UAV-based data acquisition involves several critical steps to ensure the success and safety of aerial imaging operations. First, the flight area and altitude required to capture the desired aerial imagery are carefully determined, considering factors such as the required resolution, the size of the study area, and the flight altitude. The data acquisition for this area was conducted using a DJI Mavic Pro camera mounted on a UAV, which operated through the DJI GS Pro (Ground Station Pro) iPad app for drone operations. Due to the large area to cover and limitations in UAV battery capacity, data acquisition flights were conducted twice during this study. Each flight covered the whole study area to locate the designated *Dipterocarpus Semivestitus* protection area. Figure 2 illustrates the UAV flight planning conducted prior to data acquisition. The flight altitude for data acquisition in this study was set at 80 meters above ground level, considering a 70% front overlap and a 70% side overlap.

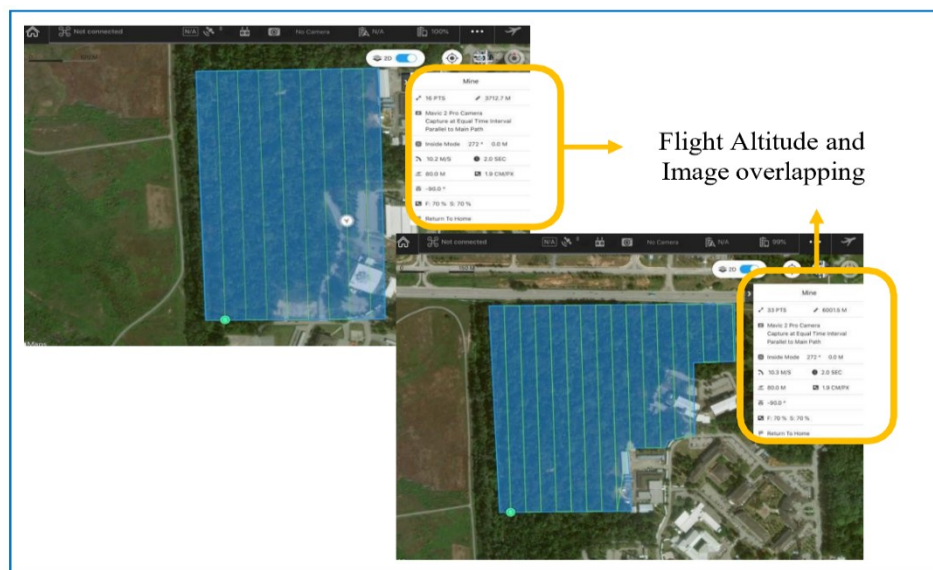


Figure 2: Designing Flight Planning before Flight Mission

The image resolution acquired during data collection depends on the flight configuration settings established prior to the mission. The flight altitude set for data acquisition affects the Ground Sample Distance (GSD) value, whereas a lower GSD value results in higher spatial resolution. In this study, the UAV

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flight paths covered distances of approximately 3,713 m and 6,001 m, corresponding to total surveyed areas of 11.47 ha and 16.90 ha, respectively (Figure 3).

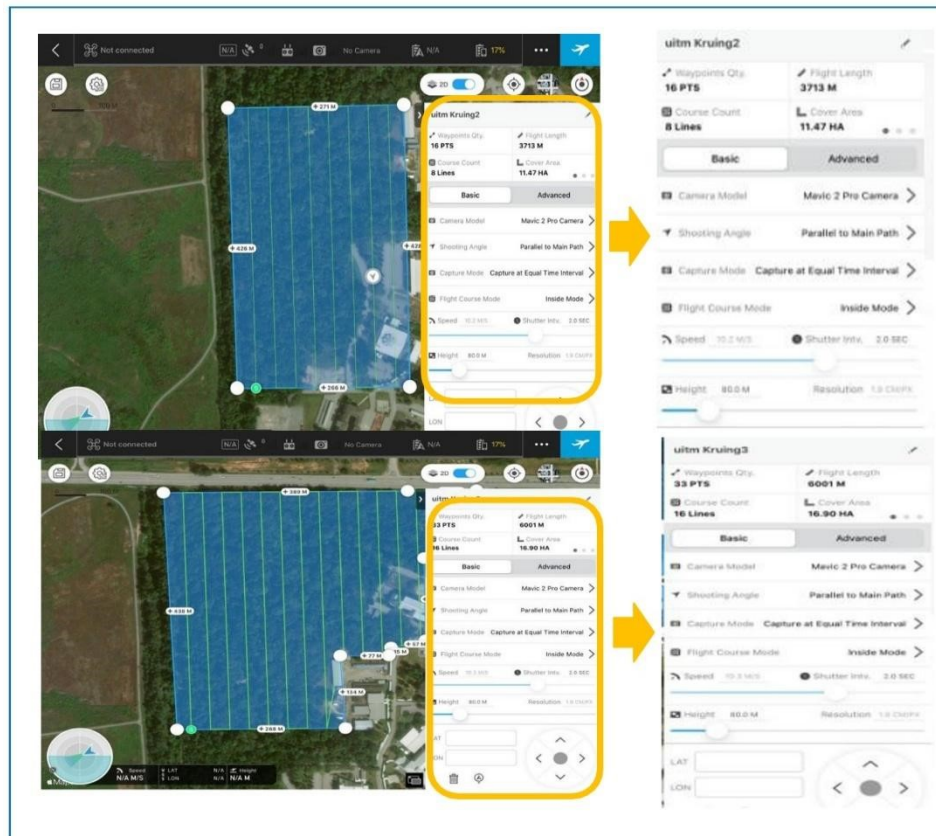


Figure 3: UAV flight paths and coverage areas within the UiTM Seri Iskandar forest zone.

Geospatial Distribution of *D. Semivestitus* GPS field observations

Field observations and GPS coordinates of *Dipterocarpus semivestitus* were recorded using the SWMap application. The collected data were then used to generate a geospatial distribution map illustrating the tree's spatial location within the study area (Figure 4). Gathering field data is critical for understanding *Dipterocarpus Semivestitus* ecological dynamics and distribution patterns.

The SWMap application was chosen for this purpose, utilising current technological breakthroughs. This introduction describes the process of utilising the SWMap application to gather accurate information about where

Dipterocarpus Semivestitus is located, how many of them exist, and the types of habitats they prefer.

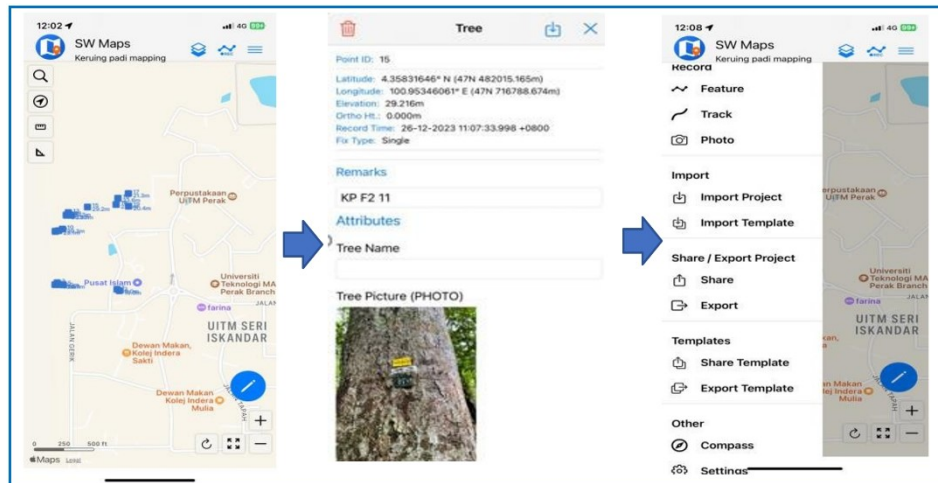


Figure 4: Geospatial distribution map of *Dipterocarpus semivestitus* created based on field observations and GPS coordinates collected using the SWMap application.

This introduction delineates the methodology for utilizing SWMap to collect precise data on the distribution, population size, and preferred locations of *Dipterocarpus Semivestitus*. It will be conducted across various regions to obtain a comprehensive overview. The goal of using SWMap during fieldwork is to simplify data collection, guarantee its accuracy, and generate useful maps for conservation planning. Each location of *Dipterocarpus semivestitus* captured using the SWMap application will be exported using the shapefile format. Each location of *Dipterocarpus Semivestitus* captured using the SWMap application will be exported in the shapefile format. All collected data will be imported into ArcGIS Pro to develop a geospatial database.

Processing *Dipterocarpus Semivestitus* Image Data

In this study, the utilization of Agisoft Metashape Professional software for processing image data of *Dipterocarpus Semivestitus* involves employing this photogrammetric tool. Agisoft Metashape is widely known for its capability to generate precise 3D models and orthomosaics using aerial imagery obtained from drones or similar platforms. Figure 5 illustrates the step of importing all aerial photographs captured during the UAV flight into Agisoft Metashape software for subsequent processing. The next step involves aligning the imported images to establish common tie points and generate a sparse point cloud representing the study area's surface.

Generating a dense point cloud from UAV images entails using drone-captured images to reconstruct a 3D representation of the terrain or objects on the ground. Initially, the point cloud generated from these images might be sparse, meaning it contains relatively few points and lacks detail. The next step is the formation of a Digital Surface Model (DSM) for this *Dipterocarpus Semivestitus* area, which is formed from dense point cloud data representing ground elevations and any features on the ground.

Generating an orthophoto from UAV images for *Dipterocarpus Semivestitus* involves stitching together individual images captured by the drone to create a single composite image that accurately represents the study area. Each image taken by the UAV covers a specific portion of the area, and they overlap to ensure comprehensive coverage. By aligning these images and correcting for distortions caused by terrain and camera perspective, a seamless and georeferenced orthomosaic is created. Overlaying existing distribution data or using classification methods on the orthomosaic allows for identifying where *Dipterocarpus Semivestitus* is located and how many trees there are in the study area. This process also helps in separating *Dipterocarpus Semivestitus* from other types of plants or land cover.

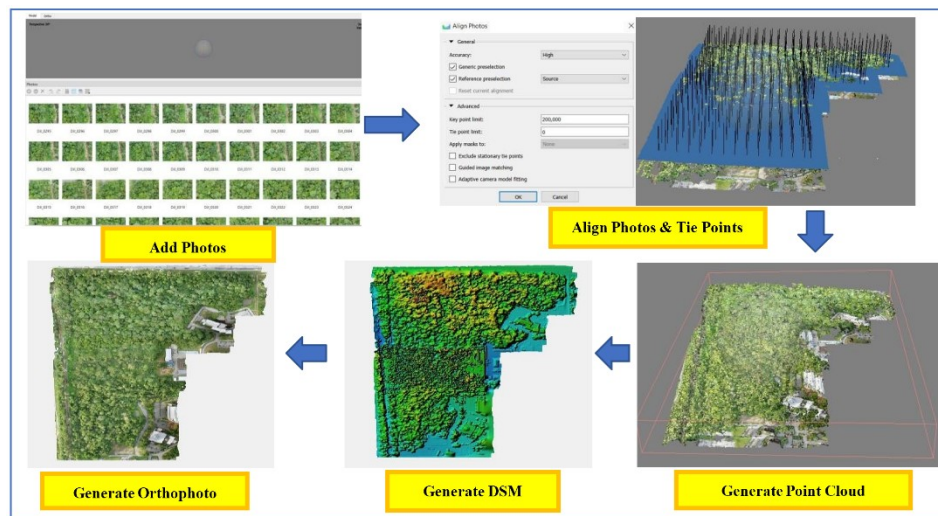


Figure 5: Image Processing for using *Dipterocarpus semivestitus* Agisoft Metashape Software

Distribution of *Dipterocarpus Semivestitus* using ArcGIS Pro Software

The distribution of *Dipterocarpus Semivestitus* can be analyzed using ArcGIS Pro software. ArcGIS Pro is a widely used GIS software that allows for the visualization, analysis, and interpretation of spatial data. With ArcGIS Pro, researchers can import spatial data layers containing information on the occurrence or presence of *Dipterocarpus Semivestitus*, such as field survey data, imagery, or species distribution models. This study employs ArcGIS Pro to map and visualize the distribution of *Dipterocarpus Semivestitus* in the vicinity of UiTM Seri Iskandar.

The generated orthophoto of *Dipterocarpus Semivestitus* is imported into ArcGIS Pro, where it is visualized and mapped based on the collected spatial data. ArcGIS Pro, a widely used GIS software, provides advanced capabilities for mapping, spatial analysis, and geographic data visualization. By utilising this software, the location of *Dipterocarpus Semivestitus* can be overlaid onto a map of the UiTM Seri Iskandar area, providing a clear depiction of their distribution concerning the surrounding landscape. This mapping method supports spatial analysis and decision-making, aiding stakeholders in gaining a deeper understanding of the spatial patterns and connections among *Dipterocarpus Semivestitus* in the study area. Figure 6 presents the mapped distribution of *Dipterocarpus Semivestitus*, based on field-collected data integrated into ArcGIS Pro for database development.

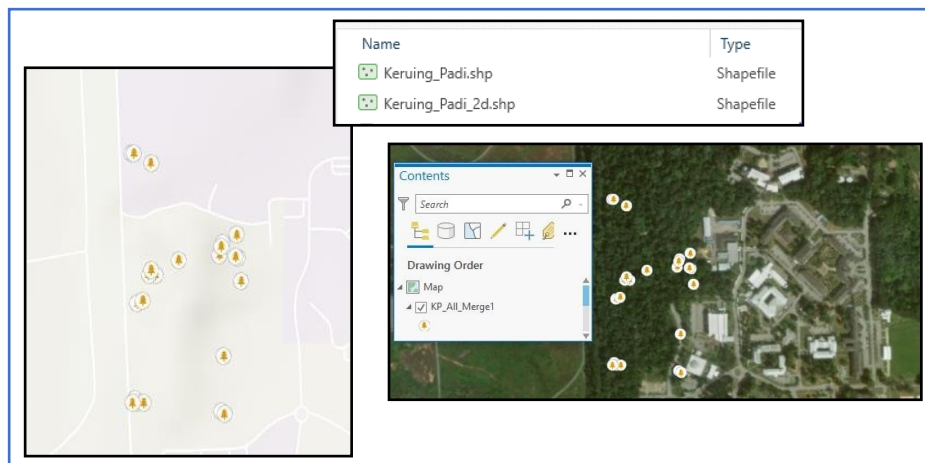


Figure 6: Spatial Distribution of *Dipterocarpus Semivestitus* Based on GPS Field Observations

RESULT AND DISCUSSION

The novelty of this study lies in the application of UAV-GIS methods for the conservation of a single *Dipterocarpus semivestitus* tree located within the peri-urban campus of UiTM Seri Iskandar. While most UAV-GIS studies in Malaysia focus on large, forested areas or ecosystem mapping, this research demonstrates the potential of UAV-based spatial analysis for the micro-level conservation of rare and isolated species. This approach introduces a spatially informed method to integrate biodiversity protection and green infrastructure management within urban development strategies.

The spatial distribution of *Dipterocarpus semivestitus* was analyzed using high-resolution UAV imagery captured by a DJI Mavic 2 Pro equipped with a 20-megapixel Hasselblad camera. The flights were conducted at altitudes of approximately 60–100 meters, producing imagery with a ground sampling distance (GSD) of 3–5 cm, which was sufficient to identify and map individual tree crowns. The UAV images were then processed and georeferenced in ArcGIS Pro. In addition to mapping tree locations, land use and canopy cover layers with a spatial resolution of 10 meters were integrated to evaluate environmental pressures within the study area. The quality and resolution of these datasets provided a reliable basis for detecting spatial patterns and assessing potential landscape-level threats to the species.

Beyond visualization, GIS analysis was conducted to detect landscape-level threats, including fragmentation patterns, proximity to land use changes, and habitat disturbances. By overlaying tree locations with land use and canopy cover data, the study identifies areas under ecological pressure thereby directly addressing Objective 3. The spatial distribution mapping of *Dipterocarpus Semivestitus* revealed that existing populations are fragmented and primarily restricted to ecotonal zones adjacent to built-up areas and disturbed landscapes. This pattern highlights the species' vulnerability to edge effects and habitat fragmentation, raising concerns about long-term population stability in peri-urban environments.

Additionally, through spatial analysis tools available in ArcGIS Pro, researchers can identify any clustering or dispersion patterns among *Dipterocarpus Semivestitus*. This analysis helps in understanding how *Dipterocarpus Semivestitus* is spatially distributed across the landscape, which could be indicative of ecological processes or environmental factors influencing their distribution. For instance, areas where *Dipterocarpus Semivestitus* are highly clustered identified using Average Nearest Neighbor and Kernel Density tools in ArcGIS Pro, may indicate suitable microhabitats or undisturbed forest patches. In contrast, dispersed or fragmented patterns, particularly near developed or cleared land, may reflect environmental stressors such as logging activity, land conversion, or edge effects. By analysing these spatial patterns quantitatively, the

study reveals potential landscape-level threats and habitat dynamics. This spatial insight is critical for informing targeted conservation and management strategies to preserve *Dipterocarpus Semivestitus* populations.



Figure 7: Mapping the *Dipterocarpus Semivestitus* Locations and Analysing Their Spatial Patterns using ArcGIS Pro

Figure 7 presents the spatial distribution and observed patterns of *Dipterocarpus Semivestitus*, offering a better understanding of its ecology and contributing to local conservation planning. *Dipterocarpus Semivestitus* distribution patterns can be detected and visualised using spatial analysis in ArcGIS Pro. In this study, the spatial distribution of *Dipterocarpus Semivestitus* revealed notable clusters of occurrences, particularly in areas with specific environmental conditions such as moderate elevation ranges and proximity to undisturbed land cover. By analyzing spatial patterns in relation to environmental variables like land cover type, elevation, and soil characteristics, the study identified potential habitat preferences and areas of ecological importance. These relationships help explain the species' current distribution and inform targeted conservation strategies. By analyzing the spatial distribution and clustering of *Dipterocarpus Semivestitus*, researchers can gain insights into the species' habitat preferences, potential seed dispersal mechanisms, and ecological interactions with surrounding landscape features such as forest edges, disturbed zones, and

vegetation types. This data is valuable for conservation planning as it not only identifies areas with high species concentration or ecologically significant zones but also includes key attribute information such as the number of individual trees, their size, health status, and age class. These attributes are essential for assessing forest structure, monitoring tree conditions, and implementing targeted protection or restoration strategies. Relying solely on spatial location would limit management effectiveness, whereas integrating both spatial and attribute data provides a more comprehensive foundation for informed decision-making.

CONCLUSION

The application of UAV-GIS technology in this study has proven to be a highly effective and scalable method for conserving *Dipterocarpus Semivestitus*, an endangered tropical species, within the peri-urban landscape of UiTM Perak Branch (Seri Iskandar). Through high-resolution spatial mapping, the study revealed that existing populations are fragmented and primarily restricted to ecotonal zones adjacent to developed or disturbed areas. Habitat condition analysis indicated signs of edge degradation, while spatial overlays demonstrated the species' increasing proximity to urban expansion underscoring the urgency for targeted conservation measures.

By enabling precise, non-invasive habitat assessments, UAV-GIS integration offers a robust alternative to conventional field surveys, which are often time-consuming, labor-intensive, and potentially disruptive to fragile ecosystems. This technology allows for rapid data collection across extensive areas while minimizing ecological disturbance, making it particularly suited for conservation planning in sensitive environments.

The insights gained from this research are critical for guiding biodiversity-sensitive land use and green infrastructure planning, particularly in rapidly transforming peri-urban academic settings like UiTM. Moreover, the study supports broader sustainability objectives by aligning with key Sustainable Development Goals (SDGs), including SDG 15 (Life on Land), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). Overall, this work reinforces the role of spatial planning and geospatial technology in preserving vulnerable ecosystems amid ongoing landscape change.

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