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Application of UAV Technology for Vegetation Community Identification in Coastal BRIS Wetland

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ABSTRACT

Unmanned aerial vehicles (UAV) based methods for reconnaissance activities aim to update wetlands' health status and are safer and cost-effective considering that wetlands normally have saturated soils, dense vegetation and wildlife. Vegetation survey work in wetland areas needs many staff to ensure the safety of researchers and equipment. This paper describes the application of UAV technology to identify and demarcate vegetation communities in a dense BRIS (beach ridges interspersed with swales) coastal wetland. The methodology employed in this research has two steps. The first step involves the utilisation of UAV imagery and Geographic Information System (GIS) technology. The second step entails ground truthing, which involves validating tree species using 15 quadrants. The utilisation of UAVs in conjunction with ArcGIS 10.3 demonstrated that the unique characteristics of tree canopy morphology and tree heights could be assessed and analysed. The UAV-GIS results are compared to ground truthing results to validate tree communities' demarcation. The findings indicate that integrating two datasets, particularly tree canopy morphology and tree height, produced an acceptably accurate vegetation community demarcation. The tree canopy form *of Hibiscus tiliaceus* (Bebaru) was differentiated from the canopies of *Acacia mangium* and *Nypa fruticans* by analysing the image. The tree height analysis involved using ArcGIS 10.3 software to

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generate the digital surface model (DSM) and digital terrain model (DTM). Validation results indicate an 87% accuracy in the demarcation work. Hence, identification and demarcation of the vegetation communities could be achieved by utilising both tree canopy morphology and tree height data obtained from UAV.

Keywords: BRIS coastal wetland, canopy morphology, *Hibiscus tiliaceus*, UAV method

INTRODUCTION

Coastal BRIS wetlands are very challenging environments to study. They are usually waterlogged and have soft soil and dense trees that restrict accessibility. Moreover, the presence of wild animals, such as poisonous snakes and wild boars, makes such environments potentially hazardous to work in (Hu et al., 2017). Additionally, a sizable workforce is needed, which is inefficient from a cost standpoint and raises the possibility of disrupting delicate plant and animal species (Pinton et al., 2020). Right now, remote sensing presents a viable answer to the problems brought on by this predicament.

Satellites and aircraft have previously been used in remote sensing operations (Thomson et al., 2003). However, their application is sometimes limited due to cloud cover, rigid data acquisition frequency, and cost. In contrast, UAVs or drones could capture high-resolution multi-spectral images even during cloudy weather as they flew at lower altitudes (i.e. below cloud cover), with a high degree of manoeuvrability, easy deployment and flexible data acquirement schedule (Tagle, 2017; Durgan et al., 2020).

The UAV image approach could differentiate various vegetation communities from an aerial perspective based on canopy characteristics (Mahmud et al., 2023). It could facilitate the process of locating wetlands and enhance plant species identification. UAV with RGB (i.e. red-green-blue light spectrum) sensor is typically used for the field sampling. UAVs with near-infrared (NIR) band and Cubert UHD 185 hyperspectral sensors have been used for more detailed vegetation observation and analysis and could distinguish between different species of mangrove trees (Abeysinghe et al., 2019; Darwin et al., 2014; Durgan et al., 2020).

This paper describes the application of UAV technology to identify and demarcate coastal BRIS wetland vegetation communities. It demonstrated a viable means of aiding wetland vegetation survey work. Vegetation community identification helps evaluate the wetland's health state and monitor vegetation alterations in a target area (Lawley et al., 2016; Zungu et al., 2018; Fang et al., 2021; Alsfeld et al., 2010).

METHODOLOGY

Study Area

The study was conducted at the BRIS wetland on the campus of Universiti Malaysia Terengganu, 20 km north of Kuala Terengganu (Figure 1). The wetland is approximately 5.26

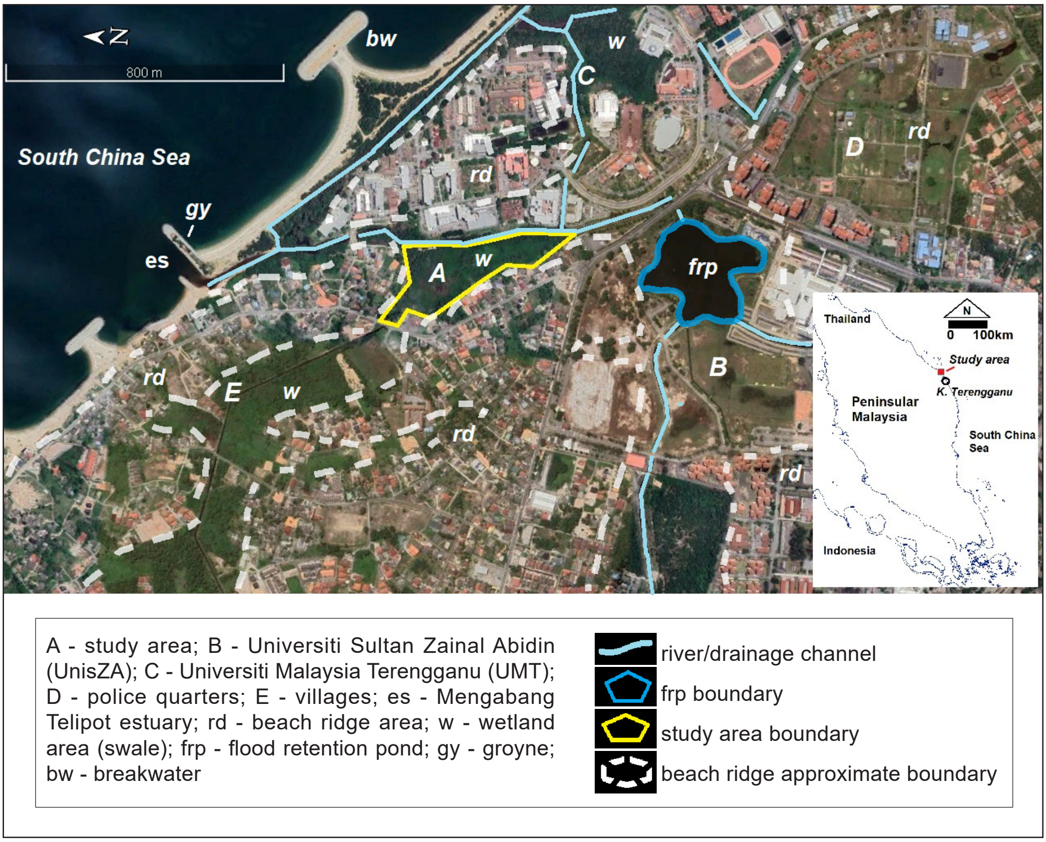

Figure 1. Study area (*Source*: Google Earth)

ha and is beside a tidal river (Figure 1). It would be flooded when the adjacent rivers overflow, resulting from high upstream flows during the northeast monsoon season and high tide.

Remote Sensing and GIS Technique

The study area was surveyed using an unmanned aerial vehicle (UAV) on July 19, 2022. This UAV method produces high-resolution images compared to aerial photography methods. A DJI Matrice 100 drone was used. Flight missions were conducted 60 meters above ground level (AGL) at 38 km/hr cruising speed. The spatial resolution was 8 cm ×8 cm. The flight paths for the drones were designed in a way similar to mowing a lawn to account for projected overlap, with 75% front-lap and 75% side-lap, respectively (Otto et al., 2018). The Zenmuse X3 camera (https://www.dji.com/) mounted on the drone captured true-colour photographs at a resolution of 12.0 megapixels (4000 × 3000 pixels).

Litchi (version 4.0.1; available at https://flylitchi.com) was used to construct flight routes and monitor progress while data was collected (Figure 2). Three hundred and seventy-eight individual pictures were digitally merged using the pix4d program (https://www.pix4d.

com). It allowed for a realistic 3D mapping and modelling ArcGIS 10 to analyse and interpret the generated image to identify the vegetation communities based on canopy morphology and height. Tree height is the elevation difference between the canopy`s top and ground surfaces. For this purpose, a digital terrain model (DTM) and digital surface model (DSM) of the study area are used. The DTM represents the ground surface elevation, and the DSM represent the top canopy surface elevation. DTM and DSM use the National Geodetic Vertical Datum or NGVD as a standard elevation reference system. The Survey and Mapping Department of Malaysia developed this system. Practically, elevations were calculated using a reference level from a surveying benchmark using the NGVD system. While DSM data was acquired from the UAV survey, DTM was generated from secondary data sources from earlier (2007 and 2020) on-the-ground topographic surveys conducted by land surveyors for Universiti Malaysia Terengganu campus development projects.

Figure 2. Flight paths for drone mapping using Litchi software

Vegetation Community Demarcation and Validation

Tree height data aided vegetation identification work as different species have different height ranges. The identified vegetation communities were demarcated using ArcGIS 10.3 software. After that, the demarcation was validated with data collected from the ground truthing work. The vegetation species and community surveyed within the quadrates discussed earlier served as ground-truthing data. It should be noted that the UAV combined with the GIS method identify and demarcates communities based on physical characteristics alone. Hence, it is not meant to demarcate species even though it may be useful under some clear circumstances, e.g., differentiating a coconut tree from a Nypa tree.

Vegetation Sampling

The vegetation sampling was carried out from October 6 to 16, 2022, in two stages: the quadrat establishment and the plant sampling (Figure 3). First, the study area was divided into a grid of 10 m × 10 m cells or quadrates and numbered. Using the random number generator in Microsoft Excel, 15 quadrants were selected. A ground check was done to ascertain the accessibility of the selected area. The finalised quadrat locations are shown in Figure 4. Plant samples (such as leaves, fruits, and flowers) found in the quadrates were collected and preserved in 70% alcohol in a plastic container. The species were identified by referring to the voucher specimens in the UMT herbarium and expertise.

Figure 3 represents the flowchart of the methodology, comprising study site monitoring, remote sensing, GIS techniques, and vegetation sampling. Quadrates measuring 10 m x 10 m were established using measuring tape and rope. The grid was drawn and numbered on the UAV image using ArcGIS software. Fifteen quadrate locations were selected based on random numbers generated in Microsoft Excel and consideration of field conditions such as accessibility and safety.

Figure 3. Flowchart of the methodology

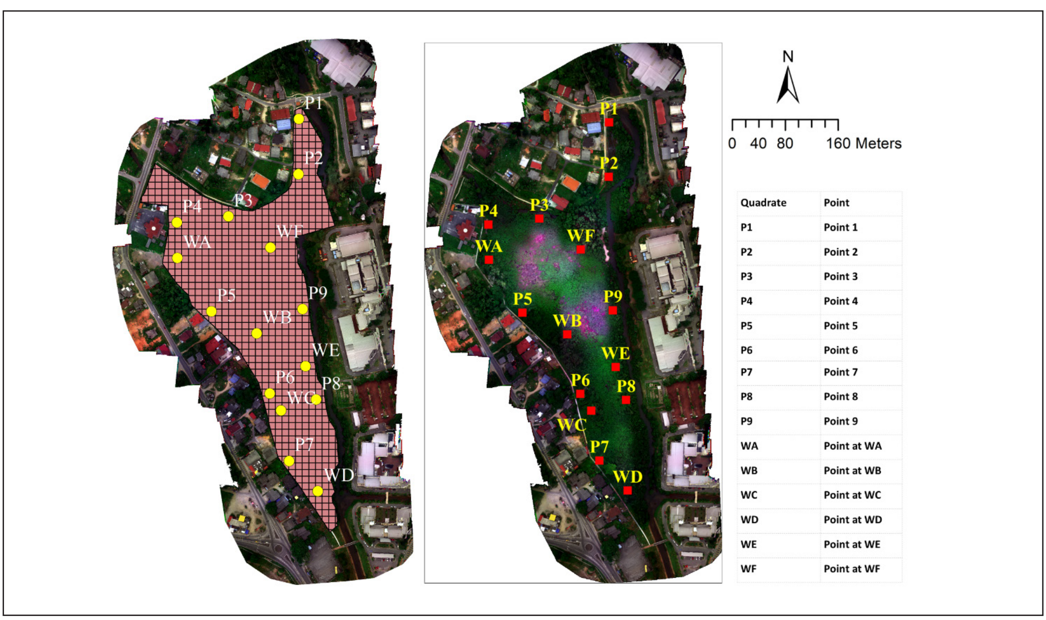

Figure 4. Fifteen quadrants are scattered in the coastal BRIS wetland, Kuala Nerus, Terengganu (*Source*: UAV Image)

Note. 'P1–P9' are just transects, whereas 'WA–WF' are transects locations with groundwater monitoring wells. The middle section is inaccessible; hence, no quadrates were assigned. It does not affect the sampling work's validity as this section has the same type of vegetation as the surrounding quadrates based on visual observation from the top floor of a faculty building located just beside the wetland on the eastern side

RESULTS AND DISCUSSION

Vegetation Canopy Morphology Identification

The study area is dominated by *Hibiscus tiliaceus* (Bebaru) (Table 1; Figure 5). It is commonly found in tropical regions. This pantropical mangrove species usually occurs in coastal ecosystems with high salinity (Santiago et al., 2000). This tree offers a wider canopy with a short trunk sprawling and intertwined branches that form an impenetrable thicker. It posed accessibility challenges during the field survey. The leaf is heart-shaped, 8–20 cm long, wavy, and bright green colour on the upper surface and greyish green and hairy below (Figures 5 and 7). It has a yellowish, short-lived, and fragile flower (Elevitch & Thomson, 2006).

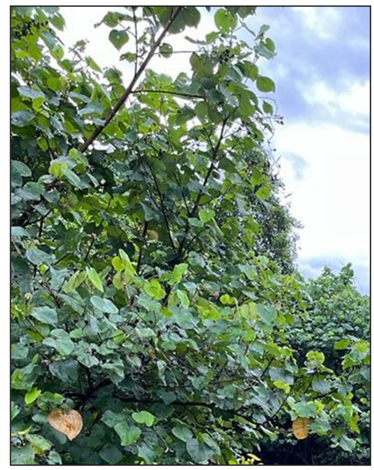

Figure 5. The *Hibiscus tiliaceus* plant is dominant in the study area

The vegetation canopy morphology was identified using the UAV image (Figure 6). The Bebaru (*H. tiliaceus*) tree canopy morphology differs from the *Acacia mangium* and *Nypa fruticans* canopy (Figure 7). The *A. mangium* leaves were usually large, 11–27 cm long (Figure 7) and 3–10 cm broad and have acute-angled, glabrous and stout branchlets (Maslin &

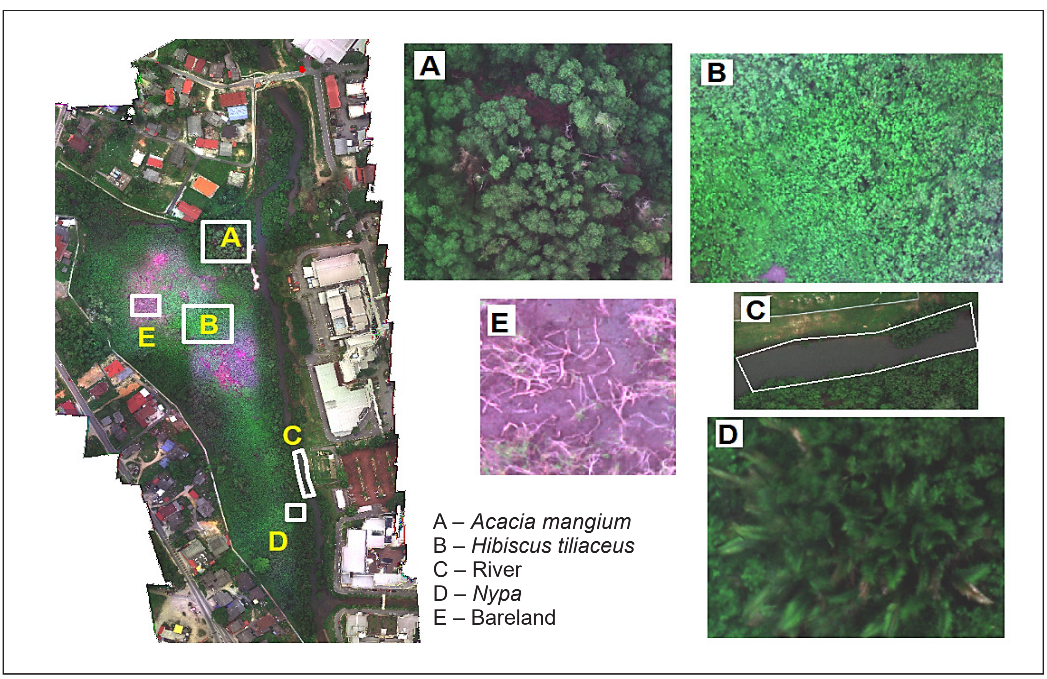

Figure 6. UAV images of canopy morphology of vegetation with location examples in the study area
Note. Bare land and waterbody (river) compare vegetated and non-vegetated

Figure 7. Leaves characteristic

McDonald, 1996). *Nypa fruticans* leaves appear from the ground, lacking a visible upright trunk with a single leaf that can grow up to 8 m (Figure 7) (Zakaria & Aslzaeim, 2010).

Vegetation Height Estimation

The digital surface model (DSM) represents the top of the canopy surface, while the digital terrain model (DTM) shows the ground level in the study area (Figure 8). The DTM was generated from topographic survey data from Universiti Malaysia Terengganu (UMT), whereas the DSM was generated from UAV data. The DTM represents the ground surface

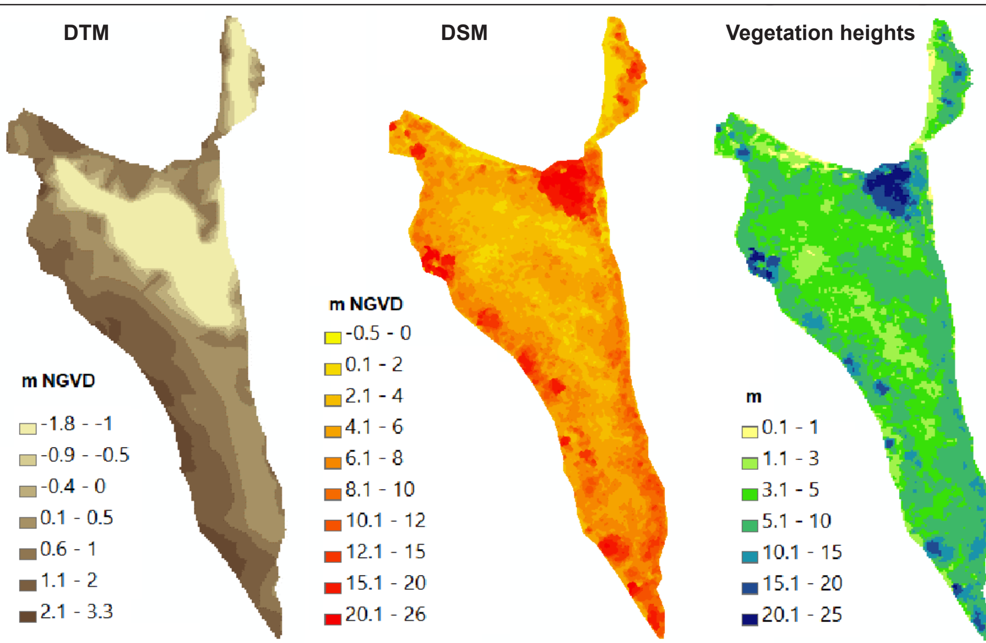

Figure 8. DTM, DSM and vegetation heights

elevations, while the DSM represents the canopy top surface elevations. DTM and DSM elevations used the same vertical datum with reference to the NGVD system; hence, they are comparable. The difference in elevations between DSM and DTM represents the vegetation height, represented by the 'Vegetation Heights' map. This vegetation heights map illustrates the diverse range of plant heights resulting from vegetation species variations. This data aided vegetation community demarcation because different species of vegetation could have different average heights. The Bebaru tree typically grows to 3–10 m in height, whereas *A. mangium* can grow to 25–35 m in height, and the *N. fruticans* tree can reach up to 9 m (Hegde et al., 2013; Zakaria & Alzaeim, 2010). Hence, when an area with certain canopy morphology (Figure 6), e.g. Berbaru, the vegetation heights range, in the case of the study area, 3 to 7 m, would help to further affirm that the area is most likely Berbaru. This approach is not meant to be used in vegetation identification, as other vegetation types could also have the same height range. It is meant to aid in identification work, especially in inaccessible areas.

Vegetation Species Identification from Quadrates Sampling

A vegetation community is the primary or prevailing vegetation type within a specific abiotic setting in a region (Diekmann, 2003). In this study, the community's determination was based on identifying the dominant species, which collectively contributes to the highest coverage within a defined quadrat. Hence, the community in each quadrate was determined based on the species dominance.

The vegetation communities have been identified using aerial photos and data from ground truthing/field surveys. UAV images provided two sorts of information: crown morphology and vegetation height. These data produced variances in canopy morphology, which may be translated into various vegetation communities. The finding was then confirmed using a field survey. A total of 29 species were identified across all quadrants. Based on this data, the dominant species for each quadrate was indicated. The dominant species, represented by the one with the highest coverage in each quadrate, reflected the composition of the community. In this study, if there is more than one dominant species, the dominancy was determined based on the highest crown cover.

The communities' assessment was made based on UAV images. Based on the variations identified by the UAV image, the field surveys identified 13 floristically and physiognomically unique plant groups. Meanwhile, the 29 species mentioned were listed from ground truthing (vegetation sampling), and some did not fit into the recognised plant groups from the aerial images.

The vegetation samples have been incorporated into the analysis conducted in ArcGIS to generate the wetland map, which includes the spatial distribution of the communities (Table 1).

Table 1
Species of vegetation collected in the quadrates

No.	Species	P1	P2	P3	P4	P5	P6	P7	P8	P9	WA	WB	WC	WD	WE	WF
1	*Hibiscus tiliceus*	\	*	*	*	*	-	*	*	*	*	*	-	*	*	\
2	*Acacia mangium*	-	-	-	-	-	\	-	\	-	-	\	\	-	-	-
3	*Cyperus esculentus*	*	\	-	-	-	\	\	-	-	-	-	*	-	-	-
4	*Sonneratia alba*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Melastoma malabathricum*	-	-	-	-	-	\	\	-	-	-	-	-	-	-	-
6	*Nephrolepis acutifolia*	-	-	-	-	-	*	\	-	-	-	-	-	\	-	-
7	*Fagraea fragrans*	-	-	-	-	-	\	-	-	-	-	-	-	-	-	-
8	*Acrostichum aureum*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	*Passiflora foetida*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	*Casuarina equisetifiloa*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	*Sphagneticola tribolata*	\	-	-	\	-	-	-	-	-	-	-	-	-	-	-
12	*Mimosa pudica*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	*Flagellaria* sp.	-	\	\	\	\	-	\	\	\	\	\	\	\	\	\
14	*Annona glabra*	-	-	-	-	-	-	-	-	-	-	\	-	-	-	-
15	*Catunaregam spinosa*	-	-	-	-	\	-	-	-	-	-	-	-	-	-	-
16	*Passiflora edulis*	-	-	-	\	-	-	-	-	-	-	-	-	-	-	-
17	*Zingiber zerumbet*	-	-	-	-	-	\	-	-	-	-	-	-	-	-	-
18	*Dolichandrone spathacea*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	*Derris trifoliata*	\	\	\	-	-	-	-	\	\	-	-	-	-	\	-
20	*Causonis trifolia*	\	\	-	\	-	-	-	-	-	-	\	-	-	\	-
21	*Spermacoce exilis*	\	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	*Tylophora flexuosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	\
23	*Salacia chinensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	\
24	*Olax imbricata*	-	-	\	-	\	-	-	-	-	-	-	-	-	-	\
25	*Mikania micrantha*	-	-	-	-	\	\	\	-	-	-	\	\	\	-	-
26	*Cyperus mindorensis*	-	-	-	-	-	-	\	-	-	-	-	-	-	-	-
27	*Coccoloba diversifolia*	-	-	-	-	-	\	-	-	-	-	-	\	-	-	-
28	*Vitex trifolia*	-	-	-	-	-	-	-	-	-	-	-	\	-	-	-
29	*Melothria pendula*	-	-	-	\	-	-	-	-	-	-	-	-	-	-	-

Note. * represents the dominant species in the quadrate, \ represents the species presence in the quadrate

UAV Vegetation Community Validation

Based on their canopy morphology and general height, vegetation communities were demarcated into polygons in ArcGIS. These polygons visually implied the boundaries of various plant species. The quadrat data of vegetation species sampled on the ground were spatially compared with the demarcated community boundaries by overlapping them in

ArcGIS. It must be noted that the purpose of doing this is not to show that UAVs can detect vegetation at the species level. Rather, it is to verify the accuracy of the vegetation community`s demarcation. Such demarcation work would contribute to the optimisation of time, cost, and safety when vegetation species surveys are done for large and low-accessible areas. The most dominant species would define the canopy morphology characteristics and general heights. Hence, in Table 1, the dominant species are indicated and used to ascertain the accuracy of the UAV-based demarcation work.

The community was identified by analysing canopy morphology and vegetation height estimation using UAV image analysis with ArcGIS. In this study, the community's determination relied on recognising the dominant species that collectively contributed to the highest coverage within a specified quadrat.

Hibiscus tiliaceus or Bebaru was the most prevalent species in the study area (Table 1). Fifteen quadrants were randomly placed around the wetland area to avoid potential biases in species data collection and enhance the accuracy of vegetation identification within the designated study region (Figure 3). The results of vegetation sampling in each quadrat and the vegetation communities demarcated are shown in Figure 9.

The *H. tiliaceus* species has been distinguished based on the analysis of canopy morphology, specifically the differences in leaf size and arrangement compared to other plant species. However, identifying small-sized plants, such as *Flagellaria* sp., was challenging in the unmanned aerial vehicle (UAV). It is a limitation caused by the spatial resolution of the UAV image. The presence of overlapping foliage can obstruct the visibility of leaves, hence reducing detectability. It is important to note that the image obtained from UAVs demonstrates a tendency towards capturing plants characterised by greater leaf size.

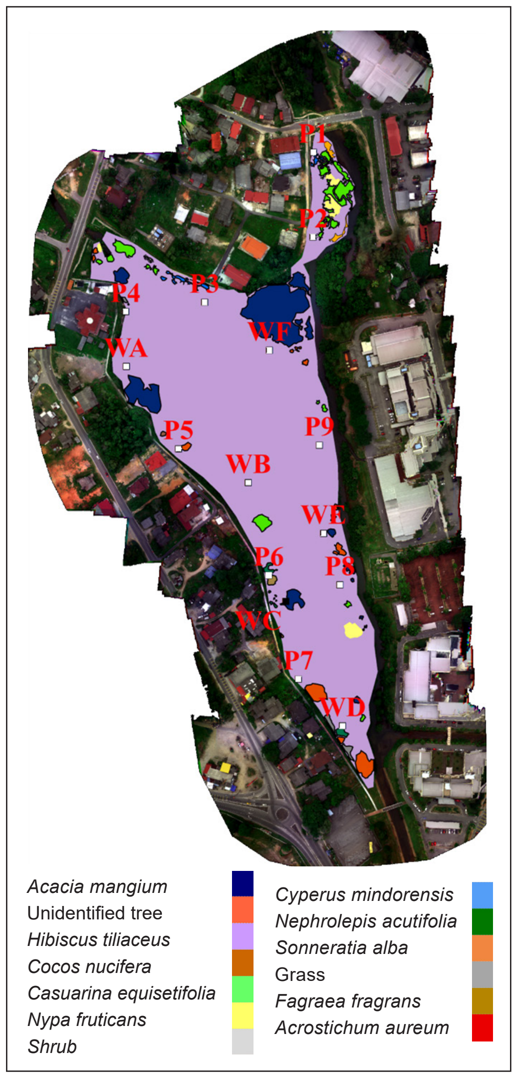

Figure 9. Vegetation communities identified via UAV technique and quadrat locations

Leaf size has a notable impact on the identification of canopy morphology, as evidenced by unimodal patterns of leaf size concerning tree size. It implies leaf size influences canopy morphology (Thomas, 2010; Ollinger, 2011). Consequently, identifying small leaves poses difficulties in UAV image processing for vegetation analysis, potentially influencing the efficiency of demarcating vegetation communities.

The demarcated vegetation communities were compared with the data from the quadrates. It means the result of fieldwork sampling, observation, and the vegetation community demarcation is independently done, making such comparison valid. All the communities were classified into 13 based on their canopy morphology and vegetation height estimation. These two parameters were determined by analysis of UAV images using ArcGIS software.

Of 15 quadrants, two did not match their community (Figure 9). Quadrat P6 has *Nephrolepis acutifolia* as its dominant species but was demarcated under Community 3, which has *H. tiliaceus* as the dominant species. Quadrat WC has *Cyperus esculentus* as its dominant species but was also demarcated under Community 3. These two quadrants were located very close to Community 3; hence, the error could be caused by the inability of the UAV`s spatial resolution to discriminate them from *H. tiliaceus*, which dominates Community 3. Overall, 13 out of 15 quadrates indicated that the vegetation community did demarcate the dominant species correctly; hence, the accuracy is about 87%. If more quadrates are used, the reliability of this UAV technique could be further attested.

CONCLUSION

UAV technology could identify and demarcate coastal BRIS wetland vegetation communities. *Hibiscus tiliaceus* was the dominant species in this study region, with 13 quadrates out of 15 displaying its presence. Through the utilisation of ground truthing, it was determined that roughly 87% of the quadrates showed correct identification and demarcation. A higher spatial resolution would produce even better results as the detection depends on the leaf size. This technology is both cost-effective and safe. Ecologists could identify vegetation communities and demarcate their areas as an initial work before actual vegetation species survey work on the ground. The design of survey transects and locations can be more effective as the availability of a vegetation community map would enable targeted work. These benefits would be even more worthwhile when applied to larger areas, especially when they are challenging terrains.

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