Utilizing Drone Imagery to Classify Swamp Cover in Patra Tani Village, South Sumatra Province, Indonesia

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The initial step of successful land use is the selection of the appropriate location in line with the type or concentration of land exploration which requires land mapping. However, mapping activities undertaken in a territory with a comprehensively changing land cover, such as swamp ecosystems, requires considerable time and cost, which could make the work ineffective. Nevertheless, through technological developments, the land with changing ecosystem can be mapped easily using remote sensing systems and aerial photography by drones. The advantages of this technology are its effectiveness and efficiency in terms of time and cost.

Under the project "Management Scheme of Inland Fisheries in the Southeast Asian Region," implemented in 2020–2024 and supported by the Japanese Trust Fund VI Phase 2, SEAFDEC Inland Fishery Resources Development and Management Department (IFRDMD) conducted the study to monitor the land cover of the Special Area for Conservation and Fish *Refugia* (SPEECTRA) in a swamp area by using a drone. Drones could produce high-resolution aerial images that can be quickly processed by analysis software such as geographic information systems and image classification algorithms. Using drone imagery to manage inland waters has great potential, both for monitoring the aquatic environmental health index and mitigating ecological damage.

A swamp is a wetland area characterized by being saturated with water, either permanently or seasonally, and is often characterized by the type of vegetation such as cypress or hardwood. The freshwater swamp is found in inland waters, while saltwater swamps can be found along coastlines (Rudledge *et al*., 2022). In inland waters, a swamp is a dynamic ecosystem that becomes a terrestrial habitat during the dry season and an aquatic habitat during the rainy season (Muthmainnah *et al*., 2019) where the water depends on discharges from inflowing streams and groundwater. The low rainfall influences the flooding of swamps and changes the habitats to become wet or dry (Roshier *et al*., 2001). The change in vegetation affects the migration of aquatic organisms, mainly in the availability of feeding, nursing, and spawning grounds (Boyd & Madsen, 1997).

In Indonesia, the Inland Fishery Resources Development and Management Department (IFRDMD) of SEAFDEC in collaboration with the Sub-Institute for Swamp Fisheries of the Research Institute for Inland Fisheries and Extension (RIIFE), Ministry of Marine Affairs and Fisheries of Indonesia developed the Special Area for Conservation and Fish *Refugia* (SPEECTRA) concept since 2019. SPEECTRA is an artificial conservation area that can accommodate fish from the river or introduce brood stock. The system should be connected to the river or other natural water bodies through canals. The main objectives of SPEECTRA development are to 1) function as artificial conservation or protected area for native species; 2) provide freshwater fish genetic bank, especially for the black fish group; 3) prevent land fires that usually occur in marginal lands; and 4) serve as a study area for developing conservation zones in inland waters.

From January to October 2022, IFRDMD monitored the land cover of the SPEECTRA established in a swamp area in Patra Tani Village, South Sumatra Province, Indonesia. The 4.8 ha SPEECTRA operated since 2019 as artificial ponds to preserve fisheries, support food security, and prevent forest fires. At the beginning of 2022, the SPEECTRA was developed for educational and tourism areas focusing on swamp fishery

Figure 1. SPEECTRA ponds in Patra Tani Village, South Sumatra Province, Indonesia observed from January to October 2022

Table 1. Characteristics of the SPEECTRA ponds in Patra Tani Village, South Sumatra Province, Indonesia observed from January to October 2022

SPEECTRA Ponds	Area (ha)	Depth (m)	Water level (cm)
Pond 1 • Connected to the main canal and river • Built with barrier soil to control the migration of fish populations • Built with a trap door between the center of the pond and canal to prevent fish from returning to the river	1.0	4	170–290
Pond 2 • Conservation model for fish and crop cultivation • Plants were planted around the pond to provide shelter for fish	1.0	4	140–200
Pond 3 • Consisted of four interconnected plots (400 m^2 each) as fish protection areas, especially for juvenile	2.0	4	150–215
Pond 4 • Away from the river and used as a nursery • Connected to Pond 3 and Pond 5 where fish can easily migrate for their life cycle	1.5	4	140–155
Pond 5 • Built based on the agroforestry concept where nutrients produced by the trees would enter the water body for phytoplankton growth	2.5	4	160–170
Pond 6 • Has a large canal connected to the outside of the SPEECTRA area • Trees and swamp grass were planted at the center of the pond to shelter fish	0.8	5	100–120

activities. The SPEECTRA is composed of six ponds as shown in **Figure 1** and the characteristics of each pond are described in **Table 1**.

Mapping the land cover of SPEECTRA

It is important to assess the extent of land cover in swamp areas in order to manage natural resources which can be done through drone imagery. Using drones which are unpiloted aerial vehicles (UAVs) in computer vision applications offers advantages over traditional surveillance cameras. The ultrahigh-resolution images acquired by small UAVs are valuable in identifying and characterizing swamp areas using a low-cost drone (Ventura *et al*., 2016). Drone imagery is a relatively accurate and efficient data source for land cover identification, which has greater efficiency and flexibility and has been quickly adopted for various purposes including agriculture, aerial photography, and surveillance (Du *et al*. 2018; Zu *et al*., 2020). It can capture high-resolution images and access areas that are difficult to reach, compared to other methods in helping to identify the types and extent of land cover in swamp areas. A drone can be used to quickly and efficiently monitor, record, and gather data from routine observations. By providing aerial capabilities for capturing and recording images and data, it can be used to study ecological phenomena at higher resolutions and on impossible scales with satellites or crewed aircraft. The drone can also gather spatial information for wildlife surveys, aquatic habitats, water resource analysis, and valuable data in scientific remote sensing to evaluate resource management.

The DJI Phantom 4 Pro drone was utilized for capturing high-resolution images of the land cover of each pond of the SPEECTRA. The drone was equipped with a 20 MP camera and a 3-axis gimbal that stabilizes the images. The aerial photographs were taken at a height of around 100 m with a spatial resolution of 2.40–2.97 cm (Hernina *et al*., 2019). Besides, the rugged and water-resistant Garmin 79s handheld GPS device was used to map the study area at a scale of 1:2,000.

Data validation by ground check is a commonly used method to ensure the accuracy and reliability of drone-generated data. Thus, the ground check was done by comparing data generated by drones with data obtained from direct measurements in the field (ground truth). After the drone flight was completed, direct measurements were taken in the field at predetermined measurement points. These measurements were made using measuring instruments such as GPS, total station, or other devices.

Agisoft software was used to create flight plans for drones as well as image processing and analysis. The software was explicitly designed for photogrammetry and 3D modeling applications and included various tools for image enhancement, georeferencing, and land cover classification. Aerial photographs were analyzed by interpreting elements such as spatial, spectral, texture, color, shape, pattern, and size. Based on object-based image analysis, the land cover of each pond was classified into different types (*i.e.* shrubs, trees, aquatic plants, water, and riparian) and was assigned corresponding colors (**Table 2**).

The spatial and temporal land cover captured by the drone from January to October 2022 is illustrated in **Figure 2**. **Pond 1** was dominated by riparian in January and February

Table 2. Classification of the land cover of SPEECTRA ponds in Patra Tani Village, South Sumatra Province, Indonesia

Land cover	Description	Assigned color
Shrubs	area covered by grass, herbaceous plants, and seedlings	Light yellow
Water	area with the deepest pool and covered by water the whole year	Light blue
Riparian	area covered by water during the rainy season or with a little water or dry during the dry season	Maroon
Trees	area covered by woody plants	Green
Aquatic plants	area covered by plants that have adapted to living in aquatic environments	Brown

which decreased slightly from March to October. In contrast, the abundance of trees increased significantly from April to October. The growth of trees was influenced by the addition of nutrients from the river flowing into the SPEECTRA system. This condition indicated that trees grew faster and changed the dominance of riparian in Pond 1.

The dominance of trees was observed for ten months in **Pond 2**. Approximately 45–78 % of Pond 2 was covered by trees while aquatic plants fluctuated depending on the water level. The riparian was not observed which could be because Pond 2 was covered by vegetation and other types of plants. The presence of trees and other vegetation in the riparian zone can stabilize the banks of the pond, filter pollutants, and provide habitat for a variety of plant and animal species. Overall, the ecology of Pond 2 was complex and dynamic, and a variety of factors including vegetation cover and water level fluctuations made impacts on the plant and animal species that inhabit the pond and its surrounding area.

Aquatic plants were dominant in **Pond 3** with around 33–55 % cover. The abundance of aquatic plants and shrubs fluctuated equally indicating that there may be a dynamic interplay between these two types of vegetation. The small percentage of aquatic plants in the pond had bloomed which could have been due to favorable environmental conditions such as increased sunlight, nutrient availability, and water temperature. The dominance of aquatic plants in Pond 3 can have important ecological implications. Aquatic plants play an important role in the pond ecosystem by providing a habitat for fish and other aquatic animals, stabilizing sediments, and helping to maintain water quality by filtering pollutants.

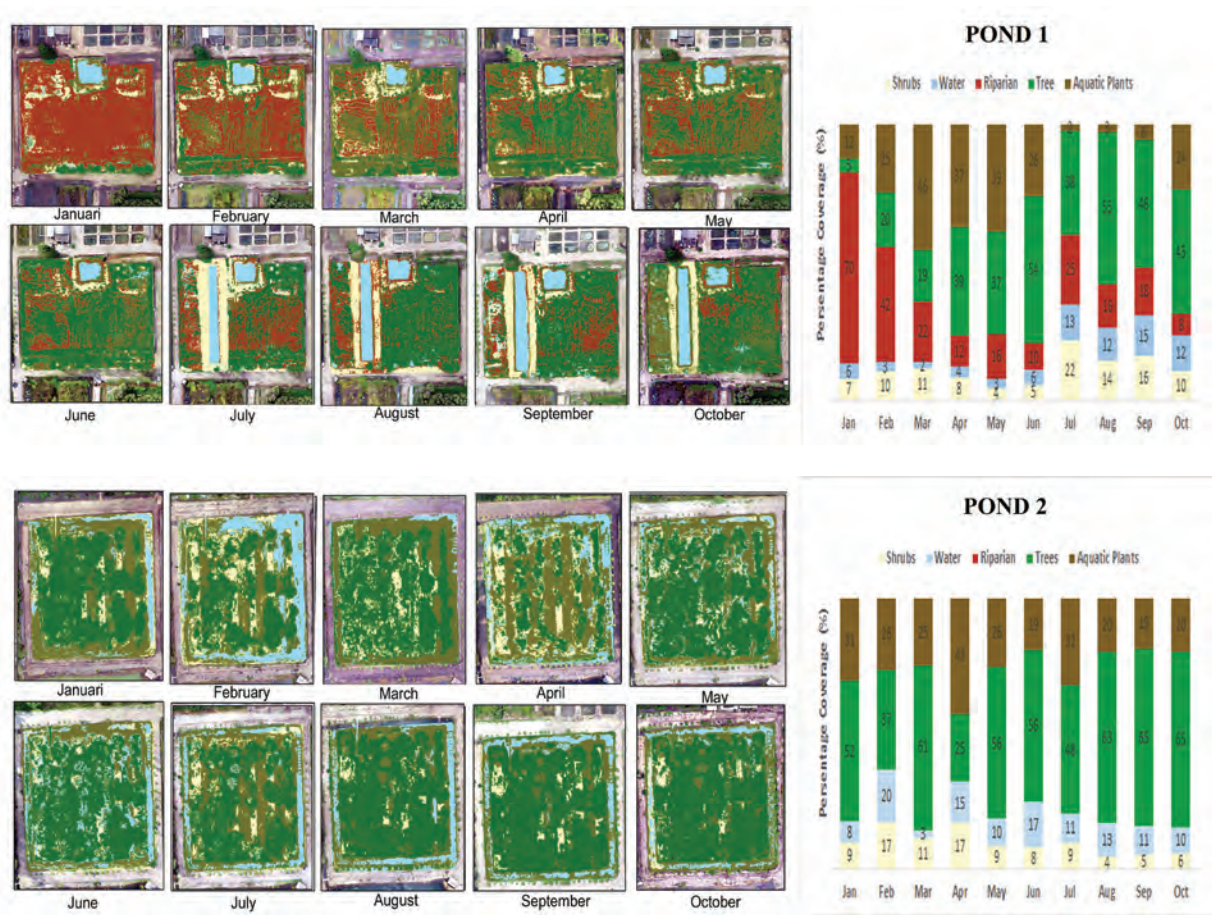

Figure 2. Land cover classification in SPEECTRA ponds in Patra Tani Village, South Sumatra Province, Indonesia observed from January to October 2022

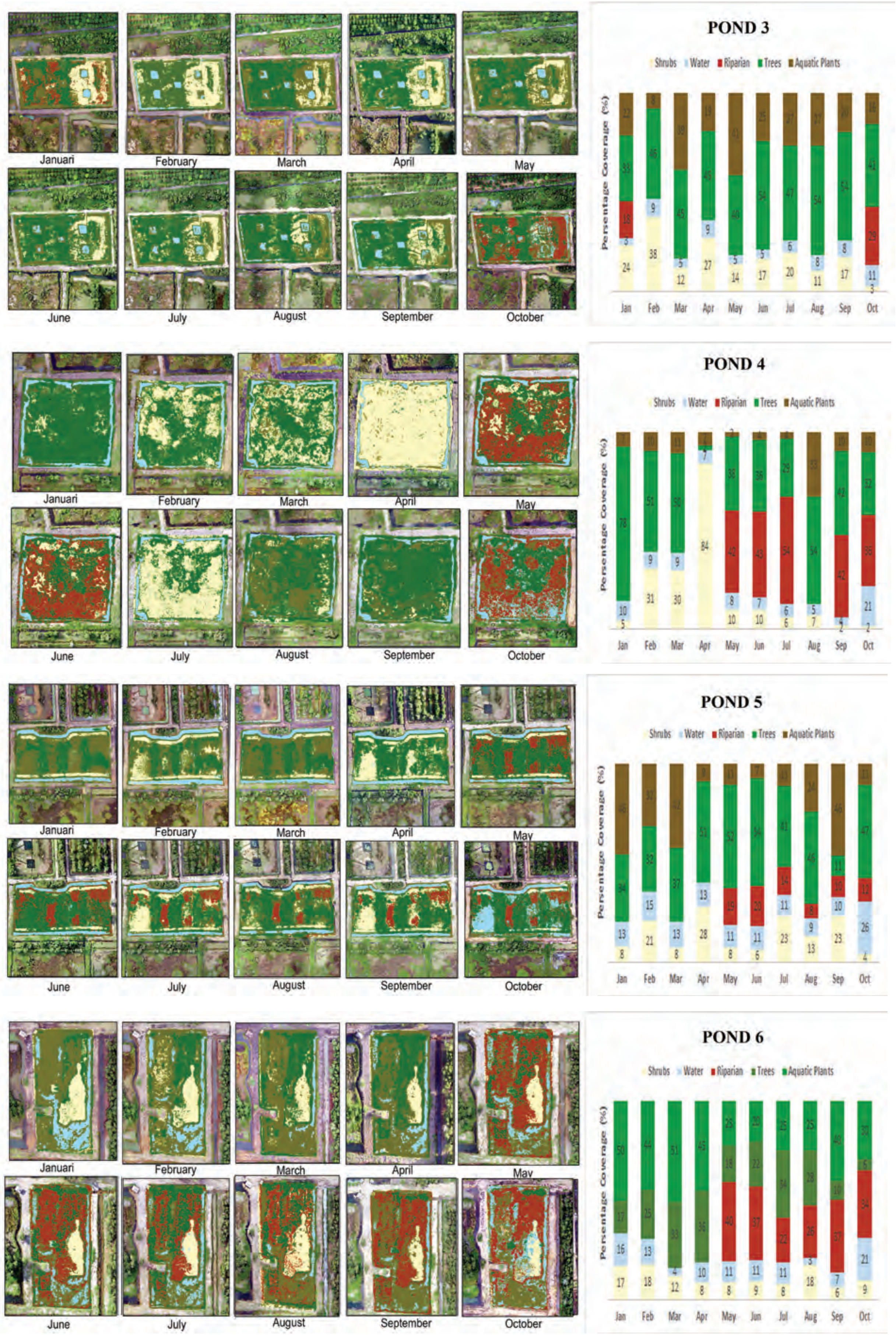

Figure 2. Land cover classification in SPEECTRA ponds in Patra Tani Village, South Sumatra Province, Indonesia observed from January to October 2022 *(Cont'd)*

However, if the growth of aquatic plants becomes too dense, it can lead to problems such as reduced oxygen level, increased sedimentation, and decreased light penetration, which can negatively impact other species in the pond.

A predominance of trees has been observed in **Pond 4** but there was a significant decrease in April. Shrubs increased dramatically from February to April but dropped significantly thereafter. In contrast, the abundance of shrubs increased dramatically from February to April but dropped significantly afterward. Riparian abundance increased from May to October suggesting that there may have been an increase in the number of plants and other vegetation in the area surrounding the pond during this time period. Riparian vegetation can be important for stabilizing the banks of the pond, filtering pollutants, and providing important habitats for a variety of plant and animal species. Overall, Pond 4 had a dynamic ecosystem where the abundance of trees, shrubs, and riparian vegetation fluctuated over time. It is possible that there are complex interactions between these different types of vegetation, and that changes in one type of plant made important implications for the others.

The agroforestry system was implemented in **Pond 5** where abundant trees and aquatic plants are a positive step towards sustainable land management. Agroforestry combines agricultural practices with cultivating trees and other vegetation to create a productive and ecologically balanced system. The abundance of trees and aquatic plants in Pond 5 indicates a diverse ecosystem, which can provide many benefits—trees provide shade, stabilize soil and contribute to nutrient cycling, while aquatic plants improve water quality, provide habitat for marine organisms, and reduce erosion. Combining these elements in an agroforestry system created a more resilient and productive environment. The recorded abundance of riparian from May to October indicated a thriving riparian zone during the wet season. The presence of abundant riparian vegetation indicated a healthy riparian ecosystem, which contributed to the overall ecological integrity of Pond 5.

In **Pond 6**, both riparian and aquatic plants had a significant presence. The riparian grew well during the rainy season from May to October as well as other vegetation surrounding the pond. Riparian can be important for stabilizing the banks of the pond, filtering pollutants, and providing important habitats for a variety of plant and animal species. Moreover, aquatic plants also had a significant cover in Pond 6, which provided a habitat for fish and other aquatic animals, helped to stabilize sediments, and maintained water quality by filtering pollutants.

Conclusion and Way Forward

Drones could be an effective tool for monitoring changes in land cover classifications in the SPEECTRA. The development of camera technology has made it possible to produce high-quality images to produce more robust algorithms for inland fisheries management. Accurate land cover maps provide adequate assistance for building the recommendations for managing aquatic resources in swamp areas. However, it is important to note that monitoring land cover change using drones should be conducted periodically in order to produce accurate and reliable data. Besides, the use of drones should also consider local regulations so as not to interfere with human activities.

Each of the SPEECTRA ponds has a unique ecological composition and dynamics that were influenced by various environmental factors such as water level, nutrient availability, and rainfall. In general, riparian and aquatic plants played important roles in stabilizing the banks of the pond, filtering pollutants, providing habitat for a variety of plant and animal species, and maintaining water quality. However, the excessive growth of aquatic plants made negative impacts on other species in the ponds. The presence of trees and other vegetation in the riparian zone also made important impacts on the ecology of the ponds and surrounding areas.

IFRDMD would continue the monitoring of land cover using drones in Patra Tani and other locations to produce high-resolution images and obtain higher-quality data. The data and information obtained would be used to support the proper management of inland fisheries in the countries in Southeast Asia.

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