Application of Remote Sensing in Mangroves at the Surrounding of Sungai Selangor Estuary in Kuala Selangor

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ABSTRACT

The mangrove forest ecosystem protects the land area from the tidal wave hence preventing the coastal areas and properties from severe damage. Mangroves provide valuable ecological services and goods, sediment retention, food sources of some animals, and stabilisation of the coastal areas. Unfortunately, the species have been experiencing an extensive loss in many parts of the world. This paper aims to detect the changes in mangrove forests and possible changes in the Selangor river basin area. The methodology uses remote sensing data via supervised classification on maximum likelihood algorithm to analyse the distribution of mangrove forests at the Selangor River basin for a thirty two-year period, from 1989 to 2021. The findings indicate that the percentage of mangroves in the study area has reduced over the study period. The coverage of mangroves has reduced from 24.29 percent (1989) to 15.57 percent in 2008, and continued to reduce to 13.12 percent in 2021. The research finding indicates a decrease in mangroves due to aquaculture, tourism, agriculture, and other human activities. Such a trend may risk coastal and river erosion, thus necessitating a revision of the management policies for environmental protection.

Keywords: mangrove, forest, remote sensing, Selangor river basin

INTRODUCTION

Mangroves are woody trees and large shrubs that emerge within the land and sea surface in tropical and subtropical areas. Mangrove forests are sheltered along with the coasts and estuaries complexes in the tropical and subtropical region. The type of species includes *Rhizophora, Avicennia, Bruguiera, Sonneratia* and *Xylocarpus* sp. in species-specific belts, depending on soil and inundation patterns (FAO, 1981). Acting as a natural filter, mangroves improve water quality by providing shelter for various aquatic life forms and acting as a significant carbon sink in the coastal ecosystem (Omar et al., 2018). Mangrove forests grow near large rivers that provide a lot of sediment from sand and mud. The Forestry Department Peninsular Malaysia, Forestry Department Sabah, and Forest Department of Sarawak reported that until 2008, the total forested area in Malaysia amounted to 19.52 million ha or about 59.5 percent of the total land area (Omar et al., 2012). The *World Atlas of Mangroves* estimates the global area of mangroves during 2000–2001 to be 152,361 km^2.

Several analyses have been performed on the mangrove forests in the local areas. Amran et al. (2020) found that the mangrove forests at Kuala Selangor Nature Park have become less or unhealthy in 2018. The study also notes that the distribution density of mangrove forests at Kuala Selangor Nature Park has changed over a year, leading towards deforestation. The rate of mangrove deforestation was about 0.1% per year between 1990 and 2017, and the changes were mainly located outside the Permanent Forest Reserve (Omar et al., 2018). However, in Tumpat, Satyanarayana (2011) discovered that the mangroves near the River Kelantan Delta have experienced significant changes as a result of human activity in 2006. Although the mangroves at Tumpat had a wide deltaic habitat with the size of 1200 hectares, they occupied only 339.6 hectares in that respective year (Mohd-Azhar, 2008, in

Satyanarayana et al. (2011). Kanniah et al. (2015) showed that the study in Iskandar Malaysia indicated a loss of 6740 ha of mangrove areas from 1989 to 2014.

It is crucial for mangroves to be monitored as they have become lost throughout the years in the world. However, monitoring mangroves using the conventional method would be costly as many of the areas are difficult to access, hence requiring more manpower. Thus, monitoring by using remote sensing technology would benefit many people, from the local community to the decision-makers. The recent trend of processing the satellite images of mangrove forests is to employ engineering and technology knowledge in performing the task. The use of innovations in remote sensing as a tool for monitoring mangroves has been extensively carried out. Landsat, which is freely available with moderate resolution data, has been deployed in many studies.

The analysis techniques adopted by previous researchers include the integration of Normalised Difference Water Index (NDWI) and Normalised Difference Vegetation Index (NDVI) with the topographic information (Alsaaideh et al., 2013). Another study employed the Normalised Difference Moisture Index (NDMI) derived from single date (cloud-free) or multi-date composites of Landsat sensor data (Otero et al., 2019). These researchers used Normalised Difference Vegetation Index (NDVI) techniques using Landsat (Amran et al., 2020; Sari & Rosalina, 2016), 2016), while another study (Akbar et al., 2020) used Sentinel-2. One more study used a mangrove recognition index (MRI) by using a model for both greenness vegetation index (GVI) and wetness index (WI), respectively (Zhang & Tian, 2013). Other researchers used supervised classification with maximum likelihood algorithm using Landsat data (Pathmanandakumar, 2019; Dan et al., 2016; Omar et al., 2018), Sentinel 2B (Chamberlain et al., 2020), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (Saito et al., 2003). A supervised classification using maximum likelihood classification was also conducted with the assistance of aerial photographs (Sulong et al., 2002; Van et al., 2015). Another study adopted remote sensing datasets (SPOT 4 and 5 imagery), object-based image analysis, and Support Vector Machine classifier (Pham et al., 2016).

A study of land cover changes is essential for monitoring the natural resources and mangrove area management. Thus, the current study seeks to analyse the mangrove area in the Selangor River Basin using three periods of images—1989, 2008, and 2021—using remote sensing and GIS technology.

STUDY AREA

This study focuses at the surrounding of estuary of Sungai Selangor, at the west direction of the State of Selangor. The coverage of study area includes Kuala Selangor Nature Park that has a mangrove forest (Fig. 1). The land cover types include forest, mangrove, river, agriculture, and built-up areas.

Sungai Selangor is also known as Selangor's primary water source, including the broad usage for the domestic sector, agricultural, industrial, and irrigation system. According to (Chowdhury et al., 2018), Sungai Selangor provides approximately 60% of the water consumed in Selangor and Kuala Lumpur (Subramaniam, 2004). Yet, an urbanisation process has left a disastrous impact on Sungai Selangor's water quality and related habitats; it has increased the number of factories, sewage treatment plants, wet markets, mining operations, and agriculture in the areas (Chowdhury et al., 2018). The Sungai Selangor basin has been increasingly polluted over the last decade due to increased urban, manufacturing, agricultural, commercial activities, and residential areas (Chowdhury et al., 2018). Such suggests that rapid urbanisation in the area of Sungai Selangor has wreaked havoc on the land cover, including the forest, mangroves, and river.

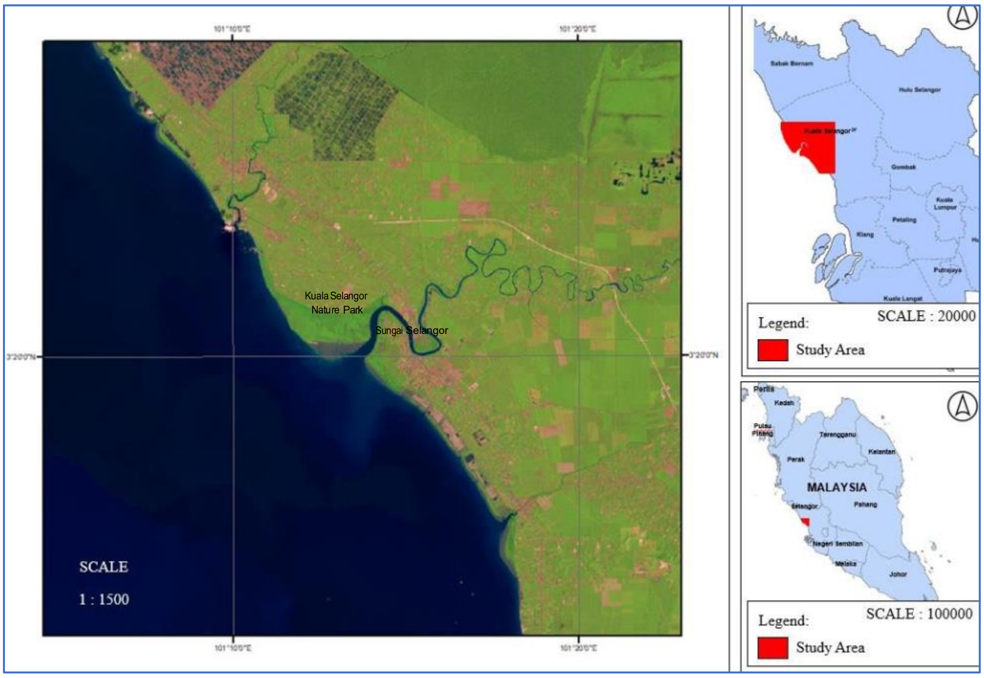

Figure 1: The study area at the estuary of Sungai Selangor, Kuala Selangor

Sungai Selangor's estuary has two permanent forest reserves, namely Banjar Utara (1,529.7 hectares) and Banjar Utara Tambahan (226.04 hectares). This area is also recognised as an Important Bird Areas (IBA) by the International Bird Society. Many migratory birds would stop at this place in their long journey from the northern hemisphere to the southern hemisphere. Kampung Kuantan, situated along the Selangor River, has its uniqueness with the existence of *Preroptyx tener* fireflies as a tourist attraction. The area has become the natural habitat for the firefly population due to the availability of mangrove trees (*Sonneratia caseolaris*). Fig. 2 shows the condition of the mangrove near the estuary of Sungai Selangor.

Figure 2: The condition of mangrove near the estuary of Sungai Selangor

METHODOLOGY

This research involved supervised classification using multi-temporal satellite data of Landsat 8 with WRS Path 127 and WRS Row 058. These images were acquired from the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The acquisition dates for Landsat Thematic Mapper (TM) 5 were 7 March 1989 and 24th March 2008, and for Landsat 8 OLI/TIRS was 29th March 2021. Only images without clouds were downloaded and used in this research. All the acquired images were for a period in March, representing the dry season in the region. This type of image was chosen because the products are freely available. Fig. 3 presents the flowchart of the analysis process.

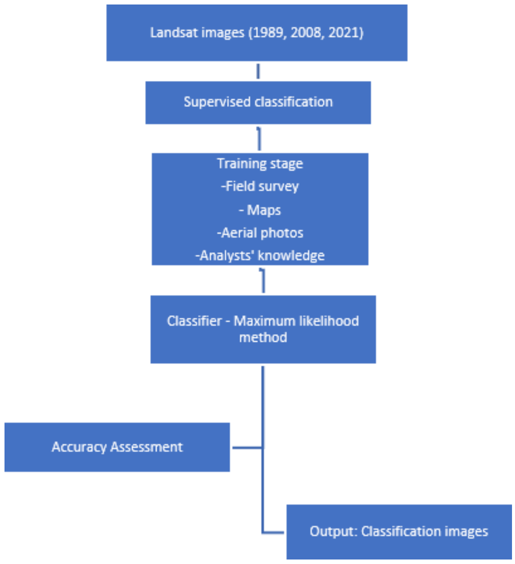

Figure 3: Flowchart of the study

The image was radiometric and geometrically corrected with the operation of the subset procedure as the process of "cropping" or cutting out a portion of an image. The digital numbers were converted to reflectance following the method provided in the NASA Landsat 7 Science Data Users Handbook. The land-cover map was produced by using the Supervised Classification. The images were categorised into six classes, including built-up areas, mangrove, palm oil/green, and water bodies. The Maximum Likelihood Classification rule requires the operator to have knowledge of the study area to enable efficiency in the choice of the representative training sets. Thus, ground-truthing and verification were needed in the process. The reference data used for the 1989 image was a topography map of Kuala Selangor that was produced in 1984. For the 2008 image, the reference data was the topography map produced in 2010, and for the 2021 image, the data reference used was that obtained from recent image of Google Map. The land cover was calibrated to ensure the appropriate accuracy is achieved. Accuracy assessment was critical for a land-cover classification to ensure the accurateness of the classification. Overall accuracy was derived from the error matrices. The land cover classification is presented in Table 1.

Table 1: The land cover categories along with the description

Code	Land cover category	Description
1	Waterbodies	Consist of water bodies includes streams, rivers or pond
2	Built-up area	Consist of built up areas, roads, bare lands
3	Mangrove	Consist of mangrove area
4	Palm Oil/Green	Consists of any greeneries and vegetation areas
5	Aquaculture	Consists of the aquaculture area

ANALYSIS

The accuracy assessment indicates the appropriate accuracy needed for the analysis (Table 2). This process was able to estimate the accuracy of the land-cover data. The total accuracy assessment for each image confirmed that all images meet the requirement for the analysis.

Table 2: The class name, producers accuracy (%) and user accuracy (%)

Class name	Producers accuracy (%)	Users accuracy (%)
Landsat TM (1989)		
Waterbodies	98%	98%
Built-up area	95%	95%
Mangrove	96%	96%
Palm Oil/Green	90%	90%
Aquaculture	-	-
Average accuracy	95%	95%
Landsat TM (2008)		
Waterbodies	93%	95%
Built-up area	90%	89%
Mangrove	93%	94%
Palm Oil/Green	91%	90%
Aquaculture	86%	90%
Average Accuracy	91%	92%
Landsat 8 OLI/TIRS (2021)		
Waterbodies	75%	75%
Built-up area	91%	88%
Mangrove	85%	90%
Palm Oil/Green	86%	87%
Aquaculture	70%	70%
Average Accuracy	81%	82%

This study applied supervised classification of Landsat images to analyse the existing condition of the mangrove areas near the estuary of Sungai Selangor, Kuala Selangor for three particular images: 1989, 2008, and 2021 (Figure 4). These images clearly show the changes in the analysed landcover.

A comparison of the classified imageries for the study period showed notable evolvement. The first image taken in 1989 shows that the whole stretch of the coastal areas was filled with mangroves. Some scattered mangroves can also be seen in the northern part of the study area. The mangrove areas spanned 2693.34 hectares or 24.29 percent (Table 1). While no aquaculture was observed in 1989, such can be seen along the coastal stretches in 2008, replacing the mangrove area in the earlier image (1989).

In the image of 2021, the aquaculture industry (mainly shrimp and fishing ponds) can still be seen. Cross-checking was performed against a google map image (Figure 5), which extended until the estuary of Sungai Buloh (which had replaced the mangroves in that area). The finding indicates that the extensive decrease in mangroves in the span of thirty years was due to aquaculture, tourism, agriculture, and other human activities. An aquaculture area was detected along the coastal area (Fig. 4). The built-up area at Bandar Melawati seems to have its edge in the 1989 image. The built-up area at Pasir Penambang, however, was surrounded by palm-oil trees. Table 3 shows that the built-up area, which spans 826.11 ha, was 7.45 percent in 1989 but doubled to 1533.24 hectares (13.85 percent) in 2008. In 2008, the pattern of the built-up area was elongated following the road at the southern part of the study area. The calculated waterbodies area, including the part of the coastal areas and its diameter and width, is most likely similar to the earlier image.

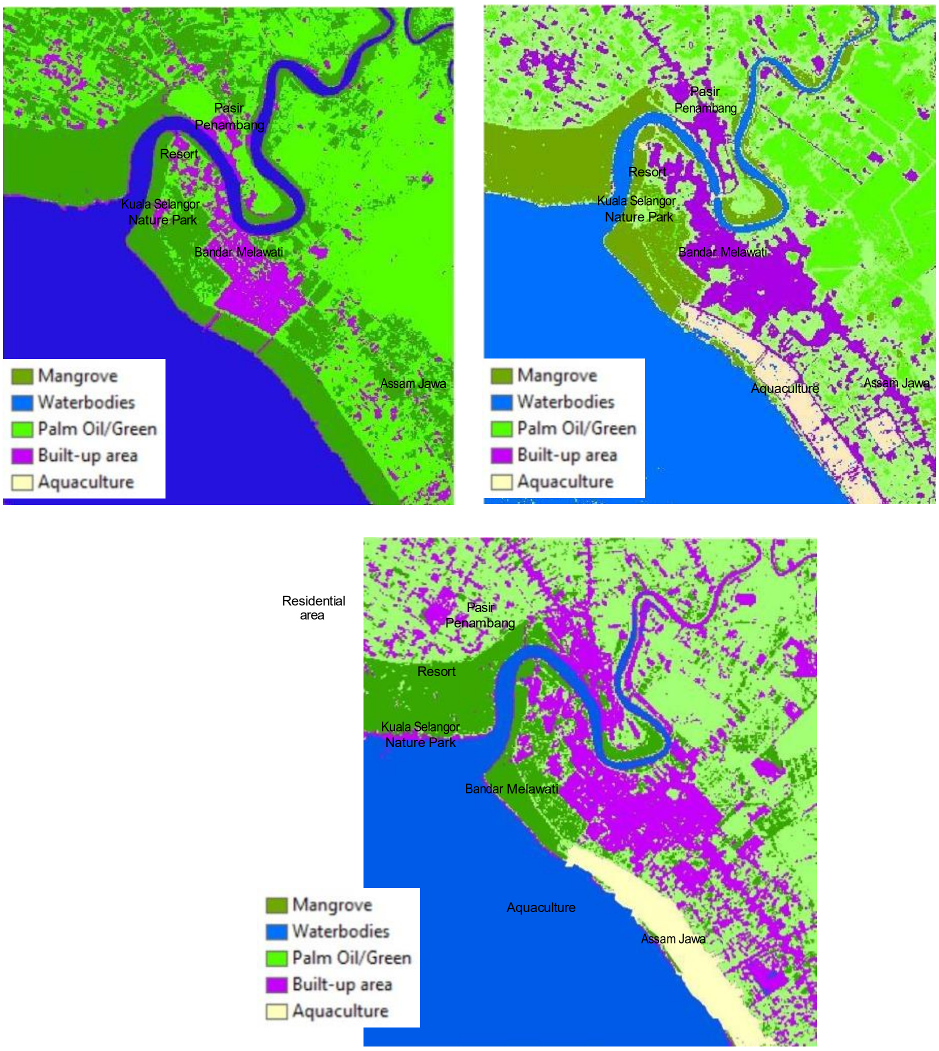

Figure 4: Images for Landsat 8 in 1989 (left), 2008 (right) and 2021 (below)

Figure 5: The condition of shrimp and fishing ponds at Assam Jawa (Source: Google Map, 2021)

Table 3: The land cover calculation in the study area

	1989	%	2008	%	2021	%
Mangrove	2693.34	24.29	1726.57	15.57	1454.62	13.12
Waterbodies	3949.11	35.61	4016.07	36.22	3748.99	33.81
Built-up area	826.11	7.45	1533.24	13.83	1854.26	16.72
Palm Oil/Green	3620.34	32.65	3093.21	27.89	3526.06	31.80
Aquaculture	0	0	719.82	6.49	505.042	4.55
Total	11088.90	100.00	11088.90	100.00	11088.90	100.00

It is evident from the above discussion that over time, the loss of mangrove areas has significantly occurred to fit developments. The encroachment of developments into the mangrove areas has resulted in many adverse environmental and social implications. Such a scenario should be controlled by both soft and hard approaches. The latter should involve physical and infrastructural works in the affected areas, such as replanting the mangrove trees. The soft approach is more relevant for long-term planning. It includes providing development policies for mangrove protection by having setbacks along the mangrove strips. The Development Plans (DP), as required by Town and Country Planning Act 1976 (Act 172), outline the planning of mangrove conservation as part of the Environmental Sensitive Area (ESA). In the forms of planning guidelines, development strategy, policies, and even development proposals can facilitate the relevant agencies in the implementation stage. The usefulness of DP in prescribing future planning to other implementing agencies, such as the Department of Forestry and Department of Irrigation and Drainage, has marked good achievement in mangrove protection efforts. Such contemporary direction indicates the relevance of the Sustainable Development Goal in the making of a DP to replicate the global action into the local action.

DISCUSSION

The coverage of mangrove has reduced from 24.29 percent (1989) to 15.57 percent in 2008, and will continue to be reduced to 13.12 percent in 2021. The finding of this research shows the extensive reduced coverage of mangroves in the estuary of Selangor River. The findings correspond to a previous study (Amran et al., 2020), which find that the decreasing mangrove species in a similar site had led to deforestation and the decline of the mangroves' health annually. Human activities were found to be the main reason for the reduction of the mangroves in the area. The changes were mainly attributed to the expansion of aquaculture as a major cause of direct loss of mangrove ecosystems. In the similar site as well, Hasyim et al. (2019) had mentioned that the decreasing of mangrove area is due to illegal land clearing mainly for oil palm plantation.

The research in Iskandar Malaysia found that mangrove areas had decreased at an alarming rate (33%) from 1989 to 2014 mainly due to development of the coastal region intensified erosion, local hydrodynamic conditions, and development of aquaculture activities (Kanniah et al., 2015). A similar scenario also happened in Tumpat, near River Kelantan Delta, which experienced significant changes as a result of human activity (Satyanarayana, 2011).

The destruction of mangroves needs to be controlled for the sustenance of the local communities. Local communities are highly dependent on the mangrove ecosystems, particularly for food resources, firewood, charcoal, and timber, among others (Zaiton et al., 2019). Programmes including mangrove conservation, as well as improvement of the policies of mangrove protection, would benefit both the human and environment for sustainability.

CONCLUSION

This research successfully applied to extract mangrove forests based on the reflectance values and spectral properties of mangrove forests in the images. The accuracy assessment shows satisfactory agreement for the analysis. This research identified a reduction in the coverage of mangroves in the estuary of Selangor river. Stern action is necessitated to ensure that mangroves are protected in the area. The contributed factors include aquaculture, tourism, agriculture, and other human activities.

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