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DETERMINATION OF LAND USE AND LAND COVER CHANGE IN FIREFLY ECOTOURISM AREAS USING LANDSAT IMAGES: A CASE STUDY OF SUNGAI SEPETANG, PERAK

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ABSTRACT

Changes in land use and land cover (LULC) are a method that facilitates the understanding of the physical and human interactions within the natural environment, thereby promoting sustainable development. The objective of this study was to determine the changes in LULC surrounding the firefly ecotourism area in Sepetang River, Perak, from 2002 to 2020. This was accomplished by utilising Landsat multitemporal satellite images and identifying the factors that influence the changes in the mangrove area. The LULC modifications were determined using the maximum likelihood classifier technique. In 2002 and 2020, the classification accuracy of LULC was 82.4% and 81.2%, respectively, with Kappa statistics of 0.81 and 0.80. The results showed a 22.06% decrease (122.52 hectares) and a 4.47% increase (24.99 hectares) in mangrove areas. The mangrove areas were converted to a variety of land uses, such as oil palm (32.7%), forests (32.3%), *settlements (9.25%), barren land (8.99%), rivers (6.8%), swamp (6.11%), urban (1.67%), paddy (1.25%), water bodies (0.77%), and road (0.09%). The total area of mangroves that were lost over the course of 18 years was 317.21 hectares, while the area of mangroves that were rehabilitated was 23.05 hectares. The results of this study demonstrate that the integration of remote sensing technologies will be advantageous for the monitoring and conservation of the firefly population in mangrove habitats.*

Keywords: *Land use Land cover (LULC), Landsat images, Mangrove, Firefly ecotourism*

INTRODUCTION

Ecotourism, which includes firefly ecotourism, is one of the prospective contributors to the gross domestic product of Malaysia (Bhuiyan et al. 2015). The percentage of tourism revenue in relation to Malaysia's gross domestic product (GDP) raised from 5.1% in 2002 to 15.8% in 2020, as per Tourism Malaysia (2020). Fireflies are a popular attraction for eco-tourism in a specific region, attracting a significant number of visitors to observe them in their natural environment (Idris et al. 2021). The fireflies' preferred habitat is the Berembang tree (Sonneratia caseolaris) (Norela et al. 2016). Fireflies are essential species in mangrove regions and play a critical role in the global maintenance of ecosystem balance (Nallakumar, 2003; Dawood and Saikim, 2016).

Fireflies are frequently observed in brackish water environments, estuaries, wetlands, and mangroves (Lewis et al. 2024). The firefly population is at risk due to the 42% decrease in the number of trees that sustain fireflies because of the riverbank cleaning (Nadirah et al. 2020). The number of fireflies inhabiting the riverine mangroves of Peninsular Malaysia has been observed to decrease progressively over time because of an increase in anthropogenic activities that induce habitat degradation and firefly devastation (Jusoh et al. 2018; Idris et al. 2022). Consequently, the potential economic advantage of firefly ecotourism for the local community will be impacted by unrestrained hazards, as evidenced by the cases of Kuala Selangor (Khoo et al. 2009), Rembau-Linggi (Jusoh 2014), and Sepetang (Jusoh 2010).

Globally, mangroves have been endangered because of the growing pressure on LULC. Jusoh (2014) reported that the reduction in firefly populations over time is linked to land use changes. In addition, the movement of high-powered vessels used to convey mangrove trunks was observed at Sepetang River, resulting in surges that affected the river shorelines. The firefly ecotourism activity at Sepetang River is also at risk due to changes in the surrounding environment and uncontrolled activities, which are affecting the diversity, abundance, and distribution of fireflies. It has become imperative to possess knowledge of LULC modifications to resolve issues.

A powerful tool for mapping and understanding LULC changes is remote sensing and Geographic Information Systems (GIS), which provide general extensive synoptic coverage of huge areas (Nino et al. 2017; Perera et al. 2011; Taylor et al. 2007; Wong & Fung 2016). Satellite images with a variety of spatial resolutions can be utilised to effectively monitor an extensive region (Tewodros et al. 2010). This technology was capable of aiding in the monitoring of mangrove habitats and the factors that influence the ecosystem. However, these studies have limitations and should be improved to understand better factors affect the population abundance of these fireflies using land use spatial analysis satellite image. For example, based on the findings of previous studies, many studies focus on abiotic and biotic factors influencing firefly population abundance in Southeast Asia mangrove.

Therefore, in this paper, a multi-temporal Landsat satellite image dataset was analysed to determine the factors that influence the change in mangrove vegetation cover and LULC in the firefly ecotourism area in Sepetang River, Perak. The research objectives consist of two primary objectives: the first is to evaluate the impact of LULC changes within the study area over the past 18 years (2002-2020), and the second is to identify the factors that influence changes in the mangrove areas surrounding the firefly ecotourism site.

RESEARCH METHODOLOGY

Study Area

The Sepetang River, which is in or near the town of Taiping in Perak, extends from 1º14.04’ to 7º48.92 N latitude and 102º5.03’ to 105º48.77’ E longitude (as illustrated in Figure 1). This river is a typical example of a riverine mangrove ecosystem in Peninsular Malaysia, flowing through Kampung Dew in Taiping, Perak. A portion of the local population along the Sepetang River is involved in fishing activities, while others engage in tourism activities, such as observing fireflies. In addition, various inhabitants lease their boats to anglers. The firefly-watching boat excursions are particularly noteworthy for their synchronised flashing lights, which provide a unique experience.

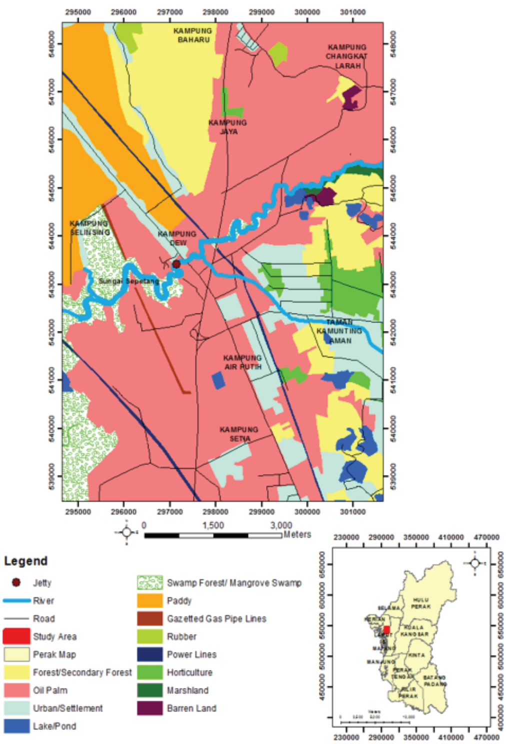

Figure 1. Map of Sepetang River, Perak

Source: Author

Satellite Data

Satellite imagery from the United States Geological Survey (USGS) website was used for this study, including Landsat 7 Enhanced Thematic Mapper Plus (ETM+) from 2002 and Landsat 8 Operational Land Imagery (OLI) from 2020. Eight spectral bands with a spatial resolution of 30 meters constitute the Landsat 7 ETM+ imagery, while nine spectral bands with a similar spatial resolution, except for band eight, comprise the Landsat 8 (OLI) imagery. The panchromatic band, which is typically located within the optical and near infrared wavelength range, is characterised by a 15-meter spatial resolution in both ETM+ and OLI. Erdas Imagine 2011 software and ArcView/ArcGIS Software 10 were employed to process the satellite images.

Data Analysis

Satellite images were used to identify the LULC type that surrounded Sepetang River, Perak, from 2002 to 2020. The study area was subset from Landsat images. The World Geodetic System (WGS-84) coordinate system was used to georeferenced and preprocess the satellite images. Figure 2 outlines the steps and methods used in this study. The images were subjected to unsupervised classification, which involves the collection of pixels into a specific spectrum of classes in natural clustering without the initial knowledge of the topography and land use pattern in the area. The spectral classes were used to derive a total of 13 land use classes, which were horticulture, mangrove, river, water body, road, settlement, paddy, oil palm, and urban (Table 1).

Table 1. A Description of the LULC Classes in the Catchment Area of the Sepetang River in Perak

Class name	Description
Mangrove	Refer to areas that are covered by vegetation such as trees or shrubs.
Forest	Refers to an expanse of land that is covered by trees.
Oil palm	The oil palm trees are situated inside a region of desolate ground.
Paddy	Paddy fields are places in which semi aquatic plants, such as rice can be grown.
Settlement	Encompasses domiciliary zones, hamlets, or agglomerations of dwellings in thinly inhabited areas.
Urban	Consisting of industrial, commercial, and administrative sectors.

Barren land	Barren rocks, sand, or bare soil collectively encompassing a certain geographical region.
Swamp	The predominant vegetation in low-lying regions next to river channels consists mostly of grasses.
Horticulture	Includes areas dedicated to the growth of flowers and fruits, such as orchards and nurseries.
Road	Encompasses both streets and highways.
River	A continuous flow of water moving via a specifically designated pathway.
Waterbody	Includes agricultural land, wastewater treatment ponds, and bodies of water.

Source: Author

The image was subsequently classified using a set of spectral signatures that were defined by the user. Ground truth data were used to support the classification process in order to help with the supervised classification. Supervised classification was then performed on the image. The Global Positioning System (GPS) was used to acquire the ground truth data. The supervised classification is conducted by combining the spectral property of the training sets, previous information, and data from field observation.

The procedure of overlaying satellite images is important for the detection of changes in the LULC using Erdas Imagine 2014. Change detection were identified by superimposing classified images from 2002 and 2020 through pixel-by-pixel mathematical combinations. The detection of changes was used to assess mangrove changes from the two images based on the land use and land cover maps. The accuracy assessment was further adopted to validate the supervised classification. The formula below was employed to determine Kappa:

$$K\hat{} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} * x_{+i})}$$

Where "K" represents the Kappa statistics, "N" represents the total number of observations, "r" represents the number of rows in the matrix, "xii" represents the number of observations in row i and column i, and "xi+" and "x+I" represent the marginal number of row i and column i, respectively (Congalton 1991).

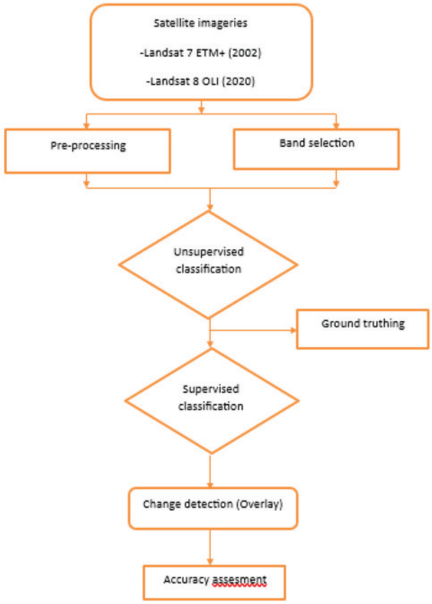

Figure 2. Flowchart of Research Methodology

RESULTS AND DISCUSSION

The land use land cover (LULC) around Sepetang River in Perak was analysed for the years 2002 and 2020, as shown in Figure 2a and 2b, respectively. According to the data shown in Figure 2a, the dominant LULC in the region in 2002 was oil palm, covering an area of 3546.87 hectares. On the other hand, the lowest LULC area was urban, which occupied just 24.70 hectares. The river downstream had the most extensive oil palm cultivation, while tiny urban settlements were identified in the northeast. However, according to the data shown in Figure 2b, the oil palm plantation had the biggest area in 2020, covering 3988.93 hectares. This plantation was mostly concentrated in the northeast and southern region, while a smaller amount of 30.69 hectares was occupied by roads in the northern and south region. The overall accuracy evaluation of the LULC map for the year 2002 yielded a score of 82.4%, while the map for the year 2020 achieved a score of 81.2%. The Kappa values for the two maps were 0.81 and 0.80, respectively (Table 2). Therefore, it is presumed that the categorization has been executed enough to evaluate the temporal variations in LULC around Sepetang River, Perak.

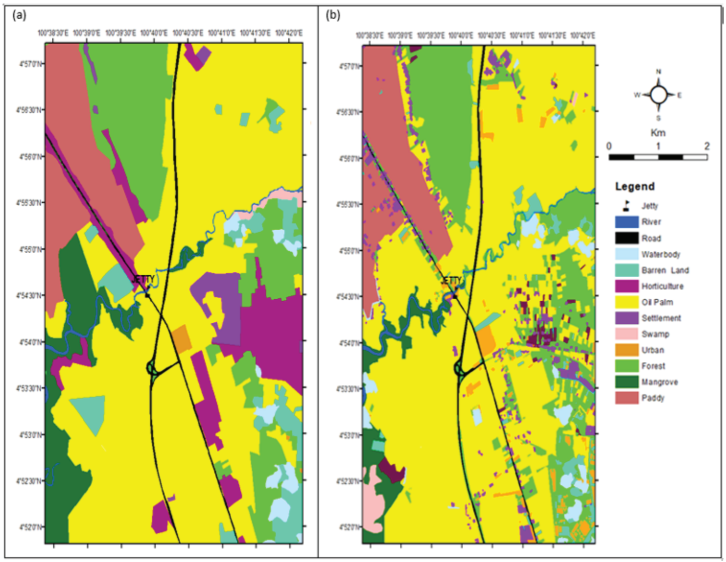

Figure 2. The Classification of Land Use and Land Cover (LULC) in the Sepetang River, Perak Watershed Area for the Years (a) 2002 and (b) 2020

Source: Author

Table 2. Assessment of Accuracy based on the Classification of Land Use and Land Cover in the 2002 and 2020 Images

Land use/ land cover	**2002**		**2020**	
	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)	User accuracy (%)
Barren Land	100	100	100	100
Oil Palm	100	100	100	100
Horticulture	100	100	100	100
Mangrove	100	100	100	100
Forest	100	100	100	80
River	100	100	100	100
Road	100	100	100	100
Paddy	87	100	88	100
Settlement	100	89	100	90
Swamp	80	100	100	86
Urban	100	78	90	100

Waterbody	100	100	100	100
Overall accuracy (%)	82.4		81.2	
Kappa coefficient (%)	0.81		0.80	

Source: Author

During the period from 2002 to 2020 (Table 3), LULC that indicated increase in area were swamp 27.94 ha (83.25%), forest 278.22 ha (25.35%), water body 14.15 ha (11.80%), road 60.81 ha (75.26%), settlement 11.16 ha (7.6%), urban 14.8 ha (59.96%) and oil palm 442.06 ha (12.46%). The most LULC change from 2002-2020 was detected from oil palm while the least change detected was from road. The increase of oil palm was observed at the southwest part. On the other hand, LULC that indicated decrease in area was barren land 105.58 ha (33.23%), horticulture 534.8 ha (87.12%), paddy 11.67 ha (1.77%), river 1.45 ha (4.51%) and mangrove 295.65 ha (59.46%). Horticulture showed the highest decrease in area and the least was river. The decrease of horticulture was found at the southeast of the study area. The invasion of this area is due to clearing of land which is basically due to reclamation activities. Clearing land from mangroves for plantation will affect the diversity of plant life associated with mangroves.

Table 3. Assessment of Accuracy based on the Classification of Land Use and Land Cover in the 2002 and 2020 Images

Land Use Land Cover	2002	2020	Area changes	% of Change
Barren Land	317.76	212.17	105.58 (-)	33.23 (-)
Swamp	33.56	61.50	27.94 (+)	83.25 (+)
Forest	1097.41	1375.63	278.22 (+)	25.35 (+)
Water body	119.89	134.04	14.15 (+)	11.80 (+)
Horticulture	613.84	79.04	534.80 (-)	87.12 (-)
Paddy	658.24	646.57	11.67 (-)	1.77 (-)
Mangrove	497.26	201.61	295.65 (-)	59.46 (-)
River	32.14	30.69	1.45 (-)	4.51 (-)
Road	80.80	141.61	60.81 (+)	75.26 (+)
Settlement	146.93	158.09	11.16 (+)	7.60 (+)
Oil Palm	3546.87	3988.93	442.06 (+)	12.46 (+)
Urban	24.70	39.51	14.80 (+)	59.96 (+)

Source: Author

The changes of mangrove forest varied in a particularly spatial pattern over the district. This can be seen in (Figure 3) that mangroves on the upstream of the river mostly disappeared but at the central part of the study area increased. The remaining mangrove was observed along the downstream riverbank. Mangrove increase in area was from barren land at (0.50 ha), oil palm (17.61 ha), river (0.77 ha), horticulture (3.89 ha) and forest (0.28 ha). Figure 4 shows LULC changes that decreased in the mangrove area from 2002 to 2020. Mangrove indicated decrease in area as a result of conversion the most to oil palm (32.7%), swamp (6.11%), horticulture (3.98%), water body (0.77%), forest (32.3%), barren land (8.99%), river (6.8%), paddy (1.25%), road (0.09%) and urban (1.67%) respectively.

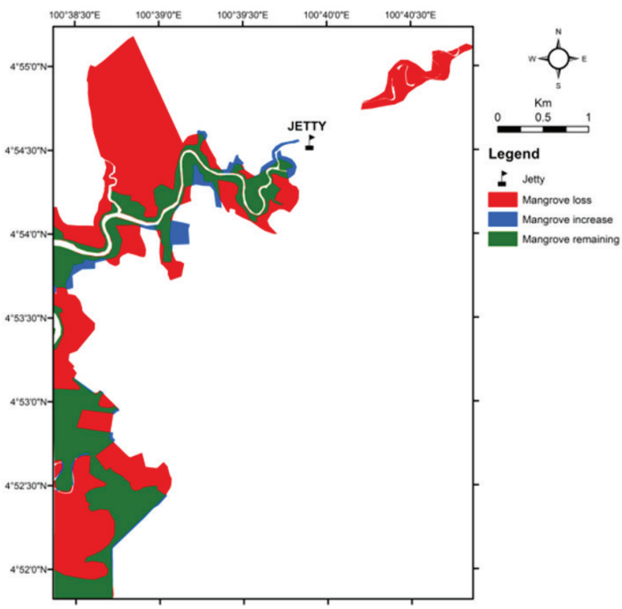

Figure 3. The Distribution of Mangrove Area at Sepetang River, Perak has Undergone Significant Changes from 2002 to 2020. Blue Represents an Increase in Mangroves, while Red Represents a Decline in Mangroves and Dark Green Represents the Remaining Mangroves.

Source: Author

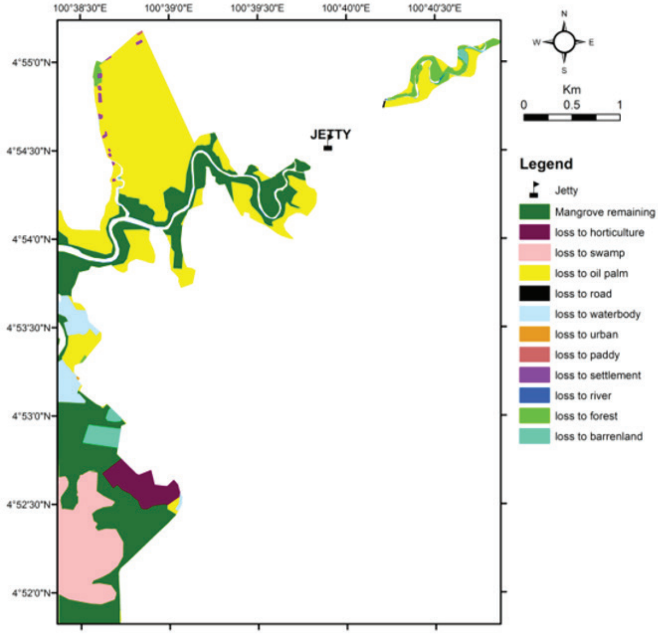

Figure 4. The Conversion of the Mangrove Area to other LULC at the Sepetang River in Perak from 2002 to 2020. The Deforestation of Mangroves is Classified into 11 Classes: Loss to Horticulture, Loss to Swamp, Loss to Oil Palm, Loss to Road, Loss to Waterbody, Loss to Urban, Loss to Paddy, Loss to Settlement, Loss to River, Loss to Forest, and Loss to Barren Land
Source: Author

Over a span of 18 years, a total of 497.25 hectares of mangrove forest have been depleted. According to a prior study conducted by Hazmi et al. (2018), fireflies in the region exhibit a high degree of sensitivity towards changes in their habitat's environmental conditions. The presence of fireflies is influenced by the discharge from the charcoal business, oil palm plantation, and shrimp aquaculture. The discharge from the charcoal factory, which includes a significant amount of organic matter, is immediately released into the river. It is crucial to monitor these actions to preserve the mangrove environment. Mangrove conservation is crucial not only for protecting the mangrove ecosystem, but also for securing the availability of mangrove resources for future use in response to environmental changes (Ramli et al., 2023). Precautions should be used to protect the mangrove ecosystem, together with educational programs aimed at raising awareness among the populations living in the vicinity of the mangrove region.

It is crucial to map the transformation of mangrove forests to other land used to identify the hazards to the ecosystem in the region (Figure 4). Encroachment was the cause of the conversion of the mangrove area to oil palm. The analysis revealed that the firefly population is at risk due to the disturbance and destruction of their natural habitat because of the conversion of the mangrove forest to oil palm. Encroachment was identified as the primary cause of mangrove deforestation in Sepetang River, which was subsequently converted to an oil palm plantation (Ibrahim, 2015). Additionally, it has been reported that prawn aquaculture was the cause of the conversion of mangrove forests. Shrimp aquaculture is also linked to the devastation of natural habitats by directly converting mangroves into conversion ponds. Mangrove casualties in Malaysia were previously reported to be the result of land use conversion for agriculture, aquaculture, and urban development, as per FAO (2007). The extinction of fireflies in Thailand is believed to be a consequence of the limited range of firefly dissemination, which is exacerbated by habitat disturbance and destruction (Arunyawat, 2017).

Over an 18-year period, most mangrove areas were converted to agriculture, with an emphasis on oil palm. This suggests that oil palm is a significant contributor to the economic resources of the region (Jusoh and Hashim, 2012). Also, the oil palm plantation was situated inland, adjacent to the mangrove trees that were situated along the riverbank in the upstream and middle streams of the river, near the firefly display trees. Due to the ongoing economic transition in this research region, it is likely that the conversion of mangroves to oil palm will continue to displace significant portions of mangrove forests in the future. The alterations in the studied region were a result of encroachment into the buffer zone of the mangrove area.

The conversion of the mangrove into an oil palm plantation disrupts the display of fireflies on the trees near the beach. The reduction in mangrove acreage may be a contributing factor to the decrease of firefly habitat. The eventual influence of oil palm plantations on this genus will result in a future decline of mangroves. The firefly population in Malaysia has dropped because there is less habitat available for the firefly larvae and the snails, they rely on for survival along the mangrove riverbank. The host snail and larvae mostly reside in the riverfront vegetation located behind the show tree and are seldom seen in the region that has been transformed for oil palm cultivation. Consequently, this disturbance to their environment is likely to pose a threat to the firefly population.

The alteration of mangroves to other land use and land cover (LULC) types in this research is attributed to the displacement produced by the passage of speedboats, leading to riverbank erosion and the subsequent uprooting of prominent trees. Riverbank erosion may have been induced by powerful currents and high river flow rates originating downstream and moving towards the riverbank. Speedboats traverse the rivers, generating water surges that gradually erode the riverbanks, resulting in the demise of the trees that serve as habitats for the firefly. The collapse of the mangrove forest is thought to have been caused by powerful water currents that sped up the erosion of the riverbank. This leads to the reduction of mangrove forests, since it changes the placement of the mangrove border, moving it away from its original position, which might impact the structure of riverbanks.

Nevertheless, swamps did not significantly influence the alterations seen in the mangroves within this research region. The presence of wetlands in the mangrove region was attributed to the influx of freshwater caused by intense rains. Flooding causes changes in salt levels, which impact the physiological processes of mangrove plants and have consequences for the firefly population. The mangrove aerial root exhibits sensitivity to prolonged periods of inundation. Firefly populations are under risk from both drought and floods. Fireflies are susceptible to drought due to their limited distribution and specific habitat preferences, indicating a potential hazard to their population. Fireflies need wet conditions to live throughout their life cycle, hence prolonged periods of dryness may pose a hazard to the rich variety of fireflies, leading to their death either by direct means or by depleting the food supplies available to them (Idris et al.2022).

The conversion of mangrove areas into water bodies leads to water pollution when garbage is released into the environment. Livestock waste contributes to pollution in the riverbank mangrove region, and the high concentration of nutrients from food and animal waste may lead to eutrophication. The decline in river water quality compels the fireflies to either move or dwindle in numbers (Jusoh et al. 2007). The direct disposal of livestock manure into the river has a detrimental impact on the environment of the firefly habitat. Fireflies may experience significant injury from inadequate water and soil conditions, since their larval stage resides and develops for an extended period either submerged in water, inside soil, or among mangrove roots and plants near adult display trees. Therefore, the larvae of fireflies may meet water contaminants. Polluted water may disrupt the osmoregulation mechanism of insects in their larval stage. This leads to a decrease in the population of mature fireflies (Norela et al. 2016).

The transformation of mangroves into dry land forest occurred due to the anticipated implementation of agricultural operations that ultimately did not come to fruition. Therefore, the mangroves along the riverside were cleared, leading to the destruction of the trees that fireflies utilize for mating displays. These factors may contribute to the decline of Berembang trees throughout time. The mature fireflies congregate each night to engage in a ritualistic display of courting on certain, conspicuous trees situated among mangrove waterways. Nevertheless, a significant number of these exhibition trees have been eliminated. Once biodiversity is lost, it is irretrievable, and the species inhabiting the mangrove forest will be impacted. The loss of mangroves leads to a decrease in the overall functioning of the ecosystem and, as a result, reduces its ability to deliver goods and services to the populations living in these ecosystems.

Hence, it is important to implement management alternatives and methods to safeguard the mangrove habitats from the adverse effects of land use and land cover changes (LULC impacts). Stringent implementation of laws is needed to effectively govern the mangrove region and sustain the long-term viability of the mangrove forests. This is crucial for maintaining the region as a sought-after location for firefly ecotourism. The habitats of fireflies were endangered due to changes in the surrounding ecosystem and the unregulated repercussions of human actions. To preserve the natural ecosystem and avoid future reclamation areas, conservation and management initiatives should include alternative ways to sustainable mangrove land-use systems.

CONCLUSION

Therefore, the overall LULC change over the 18-year study period led to a 22.06% decrease and a 4.47% increase in mangrove area. The mangrove area was converted to oil palm plantations (32.7%), forest (32.3%), settlements (9.25%), barren land (8.99%), river (6.8%), swamp (6.11%), urban (1.67%), paddy (1.25%), water body (0.77%) and road (0.09%). This study demonstrated the potential of remote sensing and GIS to map changes in land use and land cover, as well as the area of mangroves. It is beneficial to furnish information regarding mangroves as a natural habitat for fireflies. This research is important for the survival of fireflies, as it seeks to protect their habitats from further degradation, thereby facilitating sustainable conservation efforts that promote firefly ecotourism in the region. The study of regions that are otherwise inaccessible is made possible using satellite imagery, which provides spatial and temporal advantages in mangrove research and facilitates the monitoring of the mangrove ecosystem. Consequently, stakeholders should implement stringent measures and implement good practice management to protect the firefly ecotourism area, based on these discoveries.

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AUTHOR CONTRIBUTIONS

All authors contributed to the design of the research, and the write-up, data cleaning and tabulation undertaken.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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