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Monitoring the Land Cover Changes in Mangrove Areas and Urbanization using Normalized Difference Vegetation Index and Normalized Difference Built-up Index in Krabi Estuary Wetland, Krabi Province, Thailand

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Abstract

Krabi Estuary Wetland (KEW) is an outstanding wetland with an estuary environment. At present, the tourism industry has rapidly grown, resulting in the impact of land cover changes. This research aims to assess the changes that have occurred in the KEW from 1999 to 2020 using NDVI and NDBI for monitoring changes in mangrove areas and urbanization in Krabi Province, Thailand. Landsat satellite images in years 1999, 2009 and 2020 were classified by using a band ratio to create land cover maps. The results show that NDVI between 0.41–1.00 clearly shows the mangrove forest area, while NDBI between 0.01–0.40 shows urban and built-up land, and 0.41–1.00 appears as bare land. The NDVI overall accuracy assessment is 82.88%, 97.46% and 88.25% with Kappa values of 0.64, 0.92, and 0.85 for year 1999, 2009 and 2020, respectively. The NDBI overall accuracy assessment is 92.81%, 77.11% and 64% with Kappa values of 0.93, 0.77, and 0.63 for year 1999, 2009 and 2020, respectively. In addition, areas that are sensitive to land-cover change appear around the Chi rat River, Pak Nam Krabi River, and Yuan River, which are tourist areas close to the Krabi and Ao Nang communities. Therefore, it is necessary to speed up the problem solving and find measures to prevent mangrove forest degradation in these 3 mangrove forest areas so that the mangrove forest areas will not decrease rapidly in the future. This research can be valuable for land-cover management in the KEW by policy and decision makers.

Keywords: Krabi Estuary Wetland; Normalized Difference Vegetation Index (NDVI); Normalized Difference Built-up Index (NDBI); Mangrove areas; Urbanization

Introduction

Estuaries have currently been encroached on by human activities, including the expansion of aquaculture areas like shrimp farms or agricultural activities and salt fields [1–3]. Vegetation in mangrove forest on the banks of the estuary

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can be of great economic value, such as mangroves from Tabun, Lamphu and Lamphaen, causing plant numbers to be rapidly reduced and destroyed, especially in Krabi Province [4]. In 1961, a mangrove forest was found in the estuary with 398.92 km^2 of area. When surveyed again in 2016, only 323.67 km^2 of land was left, which was a reduction of 18.87% [5]. After 55 years, the average mangrove forest decreased 3.87 km^2 per year. Therefore, research is necessary to find a fast and efficient measurement system for surveying the estuary area in Krabi Province. Ramsar saw the importance of the area and let Krabi Estuary become registered under the 4th Ramsar Convention in Thailand, announced on 18 June 2001, due to its unique characteristics and appropriate biogeography [6]. The Krabi Estuary includes a 45 million-year-old mollusk fossil in the south of Klong Gilard estuary, 221 species of birds and mud flats and mangrove forests supporting the larvae of many economic marine organisms such as *Lates calcarifer*, *Mugil spp*., and Scylla serrata [7]. It is also in line with the United Nation's Sustainable Development Goal 15 guidelines to protect, restore and promote the sustainable use of terrestrial ecosystems, where conservation and sustainability approaches are needed to enable people and the environment to live together happily [8].

The estuary environment is the lower area of the estuary that is so wide that it resembles a bay [9]. The mouth of the river gradually narrows to the upstream, making it look like a cone. The water in this area is found to be sinking, wide and deep, causing sediment that flows from the upstream to the downstream to not precipitate in the middle of the water, so on both sides of the estuary river sediment can accumulate in this area [10]. Therefore, a unique ecological system is the mangrove forest, and its very fertile sediment that is rich in clay minerals [11]. Minerals that have cation exchange properties can absorb nutrients in the soil, especially organic matter and colloids, making the environment a suitable ecosystem with an abundance of nutrients, causing an estuary environment to frequently be invaded [12–13].

In the past two decades, the KEW has been invaded by humans often, whether for the expansion of agricultural areas for shrimp farming and aquaculture, or for the expansion of business and tourism industry growth, causing buildings to encroach on the KEW [14]. According to Strategy and information for Krabi Provincial Development group [15], the number of tourists in Krabi in 1999 was 787,726. As a result, Krabi's gross provincial product (GPP) was 20,087.54 million baht. In 2019, the number of tourists increased to 4,284,619 people, generating enormous income for Krabi, and 86,684.49 million baht for GPP. Over the past 20 years, Krabi's tourist numbers have increased by 543% and Krabi's gross provincial product has grown 431% from the expansion of tourist's population and GPP during 1999-2020. For this reason, Remote sensing technology is necessary in the KEW to survey the area by using satellite images with a multispectral band for land cover surveying [16–17].

Hilbert [1] studied the Land Cover Change of the Grand Bay National Estuarine in the USA between 1974–2001 using Landsat MSS, TM and ETM satellites for analysis using Normalized Difference Vegetation Indices (NDVI). Amanollahi et al. [18] also used this analysis for the Assessment of Vegetation Variation in Syria, Iraq, and Saudi Arabia to examine the abundance of vegetation cover in the desert. In an ecologically diverse coastal region like the Southeastern Australian estuaries, Al-Nasrawi et al. [19] brought in NDVI to explore the geomorphological characteristics of the highly-dynamic intertidal estuarine landforms there to monitor changes in vegetation cover.

A study using NDVI is an empirical method for surveying vegetation cover which can effectively classify vegetation diversity. In addition, Normalized Difference Built-up Index (NDBI) analysis has also been used in collaborative research with NDVI. Guo et al. [20] studied urban biophysical composition which examined urban growth in Guangdong Province, China, like Sekertekin et al. [21], where NDBI was used to study Zonguldak city in the Western Black Sea region of Turkey, it found that it was required to implement a thresholding method to highlight the urban and non-urban areas efficiently. In the study by Mohammadi et al. [22], even in tropical regions like Malaysia in the Cameron Highlands, the same technique has been applied. With the effectiveness of remote sensing, the technique that uses NDVI and NDBI analysis principles to explore land cover and vegetation makes it possible to obtain information quickly, not spend a lot of money on education, and also obtain data that covers a large area, and the data is quite accurate [23–24]. Therefore, it is suitable for environmental research and able to monitor the changes very well. In addition to a technical study to find land cover in the KEW area that visualized the change in land cover in each period, Dastgerdi et al. [25] has laid out a constructive strategic direction for sustainable environment management in the Umbria Region, Italy. The study results on solving environmental problems showed that participation of highly qualified partnerships between local people and relevant government agencies; and stakeholders in a network of local communities cooperating to conserve the natural protected areas will be able to sustainably solve environmental problems in the reservation area.

This study aims to assess the changes that have occurred in Krabi Estuary Wetland from 1999 to 2020 using NDVI and NDBI for monitoring the changes in mangrove areas and urbanization in Krabi Province, Thailand. This study sees the benefits of remote sensing techniques in environmental management, which can be used for spatial analysis and temporal monitoring. With NDVI and NDBI one can use the results of the study as a guideline for planning and defining a framework for preventing and reducing mangrove forest damage in the KEW area. This can create a database for a spatial model for systematic land use management planning to support sustainable changes in the future.

Material and methods

1) Study area

This study covers the KEW area, located in the study area with coordinates of 475000E, 865000N on the northwestern edge and 505000E, 900000N on the southeastern edge in the Universal Transverse Mercator (UTM) projection for the 47N zone in the WGS 1984 ellipsoid. The total study area is approximately 280.77 km^2. The topography of the study area is a drowned river valley-type estuary. The north of the study area is the location of Krabi town, the west side connects to Ao Nang and the Andaman Sea, the east connects Nuea Klong District, and the south is next to Phela Estuary. KEW is an area of 3 large outlet river mouths: Chi Rat River; Pak Nam Krabi River; and Yuan River, which encompasses a large mangrove forest ecosystem in southern Thailand (Figure 1).

According to the National Statistical Office of Thailand [26], the number of tourists in Krabi in 1999 was 787,726. There have been 124 hotels listed with 4,517 rooms. In 2019, the number of tourists increased to 4,284,619 people, the number of hotels was 714 and 21,853 rooms. It was 543% growth of tourists, causing the number of hotels and rooms to increase accordingly to accommodate tourists. The expansion was 575% and 483% respectively, which would have a significant impact on urbanization in the KEW area.

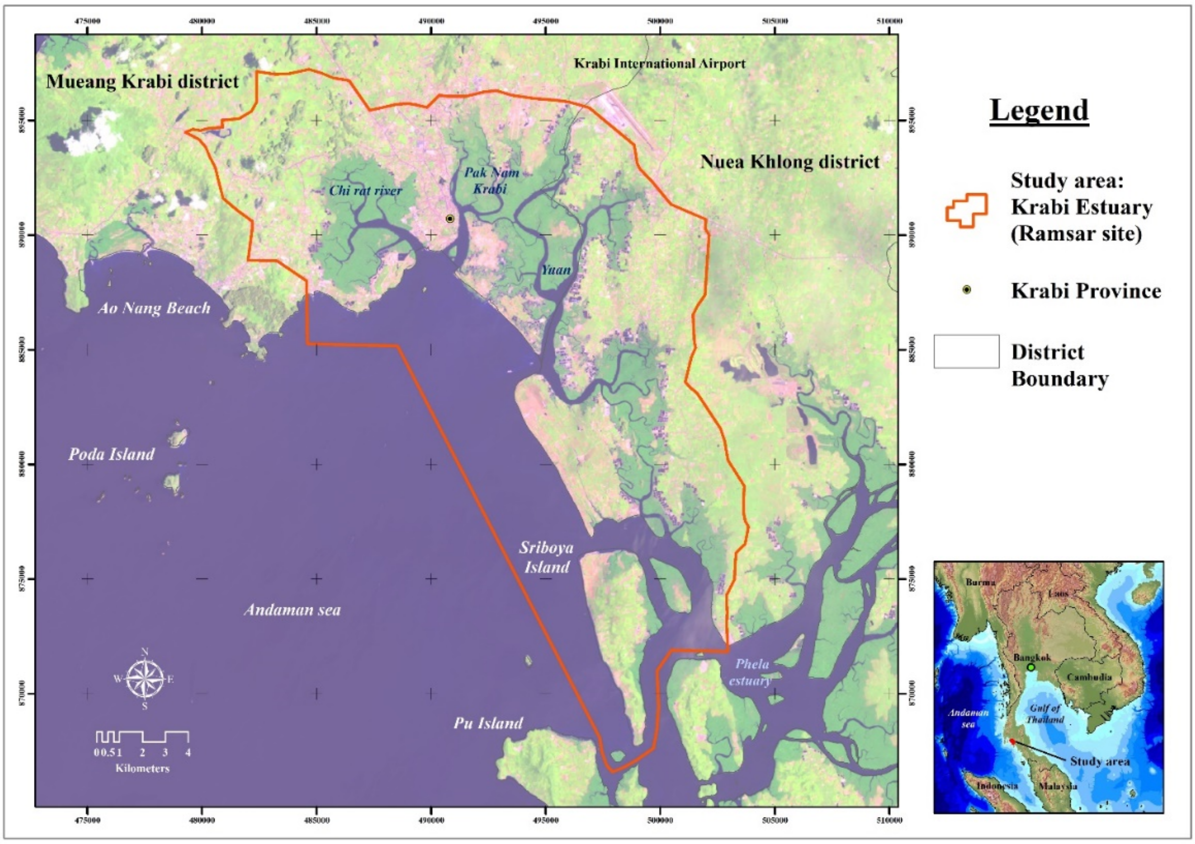

Figure 1 Geographic setting of the study area of the KEW area.

2) Data collection and analysis

This study used satellite images Landsat 5-TM and Landsat 8-OLI/TIRS downloaded from Earthexplorer.usgs.gov website, with details of the data in Table 1, covering the years 1999, 2009 and 2020, respectively. However, in the image processing process, Erdas Imagine 9.2 software was used to examine data and improve data quality before analysis which was radiometrically and geometrically corrected [27]. We then go into the band combination process in the following bands: Landsat 5-TM satellite data in 1999 and 2009 with Band Combination 4:3:2 and 5:4:3 (Red:Green:Blue); and Landsat 8-OLI/TIRS satellite data in 2020 with Band Combination 5:4:3 and 6:5:4, before analyzing the NDVI and NDBI in the following order [28], as shown in Figure 2.

3) Spatial analysis for mangrove area detection and urbanization monitoring with NDVI and NDBI

Remote sensing data are the primary sources for analyzing environmental processes on a local or global scale [29–31]. The band combination process adopts the principle of the electromagnetic spectrum contained in the sensor system and installed in the satellite in the form of a band. In this research, NDVI and NDBI principles are used for spatial analysis to detect mangrove areas and monitor urbanization [32–33].

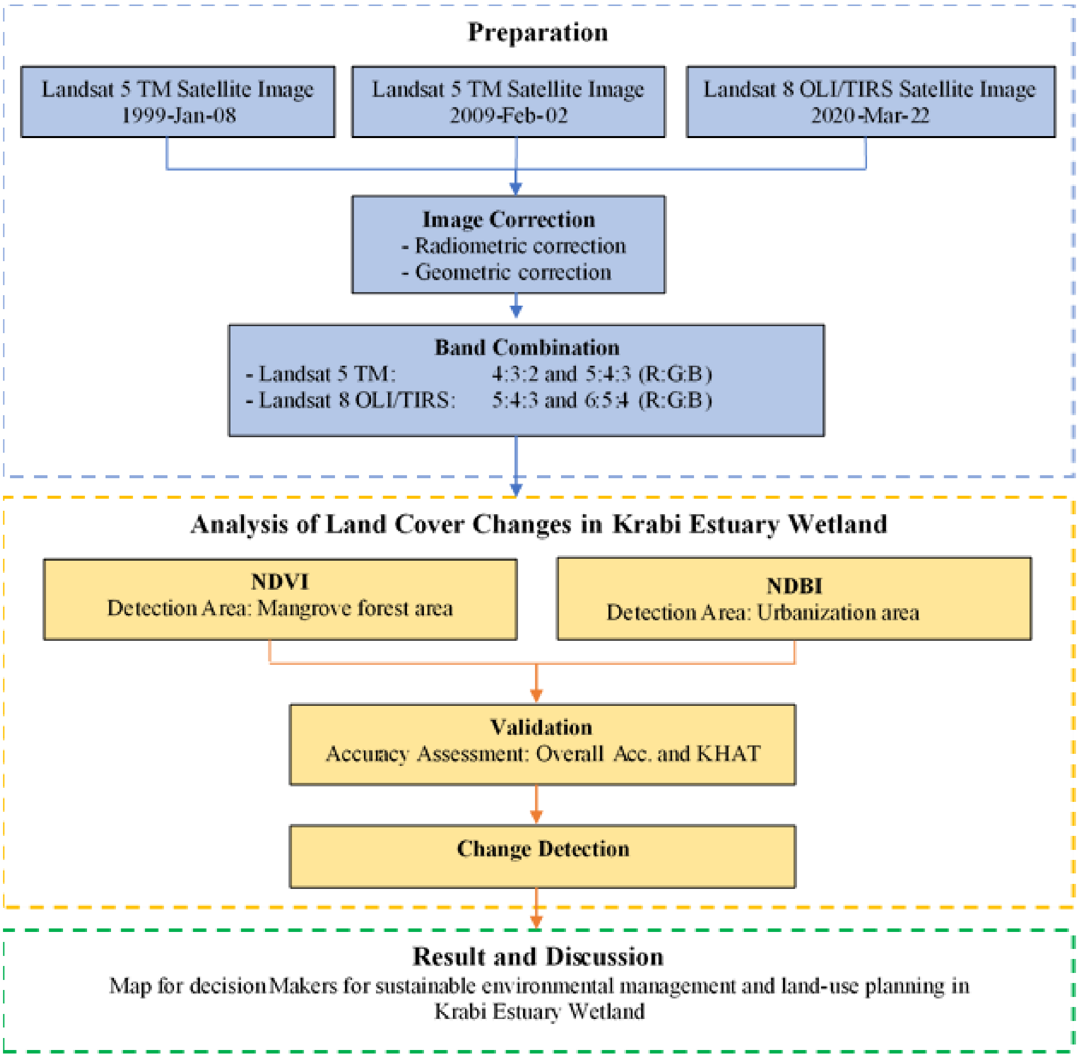

Figure 2 Flowchart of the main methodology carried out in this research.

Table 1 Satellite image data over the KEW for analysis

Image type	Path/row	Band (R:G:B)[a]	Acquisition date	Original		
				Format	Resolution	Source[b]
Landsat 5-TM	129/054 129/055	4:3:2	1999-Jan-08	TIFF	30 m	USGS
	129/054 129/055	5:4:3	1999-Jan-08	TIFF	30 m	USGS
Landsat 5-TM	129/054 129/055	4:3:2	2009-Feb-02	TIFF	30 m	USGS
	129/054 129/055	5:4:3	2009-Feb-02	TIFF	30 m	USGS
Landsat 8-OLI/TIRS	129/055	5:4:3	2020-Mar-22	TIFF	30 m	USGS
Landsat 8-OLI/TIRS	129/055	6:5:4	2020-Mar-22	TIFF	30 m	USGS

[a] R:G:B red:green:blue

[b] USGS United States Geological Survey

The NDVI is a common vegetation index for global greenery observation. The Landsat 5TM satellite analyzes Band 4 with high reflectance in the Near Infrared (NIR) range and an electro-magnetic wavelength between 0.77 to 0.90 µm with Band 3, which is in the Red (0.63 – 0.69 µm) spectrum for density determination and natural vegetation classification. It shows where the mangrove forest covers the estuary, as in Eq. 1 [3]. But Landsat 8-OLI/TIRS uses Band 5, which is NIR (0.851–0.879 µm) analyzed together with Band 4, which is the Red (0.636 – 0.673 µm) spectrum in our NDVI study, as in Eq. 2 [34–35].

NDVI (Landsat 5-TM) = (Band 4 – Band 3) / (Band 4 + Band 3) (Eq. 1)

NDVI (Landsat 8-OLI/TIRS) = (Band – 5Band) / (4Band + 5Band 4) (Eq. 2)

Analysis results show that the NDVI value varies from -1 to 1. If the NDVI appears high, it means dense greenery of the land cover in the area [36]. We generally classify the ground cover with the following index values and have obtained the following results:

NDVI = -1.00 to -0.10 represents water bodies
NDVI = -0.09 to 0.20 represents barren rocks or sand
NDVI = 0.21 to 0.40 represents shrubs and grasslands or senescing crops
NDVI = 0.41 to 1.00 represents dense vegetation or tropical rainforest

However, in the KEW study area, it is necessary to find ground cover caused by human activities, so the NDBI is also used in this research. NDBI will provide the indices for the analysis of built-up areas, and is able to classify the build-up areas and bare soil reflected with short-wave infrared (SWIR) in conjunction with NIR waves. Therefore, with the Landsat 5TM satellite, Band 5 will be used. It is a SWIR band that has an electromagnetic wavelength between 1.55 and 1.75 µm, analyzed together with Band 4 (NIR), as in Eq. 3 [37]. But Landsat 8-OLI/ TIRS uses Band 6, which is SWIR1 (1.566–1.651 µm) to be analyzed together with Band 5, which is in the NIR spectrum in the NDBI study, as in Eq. 4.

The result will be NDBI between -1 and 1. A negative value for NDBI represents water bodies, whereas a higher value represents build-up areas [38]. The NDBI value for vegetation is low. NDBI analysis can quickly and efficiently detect land cover types, urban areas and buildings.

For accuracy, after NDVI and NDBI analysis the data was validated by field survey and land-use data from the Land Development Department (LDD) in the KEW area by overall accuracy and Kappa coefficient determination [39], as in Eq. 5 and 6, respectively.

Kappa coefficient is a way to measure the accuracy of classification, calculated by multiplying the total pixels in all the ground truth classes by the sum of confusion matrix diagonals, then subtracting the sum of the ground truth pixels in a class, times the sum of the classified pixels in that class, summed over all classes, and divided by the entire pixels [38–39].

NDBI (Landsat 5-TM) = (Band 5 – Band 4) / (Band 5 + Band 4) (Eq. 3)

NDBI (Landsat 8-OLI/TIRS) = (Band 6 – Band 5) / (Band 6 + Band 5) (Eq. 4)

$$\text{Overall accuracy (OA)} = \frac{1}{N}\sum P_{ii} \quad \text{(Eq. 5)}$$

Where: N = Total number of test pixels, and $\sum P_{ii}$ is Total pixels that are correctly classified.

$$\text{Kappa coefficient} = (\text{OA} - \frac{1}{q})\ (1 - \frac{1}{q}) \quad \text{(Eq. 6)}$$

Landsat images used overall accuracy values and Kappa coefficients (KHAT) to assess the accuracy of each type of classification for identification of the area [40].

< 0, less than chance agreement,
0.01–0.40, poor agreement,
0.41–0.60, moderate agreement,
0.61–0.80, substantial agreement,
0.81–1.00, almost perfect agreement.

4) Dynamic annual change of LUC

From the land cover classification using NDVI and NDBI methods, the result is a land cover model that covers the study area, which is an important result that helps us to know what appears in the spatial database to create a database in GIS, then analyzes the land cover for each period to check for changes in the ground cover [41–42], as in Eq. 7.

$$\Delta = [(A2 - A1) / A1 \times 100] / (T2 - T1) \quad \text{(Eq. 7)}$$

Where Δ is the proportion of land use patterns that have changed (percentages), A1 is the type of land use at the first check (T1) and A2 is the type of land use at the second check (T2).

The results show the proportion of each type of earth cover on the map, which shows the pattern of any earth cover changes between 1999 and 2020, along with a change detection comparison table from overlay analysis using the tabulate area tool in ArcMap 10.3.

Results and discussion

From the NDVI and NDBI in 1999, 2009 and 2020, the KEW area is shown, as seen in Figure 3.

According to the NDVI study from 1999 to 2020, the results show that the index below 0 mainly indicates water and sea area, which is the coastal area of the KEW area. Values above 0 can be classified as follows: NDVI 0.41–1.00 clearly shows forested areas, especially those between 0.61–1.00, which are densely covered areas with high soil moisture. NDVI 0.21–0.40 indicates areas with slight canopy cover, which includes areas of agricultural activities such as orchards, field crops, horticulture etc. In areas with buildings, the NDVI value is displayed at 0.11–0.20, and beach areas on the coast and abandoned areas have a NDVI of 0.01–0.10.

The study of NDVI changes between 1999 and 2020 (Table 2) found that NDVI values were between 0.41–1.00 (dark green), which indicates an area that is densely covered with trees and has had a tendency to reduce its amount of area throughout the 21 years, especially in the areas of the Chi Rat River, Pak Nam Krabi River, and Yuan Rriver. In 1999, the NDVI values were high and spread around the river, covering 216.66 km^2, but by 2020 the NDVI had been reduced to 148.76 km^2. The increase was in the area with the NDVI 0.2–0.4 (light green), which was the area where agricultural expansion appeared during the year. In 1999, that area was 43.93 km^2, but by 2020 it had increased to 100.71 km^2 with the expansion of oil palm plantations, rubber, shrimp farms and orchards continually in-creasing every year.

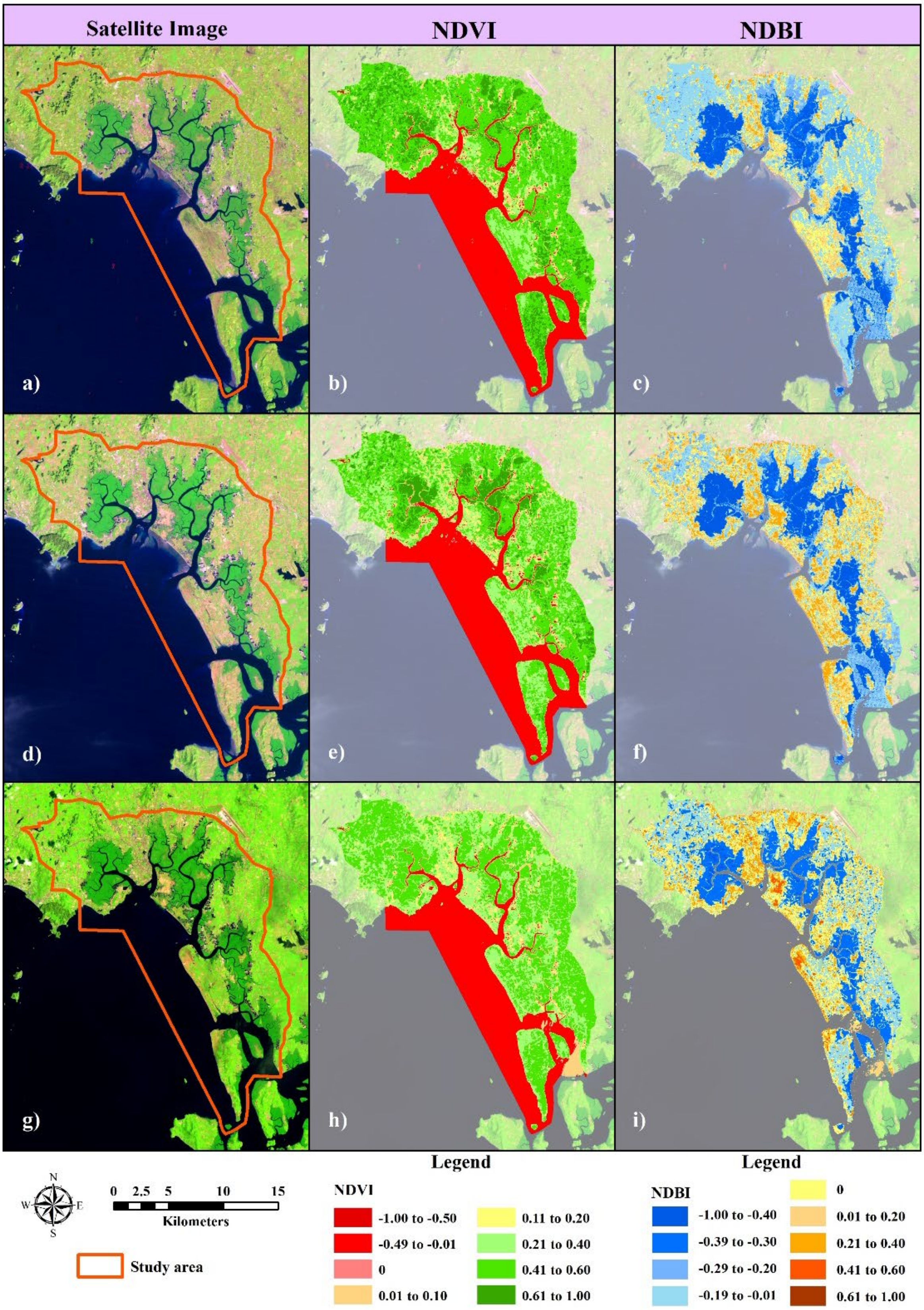

Figure 3 Landsat Satellite Image, NDVI map and NDBI map of the KEW area for (a, b, c) 1999, (d, e, f) 2009 and (g, h, i) 2020.

Table 2 NDVI analysis results showing the proportion of ground cover in 1999, 2009 and 2020

NDVI	Area (km^2)			Classify
	1999	2009	2020	
-1.00 to -0.50	0.07	0.00	0.00	
-0.49 to -0.01	108.48	108.24	108.77	Sea
0	395.22	395.58	395.04	
0.01 to 0.10	8.95	11.30	11.77	Abandon area, beach
0.11 to 0.20	11.25	15.59	19.55	Urban
0.21 to 0.40	43.93	75.16	100.71	Agricultural area
0.41 to 0.60	142.78	115.35	122.70	Forest area
0.61 to 1.0	73.88	63.39	26.06	(Mangrove forest)
Total	784.56	784.61	784.61	

The NDBI study between 1999 and 2020 shows that values below 0 indicate forest covered areas, but the most clearly identified are urban areas and buildings with NDBI values greater than 0, as follows: concentrated areas of community districts appear to have values of 0.01–0.40, especially with values between 0.21–0.40, which are densely populated communities. However, values that are higher than 0.4 are not always community areas. In this study it was found that NDBI values greater than 0.41 to 1.00 are open areas with low fertility soil and very low soil moisture.

The results of NDBI changes between 1999 and 2020 (shown in Table 3) show that the area appearing 0.01–0.40 (light yellow and orange) increased during the period, as shown in 1999. The NDBI value range 0.01–0.40 had an area of 32.95 km^2, but after 21 years, it appears that in 2020 it had grown to 48.16 km^2. It was found that the mangrove forest area (dark blue) showed expansion along the coast of the KEW area and increased. In addition, it was found that in 2020, the dark blue area began to appear light blue, indicating that the mangrove forest area in the KEW area began to change to other areas, or suffered more encroachment in that area.

The NDVI and NDBI studies have validated land-use data from the LDD in the KEW area using tabulated area analysis in GIS software. The results show the overall accuracy and Kappa coefficient, which indicates how reliable the data set is from the study results. The results show that the NDVI map shows an OA of 82.88, 97.46, and 88.25% respectively, and KHAT values of 0.641, 0.915, and 0.849 respectively. The NDBI map shows OA of 92.81, 77.11, and 64.00%, respectively, and KHAT values of 0.927, 0.765, and 0.626, respectively. Validated results cause most of the data sets to be substantial and in almost perfect agreement.

The importance of the assessment of estuary wetland studies in different parts of the world have seen applied NDVI principles, such as with Sun et al. [27], using Landsat imagery to classify vegetation and map it in the Virginia Coast reserve area, USA. That study showed monthly NDVI results to see the distribution of land cover and found that vegetation communities had a density of 1–2 m above the terrain, it also showed dune and agricultural areas that were expanding. This corresponds to the study of the distribution of NDVI 0.4–1.0, which has found that concentration is occurring at that altitude, which is an important mangrove forest area of KEW, the estuaries of the Chi Rat River, Pak Nam Krabi River, and Yuan River. In addition, land-cover changes, especially those in mangrove forest areas, can be indicators of annual data, as Al-Nasrawi et al. [19] reported on with applied technology Geo-informatics to analyze changes of vegetation and intertidal sedimentary landforms in southeastern Australian estuaries from 1975–2015. Those results showed that the NDVI index tended to decrease every year, in line with this study, where the NDVI in KEW tends to decrease, indicating an abundance of plants that are threatened, and changes in mangrove forest areas from agricultural expansion activity in the KEW.

For assessment in the KEW area to obtain all forms of land-cover data, NDBI principles are also used for analysis to find agricultural and urban areas, and buildings that can provide spatial change as empirical information, as Guha et al. [24] illustrated with NDVI and NDBI using Landsat 8-OLI and TIRS data to analyze land-cover in Florence and Naples, Italy. Their results show that NDBI is an index that can clearly define the zone of the built-up area and bare land showing KHAT and OA values. Up to 0.89 and 92.36 respectively. Also, the built-up area expands into the vegetation area, which is measured by NDBI values. In addition, Li and Chen's study [33] studied combining VIIRS, DNB, NDVI, and NDBI as well. Their results show that the area can clearly distinguish urban areas with its dark rural background, giving an insight into the urbanization of various areas as follows: Yangtze River Delta, Chengdu-Chongqing, Changsha-Zhuzhou-Xiangtan, Beijing-Tianjin-Hebei, and Pearl River Delta. The area showed very high urban expansion, which is consistent with studies in the KEW that found that urban and built-up land increased throughout 1999–2020 (Table 5). It was found that urbanization occurs rapidly in study area, divided into 2 periods: In the years 1999–2009, urban areas expanded slowly, a 17.59 km^2 increase in urban and built-up land was observed as a result of the changing in forest area, agricultural area, and bare land, representing a total of 16.75, 0.82, and 0.02, respectively. The second phase was 2009-2020 found that urbanization occurs rapidly, urban and built-up land increased up to 43.54 km^2. The forest area is decreased about 41.43 km^2, in line with The National Statistical Office of Thailand (2020), where during this period the number of tourists increased to 4.3 million. As a result, the number of rooms in Krabi hotels and resorts has to be expanded to 4,517 rooms in 2019, causing other types of areas to be transformed into urban and built-up land. In addition, the forested area, which was mostly mangrove forest, had been transformed into agricultural area of up to 21.03 km^2, and became urban with 3.89 km^2. The study of changes in land-cover in the KEW area is shown in Figure 4.

Table 3 NDBI analysis results showing the proportion of ground cover in 1999, 2009 and 2020

NDBI	**Area (km^2)**			**Classify**
	1999	**2009**	**2020**	
-1.00 to -0.40	30.86	43.83	3.98	Forest area
-0.39 to -0.30	29.5	27.43	60.79	
-0.29 to -0.20	32.94	25.65	72.04	
-0.19 to -0.01	107.82	60.74	5.5	
0	40.03	45.18	85.57	Urban and built-up land
0.01 to 0.20	22.81	47.59	17.66	
0.21 to 0.40	10.14	30.24	30.5	
0.41 to 0.60	4.17	0.11	4.73	Abandon area, beach
0.61 to 1.00	2.5	0	0	
Total	280.77	280.77	280.77	

Table 4 Validation between the NDVI, NDBI map and land-use classification data derived from the LDD

Year	NDVI		NDBI	
	OA %	KHAT	OA %	KHAT
1999	82.88	0.64	92.81	0.93
2009	97.46	0.92	77.11	0.77
2020	88.25	0.85	64.00	0.63

Table 5 Land-cover change in KEW area during 1999–2009, 2009–2020 and 1999–2020. (km^2)

	Land-use	2009			
		Agricultural area	Forest	Urban and built-up land	Bare land
1999	Agricultural area	78.27	14.48	0.82	0.00
1999	Forest	10.32	120.06	16.75	0.03
1999	Urban and built-up land	0.99	18.27	12.73	0.08
1999	Bare land	0.00	0.01	0.02	0.02
		2020			
	Land-use	**Agricultural area**	**Forest**	**Urban and built-up land**	**Bare land**
2009	Agricultural area	56.26	18.30	2.07	0.09
2009	Forest	7.92	95.55	41.43	1.54
2009	Urban and built-up land	0.72	9.39	16.82	3.22
2009	Bare land	0.00	0.00	0.04	0.08
		2020			
	Land-use	**Agricultural area**	**Forest**	**Urban and built-up land**	**Bare land**
1999	Agricultural area	54.12	20.97	4.53	0.21
1999	Forest	9.96	90.76	38.39	2.62
1999	Urban and built-up land	0.80	11.49	17.38	2.06
1999	Bare land	0.00	0.00	0.02	0.03

However, the urban expansion occurring in the Pak Nam Krabi and Yuan Watershed in the northern part of the KEW area (Figure 4) from the over-tourism phenomenon affects the expansion of urban and built-up land and agricultural area. In addition, the area lacks a screening system and a wastewater treatment system of the local administrative organization, and still not covering the emerging community area in that area. Therefore, there is a problem of drainage into natural water sources. Municipal waste and food grease are contaminated and residues in clay and peat in the mangrove forests of the Pak Nam Krabi downstream and Yuan River Basin, which affects very dangerous to ecological systems towards the KEW area [43]. However, this research is aware of the sensitivity of reservation area to deforestation in the northern and southern mangrove forests of the KEW area. To plan for sustainable land cover utilization should be pushed for concrete action, requiring the surrounding communities and government agencies to find common ways to conserve the surrounding mangrove forests. In other words, coastal ecosystem planning should provide environmental resilience in line with Dastgerdi et al. [25] that the system should be used is participation of highly qualified partnerships between local people and relevant government agencies; and stakeholders in a network of local communities cooperating to conserve the natural protected areas. Therefore, in the KEW areas, communities; entrepreneurs; and farmers living near the mangrove forest should be encouraged to take part in the maintenance of mangrove resources, along with the development of tourism in Krabi Province. The government sector should adopt modern technology such as establishing an efficient wastewater treatment system; adopt a technology to increase seafood production by promoting skills development and finding support markets to increase the value of seafood products; pushing hotel establishments to take care of mangrove areas; reducing construction expansion into the mangrove forest area, more importantly, the government should set clear and appropriate boundaries of land use by using mapping media to create understanding of communities, etc. which will make the community and surrounding establishments reservation area can coexist with nature and cooperate to protect and reduce encroachment on mangrove forest areas sustainably.

Figure 4 shows the actual land-cover change and found that the surrounding mangrove forests in the 3 KEW areas are considered to be very sensitive to change caused by human activity because they can easily access the mangrove forests. The surrounding area has been changed into agricultural and urban areas with buildings due to Krabi Province promoting the tourism industry, resulting in high demand for land use and therefore land-cover changes on the north side of the Pak Nam Krabi River and the west side of the Chi Rat River that are broadly expanded. For this reason, the importance of geo-informatics is that it is a technology that can quickly and accurately assess environmental work and provides a wide range of environmental information that is easily accessible and very suitable for environmental management.

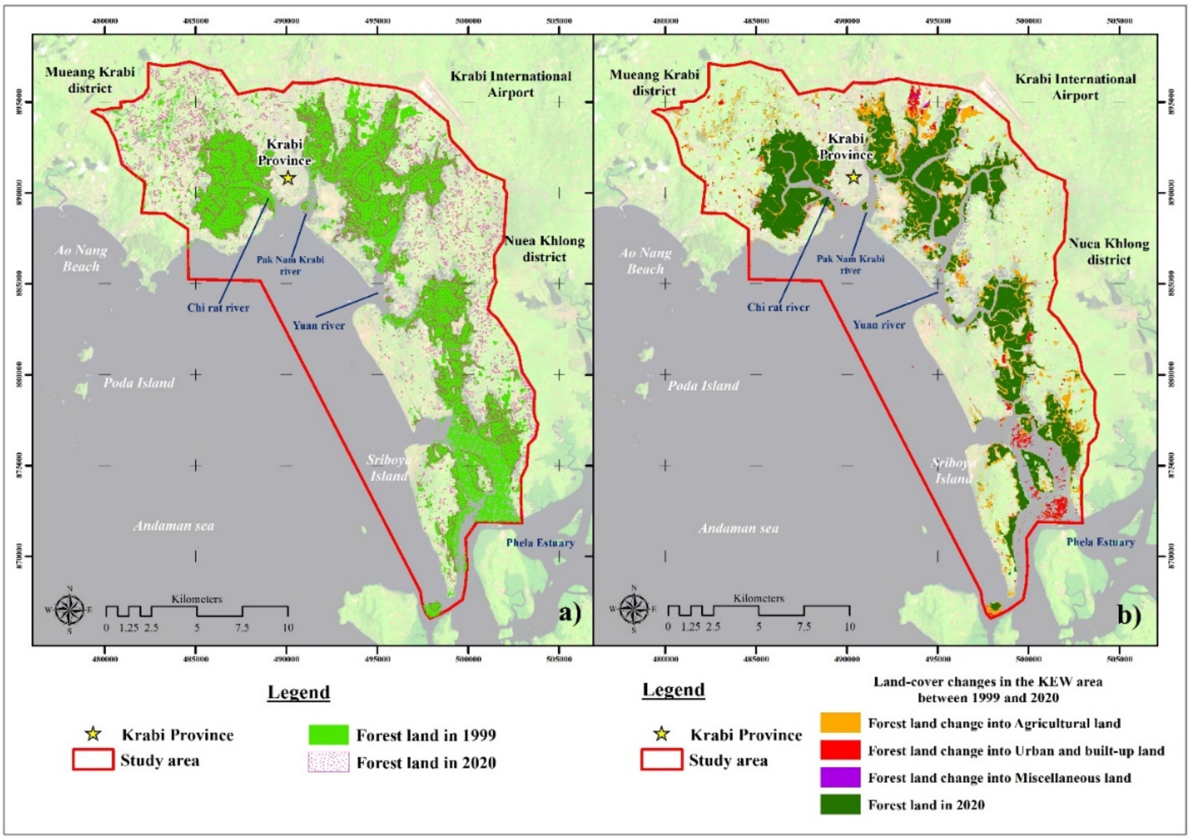

Figure 4 Land-cover changes in the KEW area between 1999 and 2020 for a) deforestation map in the KEW area between 1999 and 2020 and b) sensitivity of mangrove forest area to change from 1999 to 2020.

Conclusion

In the environmental assessment and land-cover study, especially in areas that are sensitive to changes in the KEW area, it shows the reality of the area and can detect the actual area by using Landsat satellite imagery to generate data with NDVI and NDBI analysis. It shows the changing conditions around the mangrove forest area which have changed into agricultural areas and urban areas quickly, accurately and efficiently by highlighting them. In this research, it was found that NDVI 0.4–1.0 can detect forested area very well. NDBI 0.2–0.4 values detect urban areas and buildings, and NDBI 0.4–1.0 can detect bare land. This information is very useful for identifying accessible vegetation detection, and NDBI can efficiently detect urbanization in other parts of the world. The study approach to land cover change using NDVI and NDBI in KEW area can be used to study other coastal areas at local and regional levels. This approach can determine the boundaries of mangrove forests and other types of land cover accurately, quickly and efficiently for the context of change that has occurred with mangrove forests worldwide to protect and preserve natural defenses from tsunami disasters, and conserve ecosystems and important marine natural resources by defining a concrete reservation area and establishing a shared empirical database between communities; entrepreneurs; and government agencies. This information is being used by government agencies and local administrative agencies to protect, monitor, prepare and solve environmental problems caused by encroachment from human activities in the sensitive areas that appear in this study. Currently, the area is expanding to shrimp farming and aquaculture, including a wide expansion of buildings such as hotels and resorts to the north of the Pak Nam Krabi River and west of the Chi Rat River. This research is therefore suitable for future sustainable land use management planning in the study area and other estuary areas that have a large context of land-use change.

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