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Land Cover Change Dataset on Both Sides of the Malacca Strait (1990−2017)

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Abstract: The extraction of land cover information with remote sensing is an important method currently used to study the status of coastal land use and ecological environmental changes. This study proposed a Standard Normalized Difference Vegetation Index (SNDVI) based on temporal features, established the rules for the extraction of agricultural land; and comprehensively used a rule-based, object-oriented, and supervised classification method to obtain the classification information of land covering a 40 km zone along the coastline on both sides of the Malacca Strait. The results of this study were verified to have an overall classification accuracy of 92%. The analysis results showed that the development intensity of 0–20 km from the coastline was significantly higher than that of 20–40 km. It was determined that between 1990 and 2017, the proportion of construction land in the 40 km from the west bank of the Peninsular Malaysia had increased by 7.4%. Also, the proportion of agricultural land had increased by 12.4%, and the forest land had decreased by 21.5%. The proportion of construction land in the 40 km from the east bank of Sumatra was determined to have increased by 3.2%; the proportion of agricultural land had increased by 17.2%; and the forest land decreased by 20.4%. The data spatial resolution is 30 m. The dataset is consisted of 8 .tif files with a data size of 3.36 GB (Compressed to one file, 47.9 MB).

Keywords: Malacca Strait; Peninsular Malaysia; Sumatra; land cover changes

1 Introduction

Land cover changes are main causes of environmental changes[1–4]. The coastal zones of the world are special transition areas where sea and land interactions occur. The coastal ecosystems are known to have the complex, marginal, and active characteristics, and are also ecologically fragile[5]. It has been found that with the development of coastal cities, the speed of the development and utilization of coastal land has accelerated. Furthermore, with the intensity of the development gradually increasing, research findings regarding land cover changes in coastal zones have received extensive attentions from around the globe [6–7].

At the present time, the most commonly used classification methods for the extractions of

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coastal land information include manual visual interpretations, traditional classifications, and object-oriented classifications[8]. However, due to the existence of such phenomena as the "same spectrum, different substances"; "same substance, different spectra"; and mixed pixels, it has been found that the traditional classification methods cannot meet the accuracy requirements[9–11]. It has been determined that the object-oriented classification method has the ability to solve this deficiency, and can adapt well to the accuracy requirements of image classifications[12–18].

This study selected a 40 km zone from coastline on both sides of the Malacca Strait as the study area, and comprehensively used a rule-based object-oriented classification method, along with a supervised classification method, to extract the land cover information. The results of this study potentially provided important reference information for the future study on land use planning and sustainable policies in the study area[19].

2 Metadata of Dataset

The metadata of the land cover dataset within 40 km from coastline along the Straits of Malacca[20] is summarized in Table 1.

3 Methods

3.1 Data Collection and Processing

The data used to develop this land cover dataset within 40 km from Coastline along the Straits of Malacca were derived from the Landsat 4−5 and Landsat 8 satellite data released by the United States Geological Survey[22]. The data time period covers both the no-cloud and less cloud coverage data for each month for the years of 1990, 2000, 2010, and 2017. The Path-row numbers of the Landsat data were 125/59, 126/(58−60), 127/(57−59), 128/(55−58), 129/(57−58), 130/(56−57), and 131/56. The statistical information which was obtained from the aforementioned Land Resource Satellites is detailed in Table 2.

3.2 Algorithms

In accordance with the land cover situations on both sides of the Malacca Strait, it was determined that the types of land cover included agricultural land, forest land, water bodies, construction land, and other unused land types.

1) Extraction of the agricultural land information

The Normalized Difference Vegetation Index (NDVI) is an effective method which is currently used for extracting vegetation. However, the threshold range of the NDVI is different for different types of images. Therefore, this study proposed a Standardized Normalized Difference Vegetation Index (SNDVI) based on the NDVI, in which the threshold demarcation points of the vegetation and non-vegetation were set to 1. This method was found to be valid for all the different images. When compared with other land types, the agricultural land had displayed obvious temporal characteristics. Therefore, by using those features, the Landsat images from different periods during the same year were obtained and then combined with the SNDVI for the purpose of extracting the information for the agricultural land in the study area.

Table 1 Metadata summary of the land cover dataset within 40 km from coastline along the Straits of Malacca

Items	Description		
Dataset full name	Land cover dataset within 40 km from coastline along the Straits of Malacca (1990, 2000, 2010, 2017)		
Dataset short name	LandCover_MalaccaStrait		
Authors	Yan, J. F. Y-1461-2018, College of Geomatics, Shandong University of Science and Technology, yanjf2004@163.com Su, F. Z. Y-1692-2018, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, sufz@lreis.as.cn Wang, M. H. X-9850-2018, College of Geomatics, Shandong University of Science and Technology, 394765196@qq.com Zhang, X. X. X-9863-2018, College of Geomatics, Shandong University of Science and Technology, 1802945892@qq.com Gao, S. S. X-9897-2018, College of Geomatics, Shandong University of Science and Technology, 1915387391@qq.com Xu, M. R. X-9942-2018, College of Geomatics, Shandong University of Science and Technology, 2272244950@qq.com		
Geographical region	Within 40 km of the west bank of Peninsular Malaysia, within 40 km of the east bank of Sumatra (0°–6°N, 95°E–105°E)		
Year	1990, 2000, 2010, 2017		
Temporal resolution	10 year	Spatial resolution	30 m
Data format	.tif	Data size	3.36 GB (47.9 MB after compression)
Data files	The dataset includes a total of 8 data files, which are land cover products within 40 km from the west bank of Peninsular Malaysia in 1990, 2000, 2010 and 2017 and land cover products within 40 km from the east bank of Sumatra in 1990, 2000, 2010, and 2017		
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Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn		
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China		
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Table 2 List of the Landsat data[22] used in this study

Data name	Data time	Spatial resolution	Path-row numbers
Landsat 4–5 TM	1990, 2000, 2010	30 m	125/59, 126/(58–60), 127/(57–59), 128/(55–58), 129/(57–58), 130/(56–57), 131/56
Landsat 8 OLI	2017		

2) Extraction of the non-agricultural land: forest Land, water, construction land, and un-utilized Land

In the current study, on the basis of the agricultural land use extractions, the forest land was extracted using the SNDVI. The water was extracted using the Modified Normalized Difference Water Index (MNDWI)[13]. The Bare Soil Index (BSI)[23] was used to extract the Un-utilized land, and the Normalized Difference Built-Up Index (NDBI) was used to extract the construction land[24].

$$SNDVI = \frac{NDVI}{\sqrt{\dfrac{\sum_{i=0}^{s-1}\sum_{j=0}^{l-1}\left[NDVI(i,j) - NDVI_{mean}\right]^2}{s \times l - 1}}} \tag{1}$$

where s represents the number of image lines; l denotes the number of image columns; $NDVI(i, j)$ indicate the NDVI value of the i^{th} row and j^{th} column pixel; and $NDVI_{mean}$ is the average value of the NDVI.

In this study, Equation (2) was used to extract the agricultural land information as follows:

$$\left\{\bigcup_{m=1}^{12}\left[\bigcup_{i=0}^{s-1}\bigcup_{j=0}^{l-1} SNDVI_m(i, j) > 1\right]\right\} \cap \left\{\bigcup_{m=1}^{12}\left[\bigcup_{i=0}^{s-1}\bigcup_{j=0}^{l-1} SNDVI_m(i, j) < 1\right]\right\} \tag{2}$$

where m denotes the month; and $SNDVI_m(i, j)$ is the SNDVI value of the i^{th} row and j^{th} column pixel at the m^{th} month.

$$MNDWI = \frac{green - mir}{green + mir} \tag{3}$$

where *green* is the green band; and *mir* indicates the mid-infrared band.

$$BSI = \frac{(mir + red) - (nir + blue)}{(mir + red) + (nir + blue)} \tag{4}$$

Where *mir* indicates the mid infrared band; *red* indicates the red band; and *nir* indicates near infrared band; and *blue* indicates the blue band.

$$NDBI = \frac{mir - nir}{mir + nir} \tag{5}$$

Where *mir* represents the mid-infrared band; and *nir* is the near infrared band.

3.3 Technology Sketch

The sketch of the land cover classification in the study is shown in Figure 1.

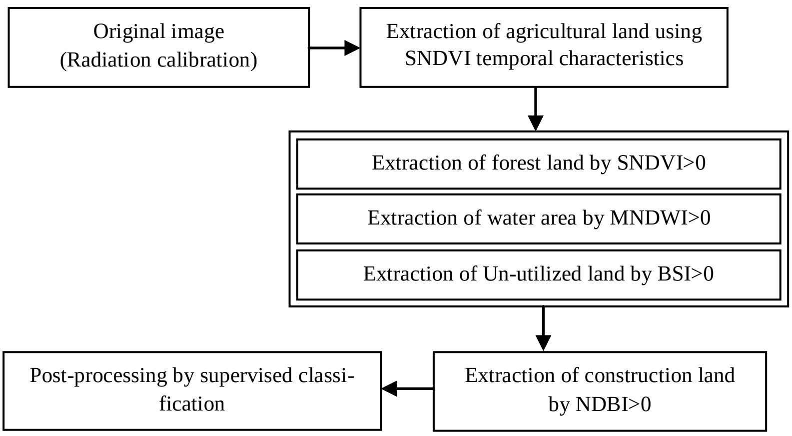


Figure 1 Technical sketch for the land cover classification

4 Results and Validation

4.1 Data Composition

The composition of the land cover dataset within 40 km from Coastline along the Straits of Malacca is shown in Table 3. The spatial distribution map is shown in Figure 2.

4.2 Data Validation

Samples were taken from high-resolution images of Google Earth for the evaluation of the accuracy of the study results. The results of the accuracy verification are shown in Table 4.

Table 3 Composition of the land cover dataset within 40 km from Coastline along the Straits of Malacca

Data name	Year	Spatial resolution	Classification code
Land cover classification products within 40 km of the west bank of the Peninsular Malaysia	1990, 2000, 2010, 2017	30 m	1- Forest land 2-Agricultural land 3-Construction land 4-Water 5-Un-utilized land
Land cover classification products within 40 km of the east bank of Sumatra	1990, 2000, 2010, 2017		

Table 4 Land cover classification accuracy verification (in pixel)

	Forest land	Agricultural land	Construction land	Un-utilized land	Water	User's accuracy (%)
Forest land	3,786	59	5	0	1	98.31
Agricultural land	725	5,023	0	0	0	87.39
Construction land	0	1	2,005	442	55	80.10
Un-utilized land	0	0	9	2,153	0	99.58
Water	0	0	0	0	3,857	100
Producer's accuracy (%)	83.93	98.82	99.31	82.97	98.57	
Overall accuracy = (16824/18121) 92.84% Kappa = 0.908,2						

4.3 Data Results

4.3.1 Land Cover Changes on the West Bank of the Peninsular Malaysia

The proportion of construction land in the 0−20 km from the west bank of Peninsular Malaysia had increased from 5.0% in 1990 to 13.1% in 2017; the agricultural land had increased from 42.9% in 1990 to 51.5% in 2017; and the proportion of forest land had reduced by 17.5% (Figure 3a). In addition, the proportion of construction land in the 20−40 km from the west bank of Peninsular Malaysia had increased from 4.0% in 1990 to 10.9% in 2017; the agricultural land had increased from 32.8% in 1990 to 47.2% in 2017; and the proportion of forest land had been reduced by 23.0% (Figure 3b).

The development of the construction land in the 40 km from the west bank of Peninsular Malaysia was found to be mainly centered in three sections. First, the North Sea and Bukit Mertajam cities were observed to have expanded and increased by 80% from 1990 to 2017, and were distributed from north to south along the coast of Penang in the north. The second main area of construction was Kuala Lumpur of Selangor in the central Peninsular Malaysia, in which the urban construction land had expanded by more than 250%. The third main construction area was located in Johor Bahru of Johor in the southern region. This had become a major industrial and commercial city in the Peninsular Malaysia, and was characterized by rapid development and an overall expansion of nearly 130%. The development of agricultural land was also found to be prominent in three main areas. The first was located in the Alor Setar area of Kedah in the northern region, which was observed to extend from west to east via Pokok Sena, extend to the Naka, and continue to extend southward through the Pendang. The second main agricultural land development had occurred in the Simpang Ampat in the southern Perak of the central Peninsular Malaysia, and had continued to extend from west to east. The southern Johor region made up the third highly developed agricultural land, which had been continuously developed from the Batu Pahat to the Keluang in the northeastern region, and had also expanded to the southeast. The development of agricultural land indicated an expanding trend from 0−20 km to 20−40 km in the study area, as detailed in Figure 2.

In the current study, the east bank of Sumatra was divided into northern (Aceh), central

(North Sumatra), and southern (Riau) sections. Among those sections, the development of urban construction land in the north was mainly centered in Banda Aceh city (which was the capital of Aceh province) and Lhokseumawe city. It was observed that from 1990 to 2017, the former had expanded more than three times, and the latter had expanded more than twice. The main development area of agricultural land was located in the southeast of Lhokseumawe. The development of the urban construction land in the central section was found to be mainly centered on Medan (the capital of North Sumatra), which had expanded by more than 80%. The development of agricultural land was mainly centered from the Belawan to the north of Medan; from the Perbaungan to the east of Medan; and the areas located south of Simalungun. The development of urban construction land in the south region was observed to be centered near the city of Dumai in Riau, in which the development area had more than doubled. The development of the agricultural land was found to have expanded to the peripheries of the cities of Dumai and Duri, as detailed in Figure 2.

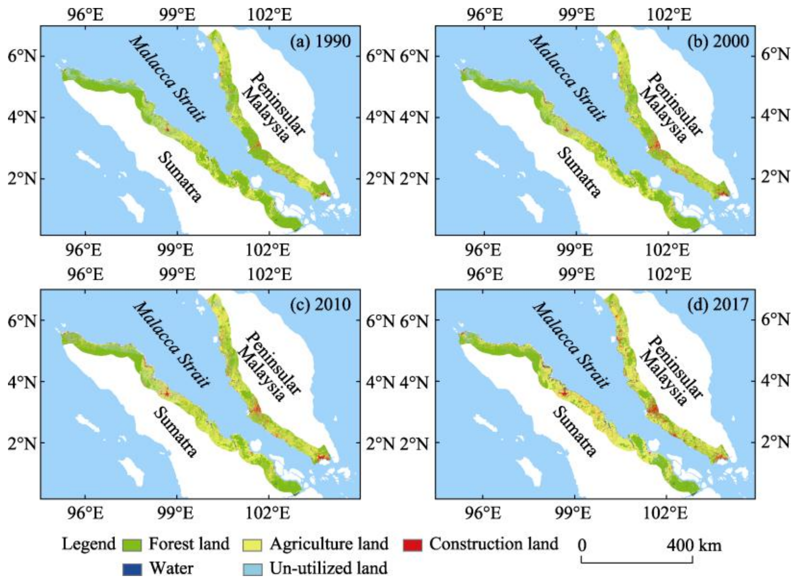
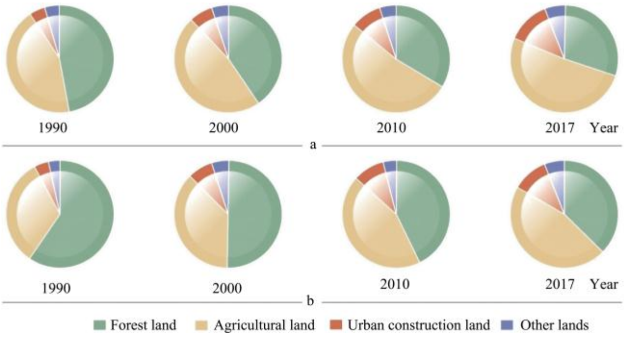


Figure 2 Spatial distribution of the land cover in a 40 km from the coastline on both sides of the Malacca Strait

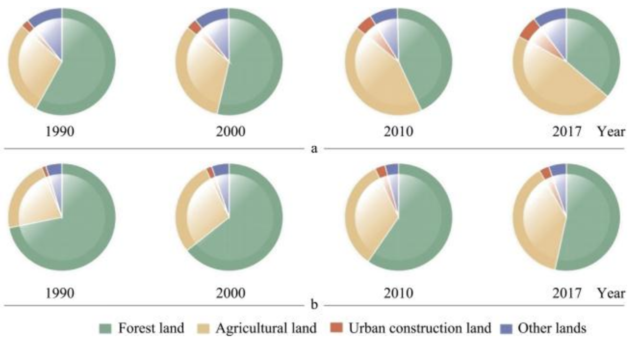
4.3.2 Land Cover Changes at the East Bank of Sumatra

The land development in the 0 to 20 km area at the east bank of Sumatra was found to be significantly higher than in the 20 to 40 km area. The proportion of construction land in the 0 to 20 km area had increased from 1.7% in 1990 to 6.7% in 2017; agricultural land had increased from 29.2% in 1990 to 47.5% in 2017; and the proportion of forest land had decreased by 22.1% (Figure 4a). It was observed that in the 20 to 40 km area, the agricultural development was the mainstay. The agricultural land had increased from 22.3% in 1990 to 38.4% in 2017. Also, the construction land had been growing slowly. However, by 2017, the proportion was still less than 3.5%. The proportion of forest land had been reduced from 71.9% in 1990 to 53.2% in 2017 (Figure 4b).



(a) 0−20 km from the coastline (b) 20−40 km from the coastline

Figure 3 Land cover changes on the west bank of the Peninsular Malaysia



(a) 0−20 km from the coastline (b) 20−40 km from the coastline

Figure 4 Land cover changes on the east bank of Sumatra

5 Discussion and Conclusion

It has been found that after nearly 30 years of port-based construction development, the urbanization of the west bank of the Peninsular Malaysia had been very rapid. It has been observed that due to the rapid population growth in the area, the urban construction land has expanded 1.7 times. Furthermore, due to Sumatra's long distance from the navigational channels and the offshore waters became shallower, and the larger ports were less. This has resulted in the Sumatra's regional economy becoming relatively weak, and the development of construction land on the east bank has been relatively slow. It is recommended that the scale of agricultural development in the study area should be strictly controlled. Also, illegal logging should be prohibited, forest land protection policies should be strengthened, and forest land nature reserves should be established to reduce the damages to the forest environments. In addition, the constructions of sewage treatment infrastructures should be carried out. In particular, it will be necessary to pay close attention to the monitoring and protection of the marine ecological environments, as well as strengthening water quality testing methods and reducing the occurrences of red tides in order to maintain the stability of the ecological environments of the coastal zones.

Author contributions

Yan, J. F. carried out the overall design for the development of the dataset; Gao, S. S. and Xu, M. R. collected and processed the Landsat TM data; Zhang, X. X. collected and processed the Landsat OLI data; Wang, M. H. and Zhang, X. X. designed the models and algorithms, and also conducted the data validation; and Wang, M. H. wrote the data paper.

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