Multitemporal Analysis of Land Cover Changes on Parangtritis Sand Dunes Using NDVI, NDSI, and Clay Index Transformation in 1972-2018

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Summary

Sand covered area in Parangtritis sand dunes has decreased significantly due to massive land-use changes. This research aims to map this sand covered area changes using NDVI, NDSI, and clay index. We use Landsat MSS, TM, ETM+, and OLI & TIRS sensors on red, NIR, and SWIR 1 & 2 bands. The NDVI, NDSI, and clay index are presented in a composite to distinguish sand and non-sand objects, then are classified using supervised technique with ROI from the sand and non-sand land cover. With the annual degradation above 7.71 hectares, it will be all covered by other land uses in eight years.

KEYWORDS: Parangtritis sand dunes, NDVI, NDSI, Clay Index, Multitemporal Landsat Imageries

1. Introduction

Parangtritis Sand Dunes is well known as a unique landform located in Parangtritis coast, Yogyakarta, Indonesia. Its uniqueness lies in the barchan form that mostly is common in arid or semi-arid regions, while Indonesia is located in humid regions (Sunarto, 2014). Unfortunately, this uniqueness is getting endangered in recent decades due to the degradation of the sand covered area. Massive developments of building and tourism sites, deforestation, land-use change for agriculture and aquaculture are the main reasons.

Parangtritis sand dunes in 1957 were the largest sand dunes in South East Asia, with the peak altitude was about 15 metres (Verstappen, 1957 in Martinez, 2008). The sand dunes in Parangtritis coast can exist since all the factors required for the sand dunes formation process are available in this area.

As a marginal land, the Parangtritis sand dunes is prone to land-use change by housing and tourism activities along the coast. Generally, there are five factors that can affect the sand dunes condition, namely (a) housing and recreation, (b) military activity, (c) water disposal, (d) agriculture, aquaculture, and fisheries, and (e) industrial and commercial use (Martinez, 2013). By looking at the phenomenon in Parangtritis sand dunes, the land-use change is mostly affected by agriculture activities such as forestry and farming. From 1992 to 2006, agricultural land-use significantly developed in Parangtritis sand dunes (Fakhrudin, 2010). Therefore, a further analysis related to the land-use change using normalised difference vegetation index, normalised difference sand index, and clay index is needed to

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discover the amount of the land-use change from 1972 to 2018.

2. Materials and Methods

This research uses several generations of Landsat satellites, there are Landsat 1 and 3 MSS (*multispectral scanner*), Landsat 5 TM (*thematic mapper*), Landsat 7 ETM+ (*enhanced thematic mapper*), and Landsat 8 OLI TIRS (*operational land imager and thermal infrared sensor*).

Table 1 Landsat sensors used in this research

Year	Series	Sensor	Bands used	Wavelength (micrometres)	Resolution (metres)	Usage
1972	L1	MSS	B5 (Red)	0.6 – 0.7	60*	NDVI
1978	L3		B6 (NIR)	0.7 – 0.8	60*	
1982						
1988	L5	TM	B3 (Red)	0.63 – 0.69	30	NDVI, NDSI, CI
1991			B4 (NIR)	0.76 – 0.90	30	
1994			B5 (SWIR 1)	1.55 – 1.75	30	
1997			B7 (SWIR 2)	2.08 – 2.35	30	
2000	L7	ETM+	B3 (Red)	0.63 – 0.69	30	NDVI, NDSI, CI
2003			B4 (NIR)	0.77 – 0.90	30	
2006			B5 (SWIR 1)	1.55 – 1.75	30	
2009			B7 (SWIR 2)	2.09 – 2.35	30	
2012						
2015	L8	OLI & TIRS	B4 (Red)	0.636 – 0.673	30	NDVI, NDSI, CI
2018			B5 (NIR)	0.851 – 0.879	30	
			B6 (SWIR 1)	1.566 – 1.651	30	
			B8 (SWIR 2)	2.107 – 2.294	30	

The NDVI, NDSI, and CI indices' transformation require Red, Near Infrared (NIR), and Shortwave Infrared (SWIR) 1 and 2 bands. Each sensor has a slight difference of wavelength interval for the same class. Landsat 1 and 3 MSS did not have SWIR, so it can only be used to transform NDVI. Even so, in 1972 and 1978 the Sand Dunes area was still clean so that NDSI and CI spectral transformations were not needed to distinguish sand and non-sand objects. Meanwhile, the spatial resolution of Landsat 1 and 3 MSS is 60 metres, which is lower than other sensors that have 30 metres spatial resolution (USGS, 2021). This gap of spatial resolution is acceptable, since this research focuses more on spectral transformation analysis with general class of data.

The method to detect land-use and land-cover changes in Parangtritis sand dunes is conducted using spectral transformation with supervised multispectral classification to know the area amount of change. Multispectral imageries between 1972 to 2018 are used to detect the land-use change (Lillesand Kiefer, 2000).

a. NDVI
   NDVI or normalised difference vegetation index is a formula to compare the greenness index of vegetation in the research area together with its density using red and infrared bands (Fadhil, 2013). The formula of NDVI is stated as follows.

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

b. NDSI
NDSI or normalised difference sand index is a spectral transformation of sand value. It is used to identify the sand of the research area using the comparison of SWIR 2 and red bands (Fadhil, 2013). The formula of NDSI is stated as follows:

$$NDVI = \frac{SWIR\ 2 - R}{SWIR\ 2 + R} \quad (2)$$

c. Clay index
Clay index is a comparison between spectral values of SWIR 1 and SWIR 2 (Danoedoro, 2012). The CI is used to identify the existence of clay composition in the research area. It assists to differentiate between sandy and non-sandy objects. The formula of CI is stated as follows:

$$CI = \frac{SWIR\ 1}{SWIR\ 2} \quad (3)$$

d. Supervised Multispectral Classification
This classification is used to differentiate between sandy and non-sandy objects in the research area. The ROI (region of interest) for classification is determined using spectral value of sand object which is acquired from spectral value of sand object in 1972. This consideration is assumed that in 1972, all the area of Parangtritis sand dunes was only covered by sand.

3. Result and Discussion

The result of NDVI, NDSI, and Clay index spectral transformations show as follows:

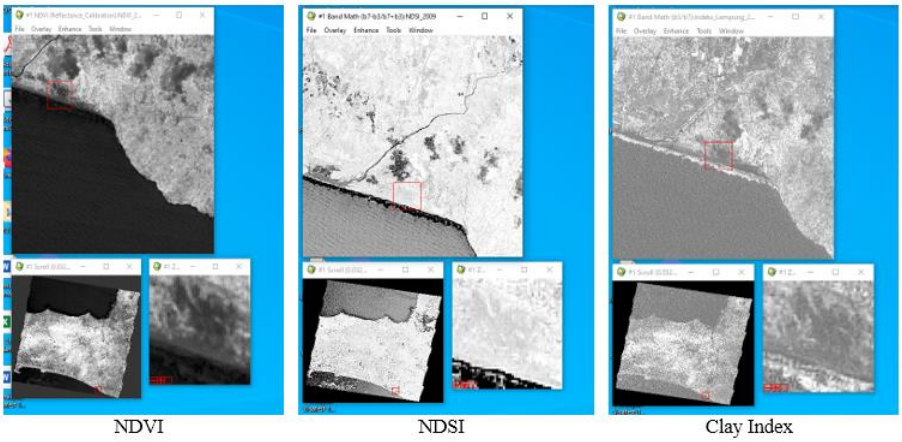
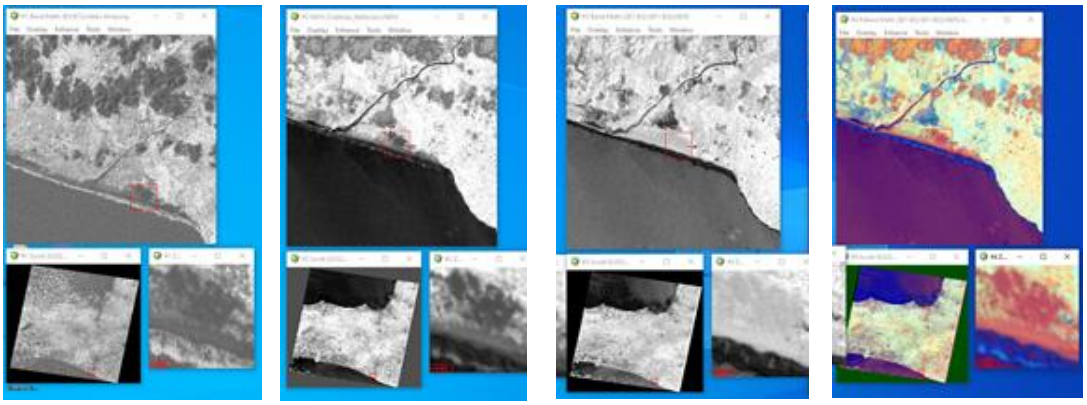


Figure 1 NDVI, NDSI, and CI derived from Landsat in 2009

Figure above shows the Landsat data in 2009, the red box indicates the Parangtritis sand dunes area. The result of NDVI transformation shows that the vegetation covered area has a bright tone, while another area without vegetation has a dark tone. The NDSI transformation shows the sand covered area is represented with grey tone. Different from the NDVI, the result of Clay Index shows that the area that contains clay material has bright tone, while another area that does not contain clay material has dark tone. The use of Clay index is helpful in detecting the land-use and land-cover change in the research area, as now the area is used for farming land. The field assessment in 2020 shows several soil samples that are taken in farming areas containing more clay than sand.

The massive land-use change in the research area resulted in difficulty in analysing the result of NDVI, NDSI, and Clay Index transformation to distinguish sand and non-sand objects. Detection analysis of land uses change cannot be seen visually if it is conducted one-by-one towards the result of such transformations. Therefore, all of them need to be composited.



Clay Index NDVI NDSI Composite

Figure 2 NDVI, NDSI, and CI results compared to its composite

In this composite configuration, NDSI is added into red colour, while NDVI and Clay Index are added into green and blue colour respectively. Its result can ease in interpreting sand objects that are identical as sand dunes and non-sand objects in the research area. In this composite result, we can find that the virgin sand dunes area has red orange colour, while yellow indicates a mixture of sand and vegetation. On the other hand, built are is identified as light cyan. The tone of the red orange colour is affected by the existence of vegetation or built area. The lighter tone indicates the area is mixed with building and/or vegetation, while the darker tone indicates that the sand covered area is purer.

The figure below shows the composite result of NDVI, NDSI, and Clay Index in Parangtritis sand dunes from 1972 to 2018.

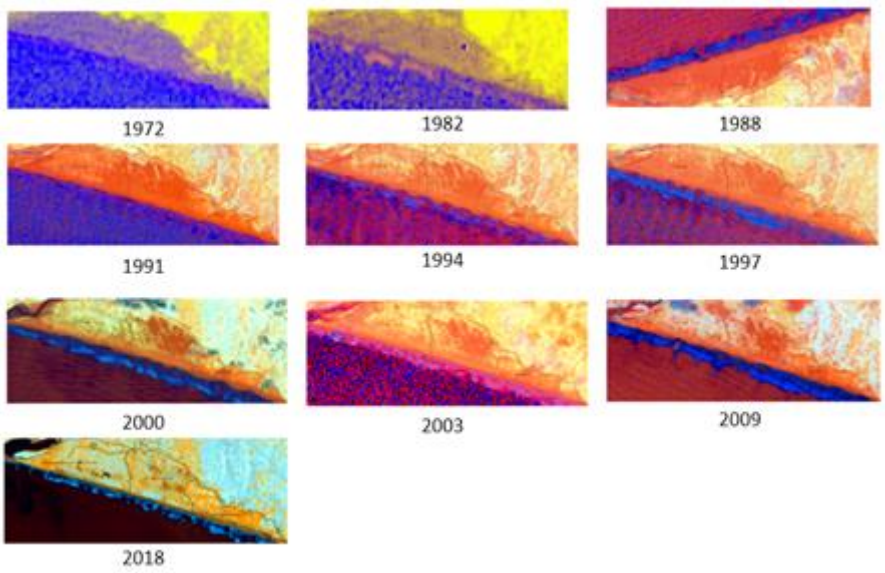


Figure 3 Composite of NDVI, NDSI, and CI from 1972 to 2018

Each composite image is then used in multispectral classification using ROI to derive the amount of change in Parangtritis sand dunes. The classification results as follows:

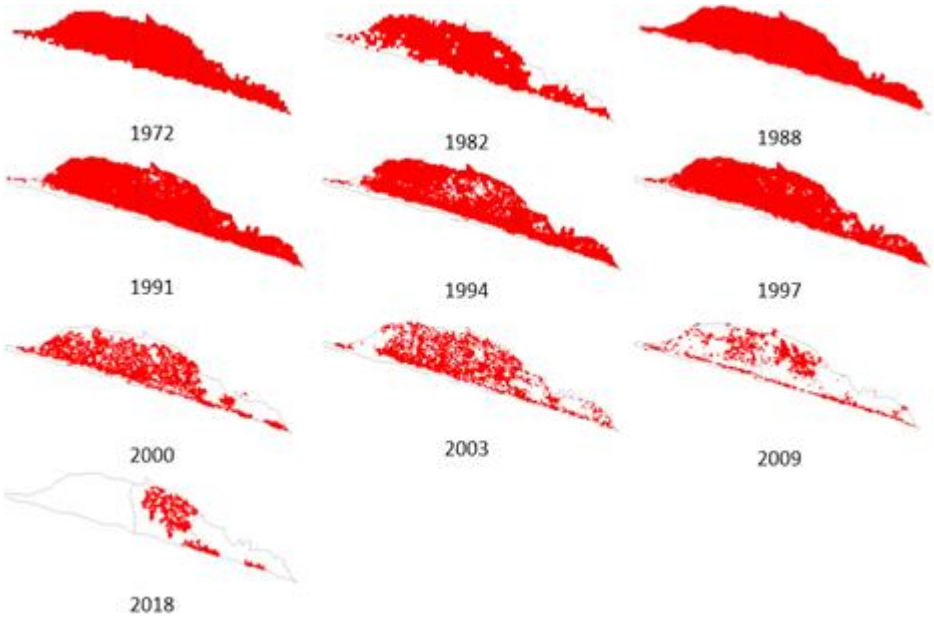
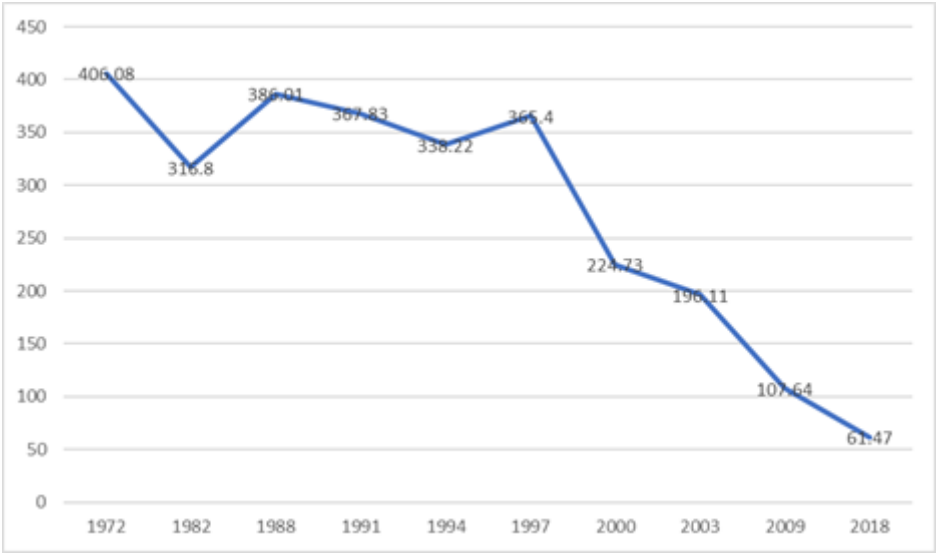


Figure 4 Sand covered area distribution in Parangtritis from 1972 to 2018

The result of these classification shows the amount of significant change in Parangtritis sand dunes from 1972 to 2018. The whole area of sand dunes has 412,8 hectares. Results of the multitemporal analysis are represented in the following graph.



Compared to the total amount of sand dunes, the sand covered area in 1972 was about 406,08 hectares (98 percent), while in 2018 it was only 61.47 hectares (14.9 percent). The annual average sand covered area degradation based on this analysis is above 7.71 hectares. Thus, we estimate the sand dunes will be all covered by other land uses in eight years if no conservation effort is conducted.

4. Conclusion

Multitemporal Landsat imagery and multispectral analysis can be used to detect land-cover and land-use changes in Parangtritis sand dunes. The results of the multispectral analysis carried out on Parangtritis sand dunes from 1972 until 2018 shows that land-use changes were first seen in 1988 and continued to experience intervention until now. In 1972 the sand covered area was 406.08 hectares (98.3 percent), while in 2018 it was only 61.47 hectares (14.9 percent).

5. Acknowledgements

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