GEOSPATIAL DYNAMIC OF VEGETATION COVER CHANGES ON THE SMALL ISLANDS, SOUTH SULAWESI, INDONESIA

(Dinamika Geospasial Perubahan Tutupan Vegetasi di Pulau-Pulau Kecil, Sulawesi Selatan, Indonesia)

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ABSTRACT

Agreement on the extent of mangrove forest in Indonesia has yet existed. The extent of mangrove forest in Indonesia 9 years ago was about 4.13 million ha. Currently, the mangrove has decreased significantly to 2.49 million ha (60%). Remote sensing could play an important and effective role for assessing and monitoring the dynamic of mangrove forest cover. The aim of this study is to measure the changes of the mangrove cover within 20 years period from 1993 to 2013, from 1993 to 2003, and from 2003 to 2013 using multi-temporal Landsat data. The study site was selected in Tanakeke Island, Takalar District, South Sulawesi, Indonesia. Results of the analyses show that the mangrove forest has decreased and it is caused anthropogenic impact.

***Keywords**: geospatial dynamic, mangrove, remote sensing, GIS*

ABSTRAK

Sejauh ini belum ada kesepakatan mengenai luas hutan mangrove di Indonesia. Luas hutan mangrove di Indonesia 9 tahun yang lalu adalah sekitar 4,13 juta ha, akan tetapi sekarang menurun menjadi 2,49 juta ha (60%). Penginderaan jauh memiliki peranan penting dan efektif untuk penilaian dan pemantauan dinamika tutupan hutan mangrove. Tujuan dari penelitian ini adalah untuk mengukur perubahan tutupan hutan mangrove selama 20 tahun dari tahun 1993-2013, 1993-2003, dan 2003-2013, dengan menggunakan citra Landsat multi-temporal. Lokasi penelitian dipilih di Pulau Tanakeke, Kabupaten Takalar, Sulawesi Selatan, Indonesia. Hasil analisis menunjukkan bahwa luas hutan mangrove mengalami penurunan yang disebabkan oleh pengaruh dari manusia.

***Kata Kunci**: dinamika geospasial, mangrove, penginderaan jauh, SIG*

INTRODUCTION

Mangrove forests, found in the inter-tidal zone in the tropics and subtropics, play an important role in stabilizing shorelines and reducing the devastating impact of natural disasters such as tsunamis and hurricanes. They also provide important ecological and social goods and services including breeding and nursing grounds for marine and pelagic species, food, medicine, fuel, and building materials for local communities. These forests, however, are declining at an alarming rate, perhaps even more rapidly than inland tropical forests, and much of what remains is in degraded condition (Wilkie & Fortune, 2003).

As a complex and unique ecosystem, mangrove has important functions and benefits for coastal environments (Rusila *et al*., 1999; Bengen, 1999) such as: waves and storms muffler, protector of abration, mudguard, and sediment trapper; producer of some detritus from the leaves and branches of mangrove trees; nursery ground, feeding ground and spawning ground of various types of fish, shrimp and other marine biota; producer of wood for contruction materials, firewood, charcoal materials, paper materials, and furniture-making materials, and supplier of fish larvae, shrimp and other marine biota.

Indonesia has lost of more than 1.2 Mha of its mangroves since the mangrove forest cover was at 4.2 Mha in 1980 (FAO, 2007). Amongst the immediate impacts of the mangrove loss is the decline in fish production, since mangroves are vital fish nurseries and rapid erosion in the absence of buffer against high waves. About 60% of this loss has been attributed to the conversion of mangroves to brackish water aquaculture ponds, which peaked in the 1980’s and 1990’s during a period of aquaculture expansion known as the blue revolution.

There is no agreement for the extent of vegetation mangrove in Indonesia, but invarious forums it is usually used the number of 4.25 million ha for that. The occurence of mangrove forest reduction is generally caused by exploitation and transferring of appropriations of land. At approximately 9 years ago, the extent of mangrove forest in Indonesia was about 4.13 million ha, but it last about 2.49 million ha (60%) nowadays.

South Sulawesi is facing massive mangrove forest destruction over the last 30 years. Deforestation and pollution have taken their toll and damaged at almost 90 percent of the total original areas. Before 1980s, the mangrove forest in South Sulawesi was over 214,000 hectares. The conversion of the mangrove forest into fishpond reduced the area into 23,000 hectares in the early 1991, or has decreased by 61 percent. The conversion of mangrove forests into fish farms was as a result of the government policy during the early 1980s that instructed local fisheries and maritime affairs offices to carry out intensification of shrimp cultivation, which was then become the state's major commodity export and revenue.

The mangrove forest in Tanakeke Island, Takalar district, South Sulawesi was accounted for 1,770 hectares in the early 1980s, however the mangrove lastly accounted for 500 hectares only after been converted to midle and failed fish farms. The phenomenon of mangrove forests degradation in Tanakeke Island is worth while to receive specific attention, given that Tanakeke Island is a small island in South Sulawesi with precious mangrove forests in coastal region.

The aim of this study is to analyze spatial dynamic of mangrove within 20 years from the 1993 to 2013, from from 1993 to 2003, and from 2003 to 2013 using multi-temporal Landsat.

METHOD

The study area is located in Tanakeke Island, Takalar District, South Sulawesi, Indonesia. The geographical boundary of the study area between 119°16'55" East and 05°29'34" South (**Figure 1**).

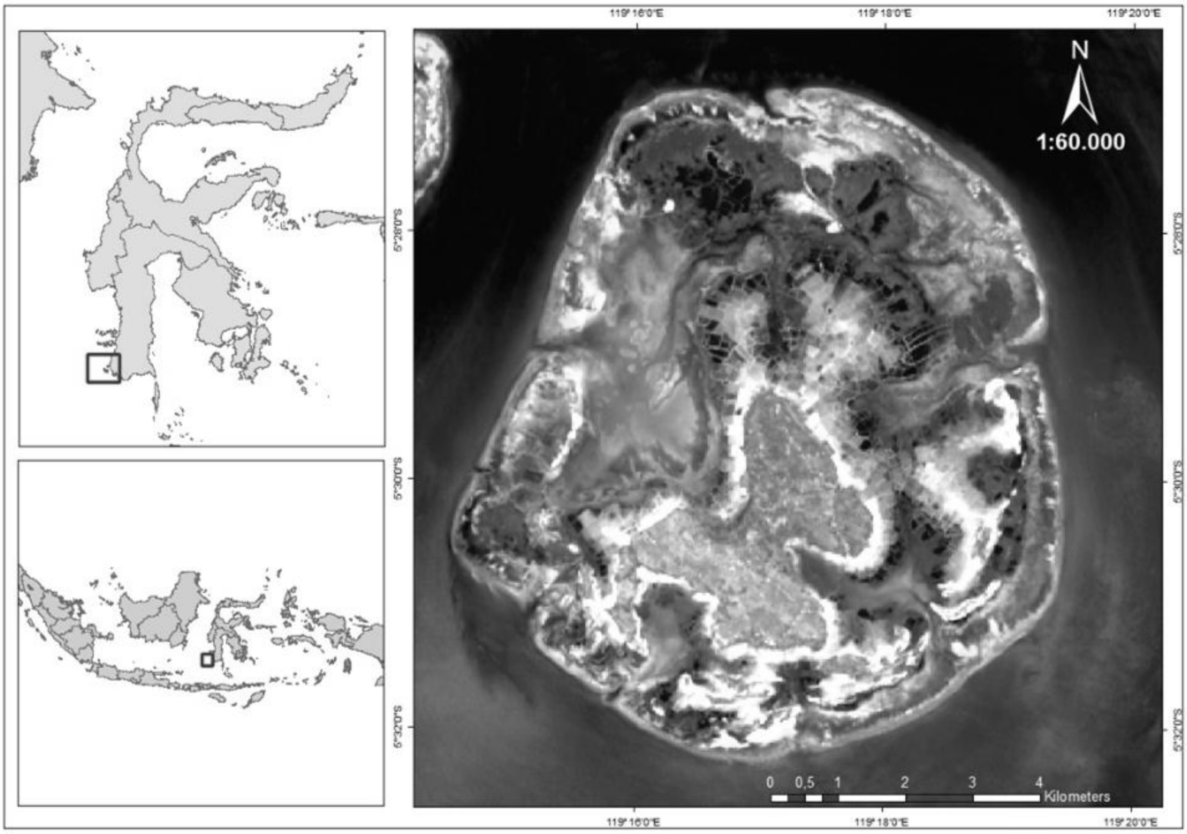


Figure 1. Map of the study area, Tanakeke Island.

A set of Landsat data, consisted of three Landsat Thematic Mapper (TM) images (26 August 1993), a Landsat Enhanced TM Plus (ETM+) image (21 July 2003), and a Landsat 8 (Operational Land Imager, OLI) image (27 April 2013) acquired from the US Geological Survey (USGS), was used in this study. The Landsat TM data have seven spectral bands, with a spatial resolution of 30 m for bands 1–5 and 7 (**Table 1**). The TM band 6 (thermal infrared) is acquired at 120 m resolution but is resampled to 30 m pixels. The Landsat ETM+ data consist of eight spectral bands with a spatial resolution of 30 m for bands 1–7. The ETM+ band 6 (thermal infrared) is acquired at 60 m resolution but is resampled to 30 m pixels. The Landsat 8 data have nine spectral bands with a spatial resolution of 30 m for bands 1–7 and 9. The ETM+ and OLI band 8 (panchromatic band) have a spatial resolution of 15 m. The spectral bands are generally between the optical and short-wave-infrared regions, except for band 9 of Landsat 8 data, which has a cirrus wavelength between 1.36 and 1.38 µm.

Table 1. Satelite data.

Satelite	Resolution	Pathand Row	Acquisition
Landsat MSS	60	122/064	28-10-1972
Landsat TM	30	114/064	26-08-1993
Landsat ETM (+)	30	114/064	21-07-2003
Landsat 8	30	114/064	27-04-2013

Image Processing Analysis

The data processing is composed of four main steps (**Figure 2**), including: (1) geometric correction, (2) preliminary analysis, (3) image classification, (4) accuracy assesment, and (5) post classification.

Geometric Correction

The varying pixel sizes of the different images were changed into a common map grid based on a reference image/map (Solomon & Breckon, 2011). Evenly-distributed GCPs (Ground Control Points) were selected in the different images and registered with the reference images/maps. A RMS (Root Mean Square) error of less than 0.5 pixels was accepted for the transformation. Resampling is performed by converting different pixel sizes to the same final image pixel sizes.

Preliminary Analysis

Preliminary analysis methods consisted image enhancement, composite RGB, and cropping was applied after the satellite images were geometrically corrected.

Image Classification

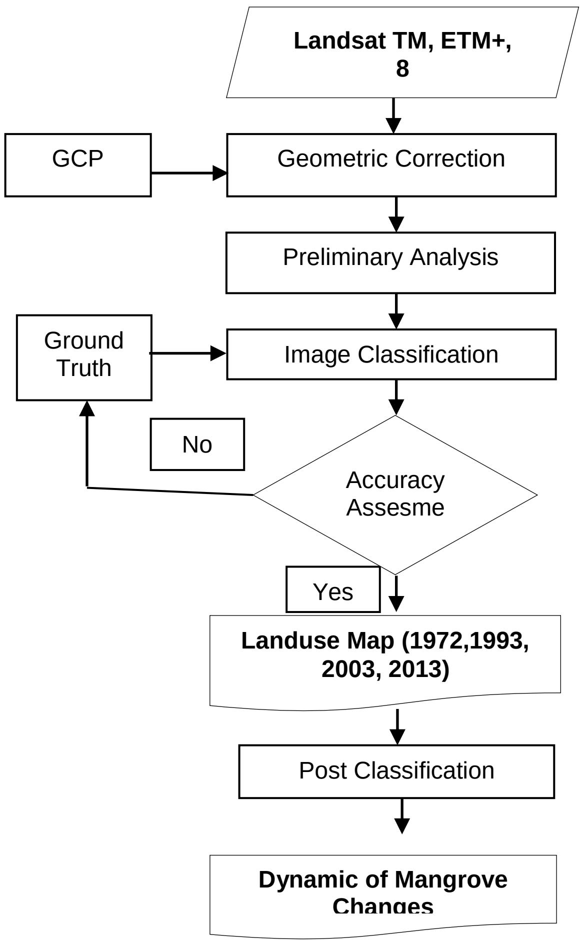
Image classification is a process of grouping all of the pixels to an image consisting of classes (Tso & Mather, 2009). Time series data Landsat imagery were used in this research to obtain information about actual landuse from each time series. A classification process in this research was used to determine the number of classes as representatives of the entities. Visual classification is semi-automatic method using screen digitizing technique. Detection performed on objects by making delineation of the outer limits of the group has the same color which differentiates then from the others.

Accuracy Assessment

Accuracy test was used to calculate each error's of all the shallow water habitat cover as a result of the satellite imagery classification by using a confusion matrix (Sutanto, 1986). The following is a table of confusion matrix form (**Table 2**). Image validation was counted based on the table such as Overall Accuracy (OA), Producer's Accuracy (PA), and User's Accuracy (UA). OA is a percentage of sample units that are classified accurately. PA and UA are ways of representing individual category accuracies instead of just the OA. PA is a percentage of probability average of a sample unit that refers to distribution of each class that has been classified in the field, while UA is a percentage of sample unit that actually represents the classes in the field. The confusion matrix in **Table 2** helped the transition of equation and mathematical notation easy to understand.

Post Classification

changes in the extent of mangrove forests during the periods 1993 to 2003, 2003 to 2013, and 1993 to 2013 were examined based on the classification maps, to gain geographic understanding of the spatio temporal evolution of the landuse in the region (Gao, 2009).



Figue 2. Flow chart of image processing.

Table 2. Confusion matrix.

Classified to class	Reference (sample point)			Row Total (N_{i+})	User's Accuracy
	1	2	K		
1	N_{11}	N_{12}	N_{1K}	N_{1+}	N_{11}/N_{1+}
2	N_{21}	N_{22}	N_{2K}	N_{2+}	N_{22}/N_{2+}
K	N_{K1}	N_{K2}	N_{KK}	N_{K+}	N_{KK}/N_{K+}
Column Total (N_{+j})	N_{+1}	N_{+2}	N_{+K}	N	
Producer's Accuracy	N_{KK}/N_{+1}	N_{22}/N_{+2}	N_{KK}/N_{+K}		

Source: Congalton & Green, 1999.

RESULT AND DISCUSSION

Image Classification

Identification of landuse in Tanakeke Island using selected Landsat TM, Landsat ETM+, and Landsat 8 to the years 1993, 2003 and 2013. In this study, the process was done by visual classification method to obtain landuse for each time series. The combination bands of 453 (RGB) was used in the interpretation of satellite image. This band combination was used because in the visual interpretation, the appearance of natural vegetation and planted areas can be seen clearly. A classification scheme was developed to obtain a broad level of classification, to derive various landuse classes, i.e., mangrove, aquaculture, bare land, settlement, and shallow water. The classification result for the 1993, 2003, and 2013 can be seen in **Figure 3.**

Accuracy Assessment

Quantitative assessment was performed using high resolution satellite data, Google Earth, Bing Maps,and ALOS AVNIR stratified random sampling approach was applied to select 50 sample points formangrove, aquaculture, bare land, settlement, and shallow water classes, respectively. An error matrix was generated with an overall classification accuracy of 87.78%. Producer's and user's accuracy for mangrove is 93%.

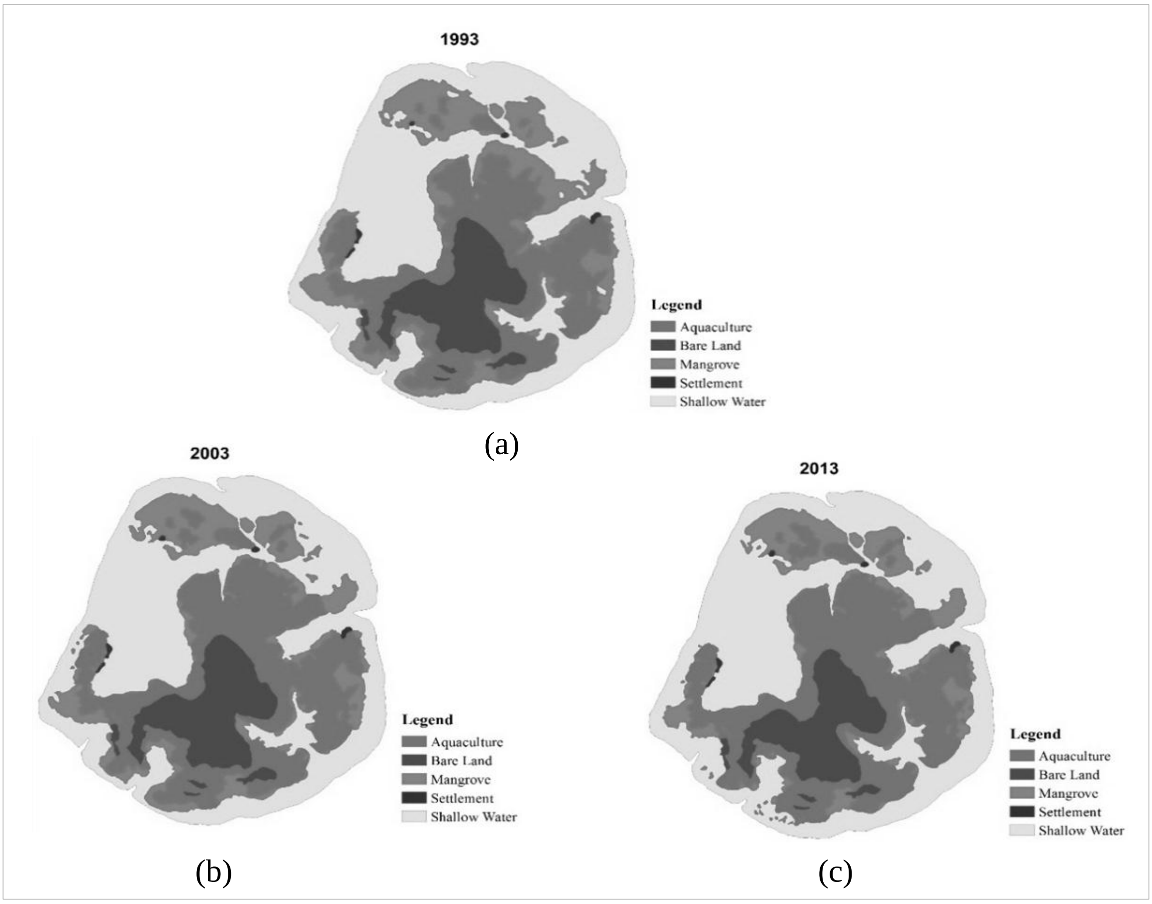


Figure 3. Landuse map of Tanakeke Island **(a)** in 1993, **(b)** 2003, and **(c)** 2013.

Dynamic Changes of Mangrove Cover

The mangrove cover change dynamic was studied over more than two decades during the year 1993 to 2013. The result of landuse distribution for years 1993, 2003, and 2013 can be seen in the **Table 3**.

Table 3. Areal estimates of major landuse types.

Landuse	Area (Ha)		
	1993	2003	2013
Mangrove	1,330.05	1,077.56	951.11
Aquaculture	1,690.80	1,963.61	2,068.18
Bare Land	769.10	763.56	705.51
Settlement	17.85	18.39	18.72
Shallow Water	2,971.71	2,956.38	3,085.97

During the period of 1993 to 2013, mangroves in the Tanakeke Island had decreased by 428.94 ha (32.25%). The rate of change, however, was not uniform throughout the 1993 to 2003 and 2003 to 2013. The deforestation rate during 1993 to 2003 was the highest in Tanakeke Island. The mangrove area decreased by 252.49 ha (18.98%). In addition, compared to the research results by Brown (2007) during the 1990's, the transmigration department had cleared 400 hectares of mangroves for aquaculture development, while local landowners, both individually and in partnership with investors converted an additional 800 ha. By the mid of 1990's, 1200 hectares of aquaculture ponds (mix of milkfish and prawn aquacultures) had been developed. During the period of 2003 to 2013, mangrove in Tanakeke Island was decreased by 176.45 ha (16.37%). The extents of major mangroves cover during the three time periods area presented in **Table 4**.

Table 4. Areal and percent landuse changes from 1993, 2003, and 2013.

Land Cover	Area Change (ha)					
	1993 to 2003		2003 to 2013		1993 to 2013	
	Ha	%	Ha	%	Ha	%
Mangrove	(-)252.49	18.98	(-)176.45	16.37	(-)428.94	32.25
Aquaculture	(+)272.81	13.89	(+)104.57	5.06	(+)377.38	18.25
Main Land	(-)5.54	0.72	(-)58.04	7.60	(-)63.58	8.27
Settlement	(+)0.54	2.94	(+)0.33	1.76	(+)0.87	4.65
Shallow Water	(-)15.32	0.52	(+)129.59	4.20	(+)114.26	3.70

Changes of Mangrove in 1993 to 2003

The mangroves in Tanakeke Island has decreased by 269.42 ha, those converted to aquaculture (14.19%), settlement 0.25 ha (1.37%), shallow water 1.48%. The mangroves cover has increase as a result of the changes of aquaculture (0.40%) and shallow water (44.39 ha or 1.84%) (**Table 5** and **Table 6**).

The changes on mangroves cover during the priod of 1993 to 2003 occured in the northern part of the Tanakeke Island, where mangroves had been converted to aquaculture and settlement. The changes of mangroves into shallow water was occured near the shoreline in west of Tanakeke Island. The spatial dynamics of mangroves cover from 1993 to 2003 can be seen in **Figure 4**.

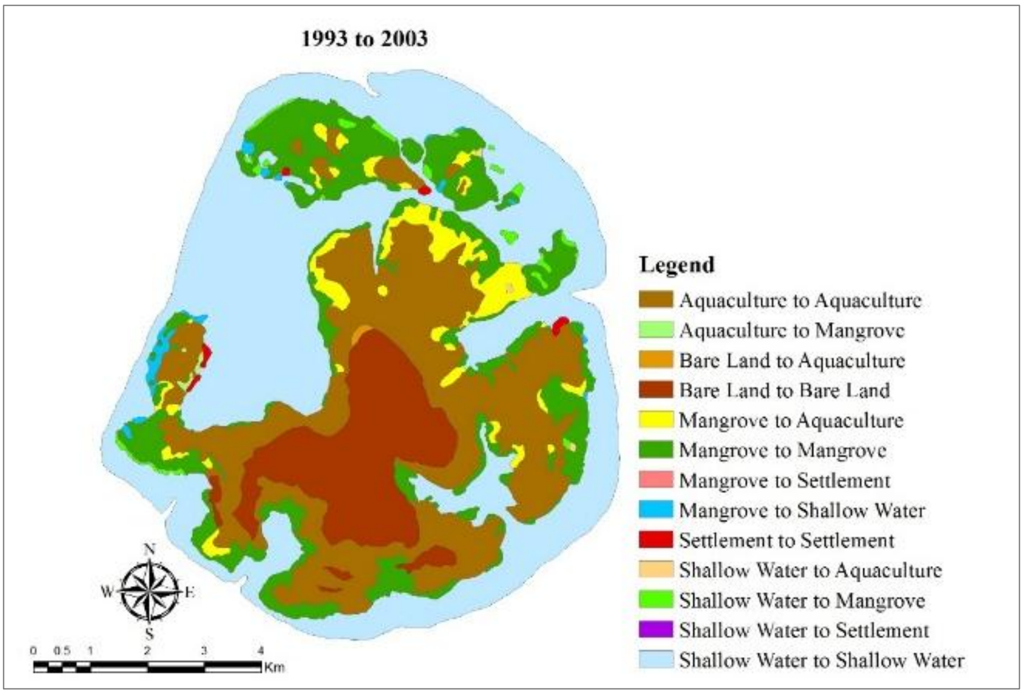


Figure 4. Post classification landuse map of Tanakeke Island in 1993 to 2003.

Changes of Mangrove in 2003 to 2013

Between 2003 to 2013, mangroves loss by 61.42 ha (5.70%) to aquaculture, decreased by 122.91 ha (11.41%) to shallow water, and increased by 7.89 ha (0.27%) from shallow water (**Table 7** and **Table 8**). Spatial dynamics of mangrove cover from 2003 to 2013 can be seen in **Figure 5**.

Table 5. Landuse changes from the 1993 to 2003.

Landuse in 1993	Landuse area in 2003 (ha)				
	Mangroves	Aquaculture	Bare Land	Settlement	Shallow Water
Mangrove	1,015.99	269.42	-	0.25	44.39
Aquaculture	6.75	1,684.05	-	-	-
Bare Land	-	5.54	763.56	-	-
Settlement	-	-	-	17.85	-
Shallow Water	54.82	4.60	-	0.29	2,911.99

Table 6. Landuse changes from the 1993 to 2003.

Landuse in 1993	Landuse in 2003 (%)				
	Mangroves	Aquaculture	Main Land	Settlement	Shallow Water
Mangroves	76.39	14.19	0.00	1.37	1.48
Aquaculture	0.40	99.60	0.00	0.00	0.00
Main Land	0.00	0.72	99.28	0.00	0.00
Settlement	0.00	0.00	0.00	100.00	0.00
Shallow Water	1.84	0.15	0.00	0.01	97.99

Table 7. Landuse changes from the 2003 to 2013.

Landuse in 2003	Landuse area in 2013 (Ha)				
	Mangroves	Aquaculture	Bare Land	Settlement	Shallow Water
Mangroves	893.2	61.42	-	-	122.91
Aquaculture	-	1,948.7	-	-	14.89
Bare Land	-	58.04	705.5	-	-
Settlement	-	-	-	18.39	-
Shallow Water	7.89	-	-	0.33	2,948.16

Table 8. Landuse changes from the 2003 to 2013.

Landuse in 2003	Landuse in 2013 (%)				
	Mangroves	Aquaculture	Main Land	Settlement	Shallow Water
Mangroves	82.89	5.70	0.00	0.00	11.41
Aquaculture	0.00	99.24	0.00	0.00	0.76
Main Land	0.00	7.60	92.40	0.00	0.00
Settlement	0.00	0.00	0.00	100.00	0.00
Shallow Water	0.27	0.00	0.00	0.01	99.72

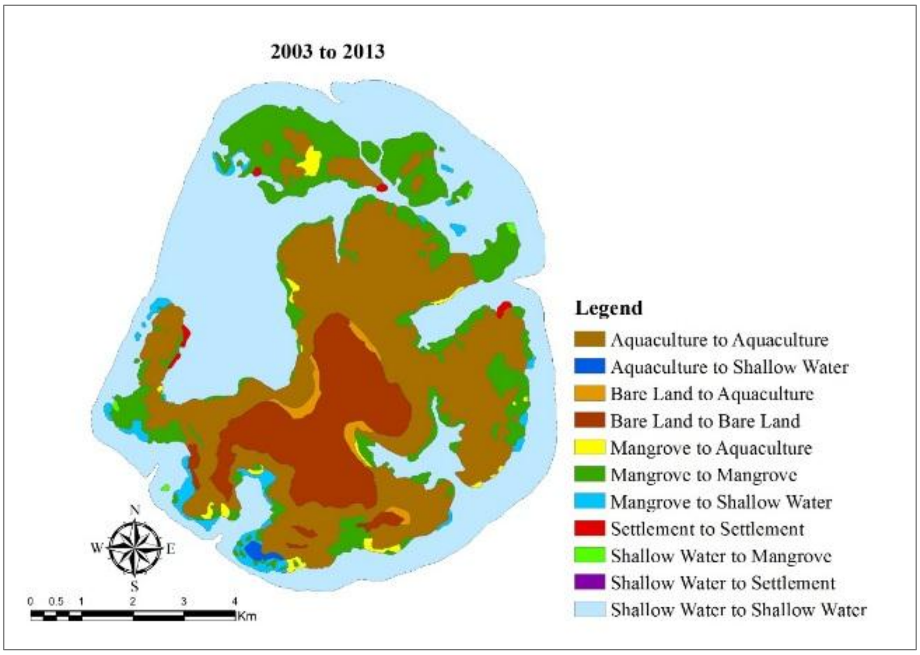


Figure 5. Post classification landuse map of Tanakeke Island in 2003 to 2013.

Changes of Mangroves in 1993 to 2013

Mangroves in Tanakeke Island decreased by 330.84 ha (24.87%) to aquaculture, decreased by 0.26 ha (0.02%) to settlement, decreased by 151.32 ha (11.38%) to shallow water, and increased by 46.73 ha (1.57%) from shallow water (**Table 9** and **10**). Spatial dynamics of mangrove cover from 1993 to 2013 can be seen in **Figure 6**.

Table 9. Landuse changes from the 2003 to 2013.

Landuse in 1993	Landuse area in 2013 (Ha)				
	Mangrove	Aquaculture	Main Land	Settlement	Water Bodies
Mangroves	847.64	330.84	-	0.26	151.32
Aquaculture	6.75	1669.16	-	-	14.89
Main Land	-	63.58	705.51	-	-
Settlement	-	-	-	17.85	-
Water Bodies	46.73	4.60	-	0.62	2919.76

Table 10. Landuse changes from the 1993 to 2013.

Landuse in 1993	Landuse in 2013 (%)				
	Mangroves	Aquaculture	Main Land	Settlement	Shallow Water
Mangroves	63.73	24.87	0.00	0.02	11.38
Aquaculture	0.40	98.72	0.00	0.00	0.88
Main Land	0.00	8.27	91.73	0.00	0.00
Settlement	0.00	0.00	0.00	100.00	0.00
Shallow Water	1.57	0.15	0.00	0.02	98.25

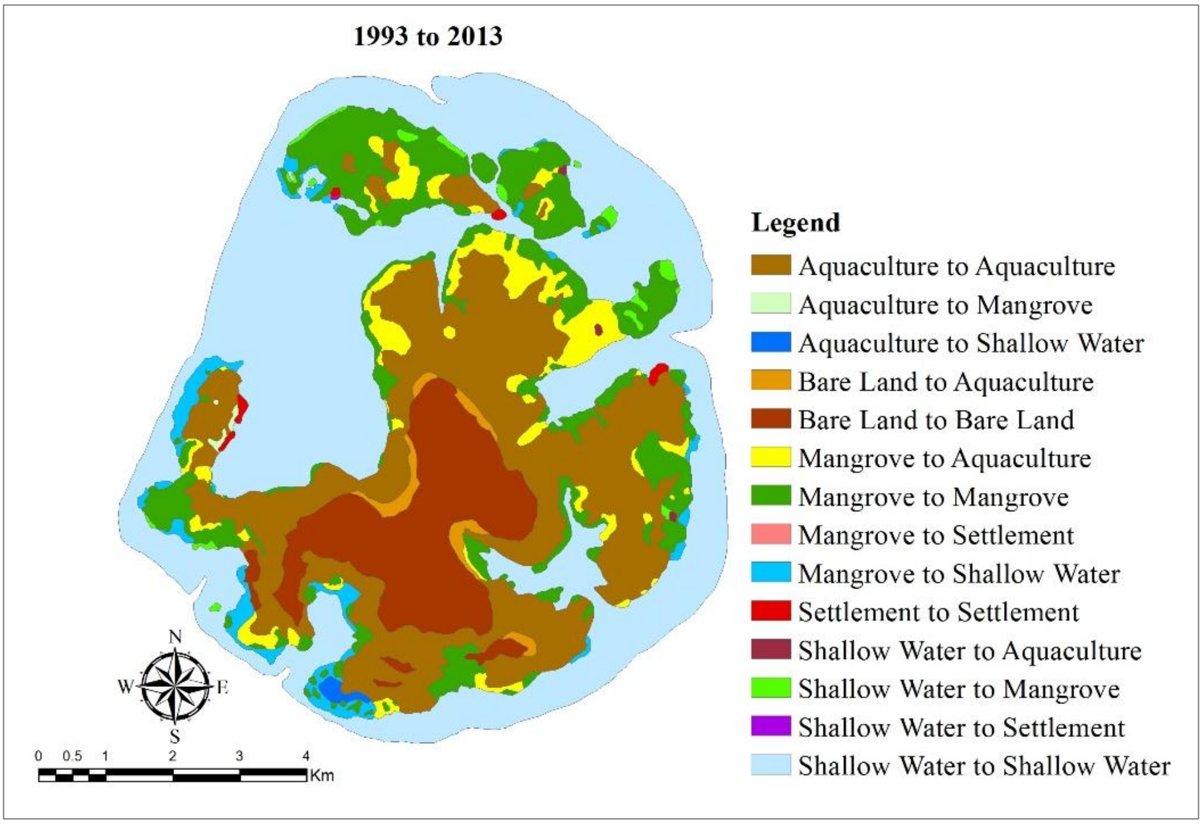


Figure 6. Post classification landuse map of Tanakeke Island in 1993 to 2013.

CONCLUSION

Result of the analyses shows that the mangrove extent for the Tanakeke Island has changed largely during the last 20 years, reached at approximately 32.25% loss. The loss of mangroves in Tanakeke Island inflencing by the anthropogenic factors consisted of aquaculture conversion, settlement, and charcoal industry.

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