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Mangrove Changes in Pannikiang Island Barru Regency South Sulawesi

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Abstract: Mangroves play an important role in coastal community livelihoods of South Sulawesi. However, due to excessive and unsustainable use, mangroves experience degradation and deforestation in the past two decades. This study aims to detect mangrove extents, densities, and distributions changes during the periods 1997, 2007, and 2018 in Pannikiang Island, Barru Regency. We used three Landsat satellite imageries with acquisition 1997, 2007, and 2018 and implemented the multispectral classification and NDVI transformation methods, and the results were tested by ground truth. The results showed mangrove extents in 1997, 2007, and 2018 were 94.83 ha, 92.07 ha, and 91.64 ha, respectively. During these periods, mangroves decrease by 3.19 ha or an annual average of 0.15 ha. The decrease is caused by the expansion of settlements and aquaculture ponds. In 1997, the mangroves high-density class about 61.74 ha, moderate-density 14.19 ha, and low-density of 18.6 ha. In 2007, the high and low-density classes decreased to 54.53 ha and 12.29 ha, while the moderate-density increase to 25.35 ha. Finally, in 2018, the high-density class continues to decline by 43.36 ha, while for the low and moderate classes increases 15.34 ha and 32.67 ha, respectively, compared to the previous decade.

Keywords: Mangrove change, Remote Sensing, Landsat imagery, Pannikiang Island, South Sulawesi.

1. Introduction

Mangrove forests are one of the tropical forests that can be found in intertidal areas (between sea and land) and are dominated by trees and shrubs [1]. They are one of the essential and productive coastal ecosystems. This forest provides products such as firewood, charcoal, food, medicines, and building materials. Besides, mangrove forests offer environmental services such as carbon sequestration, coastal protection from erosion and seawater intrusion, spawning areas, and the development of marine animals, including pelagic fish, education, research, and ecotourism that significant supporting for the human well-being [2, 3].

The most recent global mangrove areas are 16.4 million hectares in 2014 and distributed in 105 countries, but mainly concentrated in 20 countries [4]. However, over-exploitation of the ecosystem products for commercial (such as firewood, timber, and charcoal products) and conversion into other land uses (such as settlements, mining, agricultural land, and aquaculture ponds), but primarily is aquaculture development [5]. Aquaculture development caused there are 914.2 thousand hectares of the global mangrove forests had deforested and degraded during the period 2000 - 2014, and resulting in an annual loss between 0.26 – 0.64% during that period [4]. Indonesia, with the largest mangrove area in the worldwide (26% of total global mangrove areas), mangrove lost about 436 thousand hectares during the period 2000 – 2014 [4].

In South Sulawesi, the main driver of mangrove deforested is aquaculture development [2, 6]. Mangrove forest cover areas of South Sulawesi were around 100 thousand hectares in the 1950s [7]. However, wood cutting activity for many purposes and expansion of aquaculture ponds for shrimp production caused mangrove deforested to approximately 12 thousand in 2005 [8]. The government and NGOs have applied many mangrove restoration projects in this region for restoring the mangrove area, biodiversity loss, and to improve the mangrove ecosystem services in the past two decades. However, the drivers of mangroves damage have been sustained.

Considering the scale and continue of mangrove deforestation in South Sulawesi and the protection and sustainable management of this forest is imperative to handle these problems. However, the importance of up to date mangrove data and information still lacks for contribution in decision-making. Therefore, the objective of this research is to detect mangrove extents and densities changes during the periods 1997, 2007, and 2018 in Pannikiang Island, Barru Regency. This island is one of mangrove rich spots in South Sulawesi but having disturbed in the last two decades, which has not been rigorously investigated regarding its changes.

2. Methods

2.1. Study Area

This research was carried out in the main mangrove area in Barru Regency, namely on Pannikiang Island (Figure 1) and included in the area of Madello Village, Balusu District. The island is 15 km from the city of Barru and can be accessed by boat for about 30 minutes. The city of Barru itself has a distance of 108 km from Makassar, the capital of South Sulawesi. The island is inhabited by 55 households whose heads of households generally work as fishermen.

This island is known as one of the mangrove ecotourism areas in South Sulawesi and is overgrown with dominant mangrove trees mainly from the species *Rhizophora stylosa* [9]. The island is a habitat for a variety of fauna, especially for thousands of bats that perched on mangrove trees [10].

Figure 1. Pannikiang Island, Barru Regency with sample plots distribution of ground truth.

2.2. Data Collection and Analysis

To detect the mangrove extent, distribution, and density changes, this study used Landsat satellite imagery with different recording times, namely 1997, 2007, and 2018. These images were downloaded from http://earthexplorer.usgs.gov/. In image processing and analysis, ER Mapper 7.0 and Envi 4.5 software (specifically for Landsat image gap-filling in 2007) were used. A geometric correction was carried out using a ground control point (GCP) from digital topographic maps to geocode the image [2]. The root-mean-square error (RMSE) should not exceed 0.5 pixels [11]. False-color composite/FCC for image enhancement was produced from three bands (Image 1997 and 2007 used 4,5 and 3 bands, respectively, while image 2018 used 5, 4 bands) [2, 12]. Image classification to categorize all pixels in an image into land cover classes was classified by using the Supervised Maximum Likelihood method [2,12]. Mangrove density in five interval classes (highest, moderate, and low densities) was extracted using band 8 as near-infrared (NIR) and band 4 as red of NDVI [2, 12]. NDVI values ranged from -1 to 1. A value near to zero characterizes no vegetation, while near to +1 shows a high density of mangrove [13].

Furthermore, the accuracy assessment for testing the classification accuracy of mangrove covers and density results was tested by a ground truth and a confusion matrix method [2]. A total of 8 GCP was selected using a random stratified method to represent mangrove density classes.

3. Results and Discussion

3.1. Mangrove Extent Changes

Based on the multispectral classification of Landsat imageries in 1997, 2007 and 2018, there are five categories of land cover in Pannikiang Island, namely *laut* (ocean), mangrove, *lahan terbuka* (bare land), *permukiman* (settlement), and *tambak* (aquaculture pond) (Figure 2).

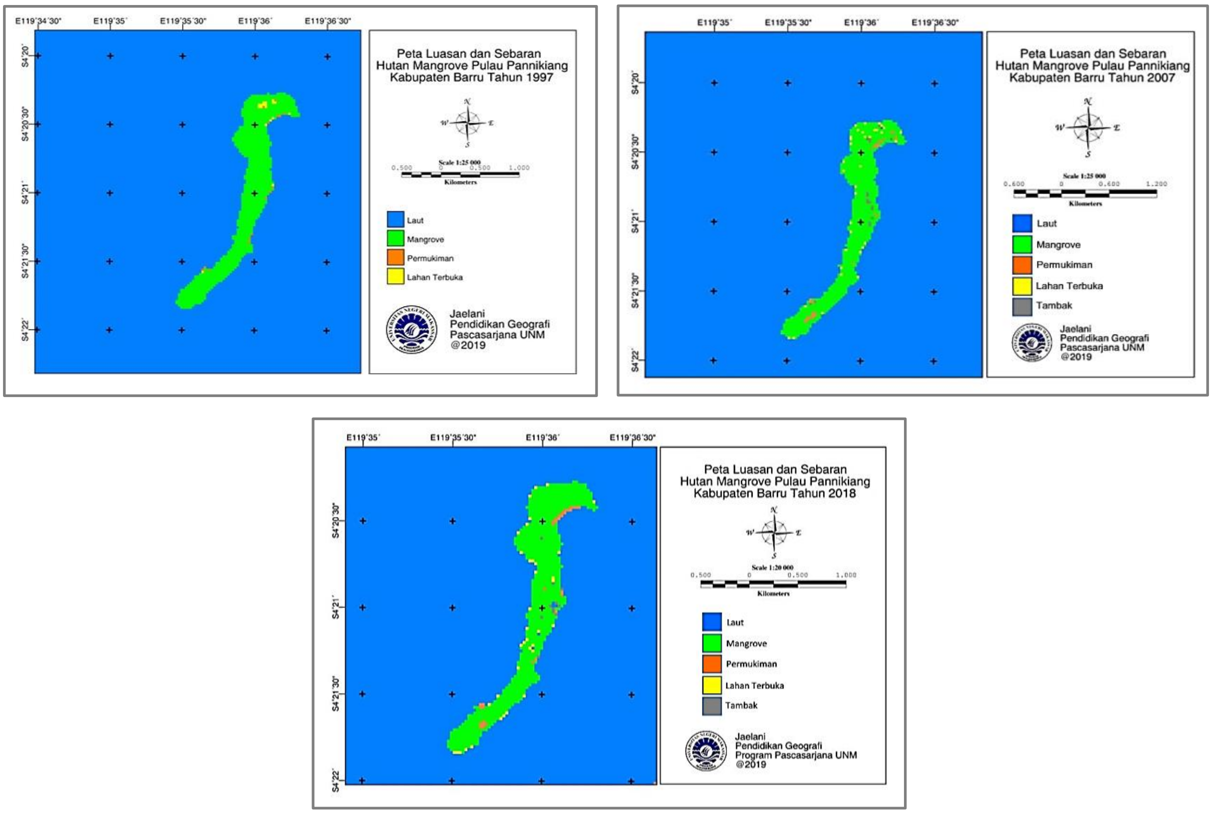

Figure 2. Mangrove extent changes during the period 1997, 2007, and 2018.

Mangroves are the main covers on this island, which in 1997 reaches 94.83 ha, 2007 reaches 92.07 ha, and in 2018 reaches 91.64 ha. The mangroves cover areas decreases by 3.19 ha (2.73%) or an average annual rate of 0.15 ha (0.13%) over the past two decades. The annual decreasing rate of mangrove in this area is much lower than the annual decreasing rate of mangrove global (0.26 – 0.64%), as reported by [4], and in the Takalar regency, South Sulawesi (1 – 5 %) as published by [2]. This decrease due to the settlements and aquaculture ponds development, which increased by 1.07 ha (1.12%) and 1.92 ha (1.98%) during the period 1997 to 2007 and 2007 to 2018 (Table 1). On the other hand, the bare land decreases by 0.72 ha (0.73%) due to the growth and development of mangrove areas that occurred between 1997 and 2007. During the past three, the decline of mangrove cover areas is still relatively low, but efforts to protect and preserve mangrove forests need to be continued to maintain the sustainability of the functions and benefits of these ecosystems (Figure 2, Table 1).

Table 1. Mangrove extent changes during the period 1997, 2007, and 2018

Land cover	Extent 1997 (Ha)	%	Extent 2007 (Ha)	%	Extent 2018 (Ha)	%	Changes 1997-2007 (Ha)	%	Changes 2007-2018 (Ha)	%	Changes 1997-2018 (Ha)	%
Mangrove	94.83	96.96	92.07	94.29	91.64	94.59	-2.76	-2.68	-0.43	+0.31	-3.19	-2.37
Bare land	1.62	1.66	1.95	2.00	0.90	0.93	+0.33	+0.34	-1.05	-1.07	-0.72	-0.73
Settlement	1.35	1.38	2.10	2.15	2.42	2.50	+0.75	+0.77	+0.32	+0.35	+1.07	+1.12
Aquaculture pond	0.00	0.00	1.53	1.57	1.92	1.98%	+1.53	+1.57	+0.39	+0.42	+1.92	+1.98
Total	97.80	100.00	97.65	100.00	96.88	100.00	-0.15		-0.77		-0.92	

(+): increase, (-): decrease

3.2. *Mangrove Distribution and Density Changes*

The mangrove high (*tinggi*) density spread throughout the entire island in 1997 and 2007 and during these period, low (*rendah*) and moderate (*sedang*) mangrove densities mainly concentrate in the north and along the coastline of this island, while in 2018, moderate density distributes mostly in the middle of the island and the low density also along the coastline of this island (Figure 3).

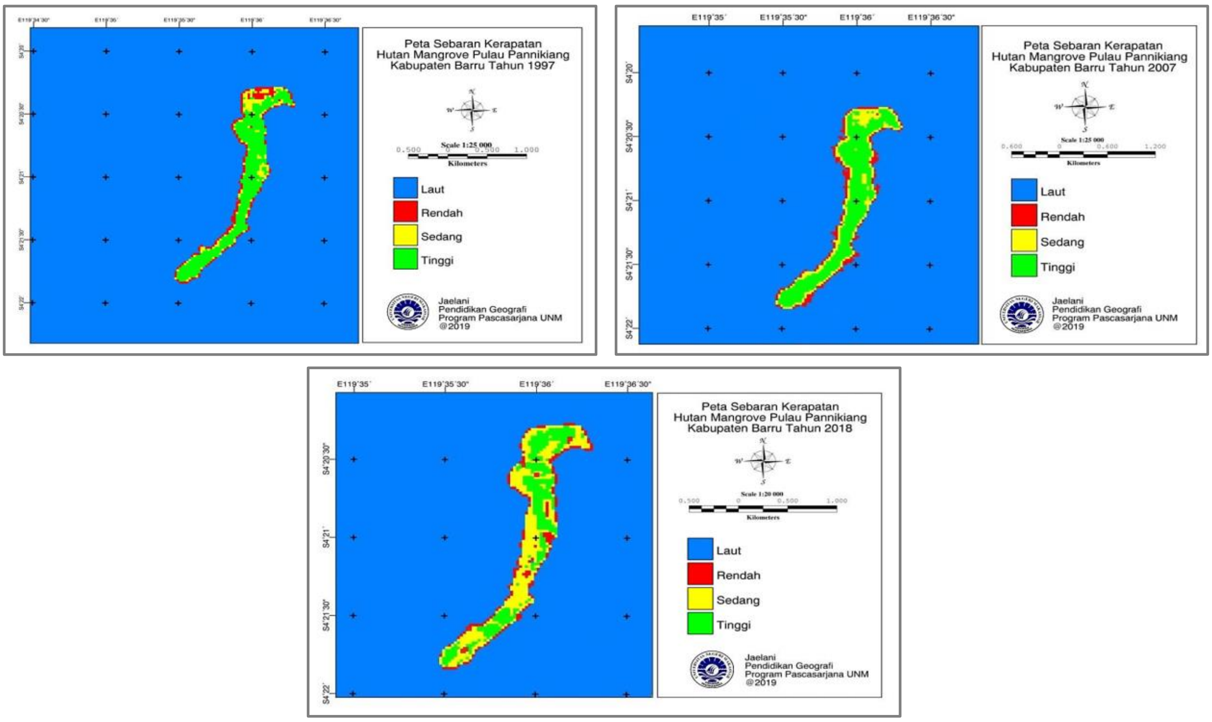

Figure 3. Mangrove distribution and density changes during periods 1997, 2007, and 2018.

With the total area of mangrove vegetation in 1997 (94.83 ha), mangrove high-density categories of 61.74 ha, moderate 14.19 ha, and low 18.60 ha. In 2007 (92.07 ha), the high and low-density categories decreased to 54.53 ha and 12.29 ha, respectively, while the moderate density increases to 25.35 ha. For 2018, with a total mangrove area of 91.64 ha, the high-density category will continue to decline to 43.36 ha, while for the low and medium category, it increases compare to the previous decade, each of which is 15.34 ha and 32.67 ha (Figure 3, Table 2).

Table 2. Mangrove density changes during periods 1997, 2007, and 2018

Density	Extent 1997 (Ha)	%	Extent 2007 (Ha)	%	Extent 2018 (Ha)	%	Changes 1997-2007 (Ha)	%	Changes 2007-2018 (Ha)	%
Low	18.6	19.61	12.29	13.35	15.34	16.74	-6.31	-6.27	+3.05	+3.39
Moderate	14.49	15.28	25.35	27.53	32.67	35.65	+10.86	+12.25	+7.32	+8.12
High	61.74	65.11	54.43	59.12	43.63	47.61	-7.31	-5.99	-10.8	-11.51
Total	94.83	100.00	92.07	100.00	91.64	100.00	-2.76		-0.43	

(+): increase, (-): decrease

3.3. *Accuracy Assessment*

The results showed that the overall accuracy is 88% (Table 3). An accuracy of ≥ 85% is considered to target when image classification is used for land cover classification [14] to determine mangrove density [2, 12]

Table 3. Accuracy assessment of mangrove density

		Fieldwork results			Total row	User accuracy (%)
		Low	Moderate	High		
NDVI transformation results	Low	2	0	1	3	67
	Moderate	0	2	0	2	100
	High	0	0	3	3	100
Total path		2	2	4	8	
Producer accuracy (%)		100	100	75		
Overall accuracy (%)			88			

4. Conclusions

This study has demonstrated mangrove cover changes (extent, distribution, and density) by using Supervised Maximum Likelihood and NDVI transformation on the Landsat images with different acquisition years (1997, 2007, and 2018) in Pannikiang Island, Barru Regency, South Sulawesi. During these periods (1997-2018), mangrove cover areas have changed by 3.19 ha or per year 0.15 ha (0.13%). The mangrove high and low densities category has decreased, while moderate category density has increased during the period 1997 – 2007. In 2018, the mangrove high-density category was continued to decline, while the low and moderate types have increased. The loss of mangroves is caused by the expansion of settlements and aquaculture ponds. Although, the annual rate of mangroves decreased much lower than yearly rates of mangrove global and in South Sulawesi, protection and conservation for this forest requires to be continued to maintain its density and sustainability of the functions and benefits of this forest.

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