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SPATIAL ANALYSIS OF MANGROVE DENSITY AND ITS EFFECT ON MACROZOOBENTHOS IN TEKKOLABBUA, SOUTH SULAWESI.

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ABSTRACT

This study was aimed to detect changes in mangrove cover using 30-meter resolution Landsat imagery for 2019 and 2021 and analysis of changes in density in relation to macrozoobenthos abundance. The research method used is analysis of satellite imagery with NDVI transformation integrated with field surveys, the relationship between mangrove density and abundance macrozoobenthos was tested by regression analysis. The results showed that in 1 decade (2009-2021) there was an improvement in the quality of the mangrove ecosystem with an increase in the cover of the mangrove ecosystem by 5.49 Ha, which was accompanied by an increase in mangrove density. Improvement of ecosystem conditions also affects the increase in the abundance of macrozoobenthos in substrates, roots and stems in mangrove ecosystems even though with a small coefficient of determination.

Keywords: Landsat Image, NDVI Transpormation, Macrozoobenthos dan Tekkolabbua

INTRODUCTION

Mangrove is one ecosystem in coastal areas with high productivity. These ecosystems are strongly influenced by ocean and land activities, have a contribution to climate change and disaster mitigation processes. Physically, mangrove has function to maintain beach stability, protect beaches from natural disasters (abrasion, tsunamis and storms), buffer against sea water intrusion (Khan et al., 2010; Marois and Mitsch, 2015, Karimah, 2017), as a carbon sink and store (Alongi, 2012; Donato et al., 2011; Sanderman et al., 2018). Biologically, mangroves function as spawning grounds, enlargement and forage for various types of organisms such as fish, crustaceans and various other types of land biota. (Field et al., 1988) and has high primary productivity (UNEP-WCMC, 2014). In addition, mangroves also have associated biota such as macrozoobenthos, these organisms live on mangrove substrates and become bioindicators of ecosystem damage. (Retnaningdyah, et al., 2022)

The area of the mangrove ecosystem in Indonesia is 3,489,140 Ha, this number represents 23% of the world's mangrove ecosystems where 47.89% are in dense conditions and 52.11% are in moderate conditions (KLHK, 2015). Likewise, South Sulawesi Province has mangrove forests with an area of 104,030 hectares or around 2.98% of the total area of mangroves in Indonesia, the composition of mangrove species in South Sulawesi is *Avicennia* spp, *Rhizophora* spp, *Bruguiera* spp, *Sonneratia* spp and several associated mangroves such as *Acanthus ilicifolius* and *Nypa fruticans* (Saru, 2011). However, the existence of mangroves in Indonesia and South Sulawesi in particular cannot be avoided from the threat of degradation and deforestation

Mangrove degradation in the world and in Indonesia in particular is caused by various factors such as climate change (e.g. rising sea surface temperatures, changes in currents and rising water levels, etc.), natural disasters (earthquakes, tsunamis, storms, etc.) and the impact of anthropogenic activities (such as pollution, aquaculture activities, urban development, etc.) (Pendleton et al., 2012). In Tekkolabbua Village, Pangkep Regency, South Sulawesi, during the period 1980-2010, there was a change in the area of mangroves from 248.4 Ha to 49 Ha, this change in area was caused by the conversion of mangroves into ponds (Tantu, 2012). This change in mangrove area in Tekkolabbua also had an impact on the mangrove associated biota, in this case macrozoobenthos. The results of Jumiarti's research (2009) showed that the average abundance of macrozobenthos was around 57.8 ind/m2. Observations using satellite data and geospatial tools make it possible to monitor land cover changes including mangrove ecosystem cover (Wulder et al., 2019). Satellite imagery temporal data is a comprehensive solution for assessing mangrove area, one of the possible satellite images to be used is Landsat and various satellite image processing algorithms such as image composites, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) (Faizal et al., 2005) In addition, in studies of mangrove forests remote sensing is often used for cover evaluation, density dynamics and biomass estimation (Mondal et al., 2019; Kauffman and Bhomia, 2017; Giri et al., 2015; Kuenzer et al. ., 2011; Simard et al., 2006).

Based on the changing conditions of mangroves in Tekkolabbua and the potential for integration between field surveys and remote sensing studies, the Spatial Analysis of Mangrove Density and Its Effect on Macrozobenthos in Tekkolabbua can be carried out. This study aims to detect changes in mangrove cover using 30-meter resolution Landsat imagery in 2019 and 2021 and analysis of changes in density in relation to the abundance of macrozoobenthos.

MATERIALS AND METHODS

Study Location

The research was carried out in Tekkolabbua Village, Pangkep Regency, South Sulawesi Province at a geographical position of 4º50'53.16"S and 119º30'30.07"E (Figure 1). There are 5 sampling points in this study, the determination of sampling points refers to initial references that have been made by Jumiarti (2009), Stations 1 and 2 are directly opposite open waters, Stations 3, 4 and 5 are at the mouth of the river. The field survey was carried out in November-December 2021. The materials used in this study were Landsat images with the specifications as in Table 1.

Table 1. Image specifications used in the study

Satellite Image Sensor	Recording Time	Path/Row
Landsat-7-EM+	November 2, 2009	114/053
Landsat-8-OLI	August 23, 2021	114/053

Figure 1. Map of the research location, Tekolabbua Village, Pangkep Regency, South Sulawesi.

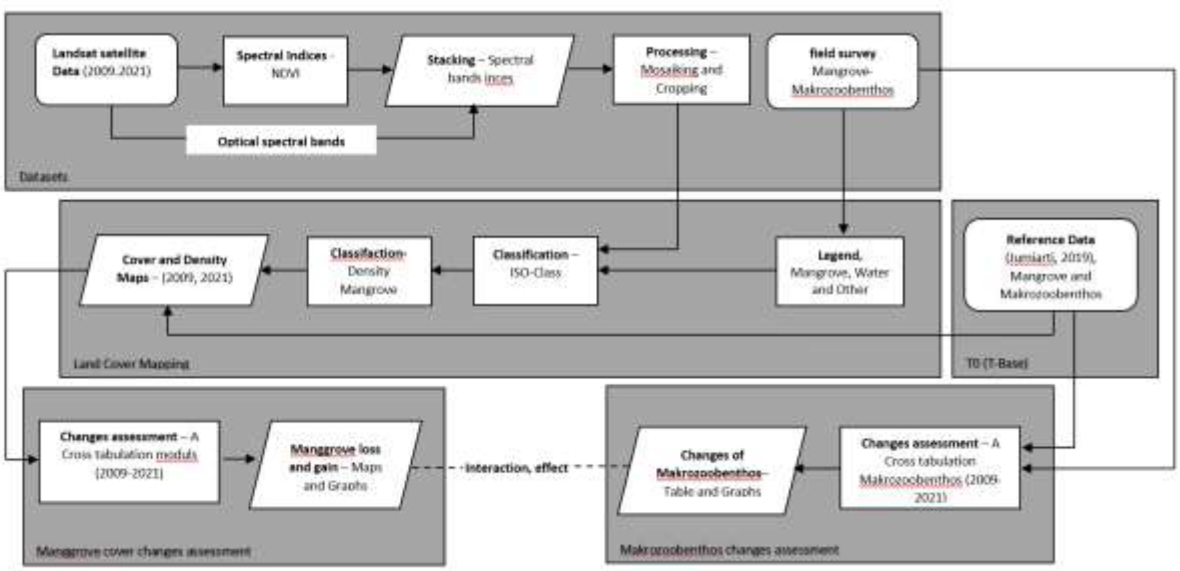

Figure 2. Research Flow Chart (Modified from Gilani et al., 2021)

Research Methods

The research was carried out by integrating satellite image processing to identify mangrove cover and density with ecological surveys and secondary data as a reference (Jumiarti, 2009) to analyze the effect of changes in mangrove density on the abundance of macrozoobenthos as shown in Figure 2.Field Survey

Field surveys were conducted to assess the condition of the mangroves and macrozoobenthos sampling. The sampling stages are as follows:

Mangrove sampling was carried out following the Indonesian National Standard (SNI) mangrove survey and mapping (2011) for each category; seedlings (rejuvenation from sprouts up to <1.5 m in height), tillers (rejuvenation with a height of ≥ 1.5 m to <10 cm in diameter) and trees (trees with a diameter of ≥ 10 cm) as shown in Figure 3

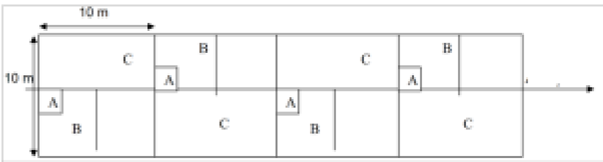

Figure 3. Design of sample mangrove observation unit (A=Observation of 1 x 1 m seedlings; B=Observation of 5x5 m seedlings; and C=Observation of 10x10 m trees)

Macrozoobenthic data were collected using a 1 m x 1 m quadrant plot (English et al, 1997; Wahab, 2019) placed in a 10 m x 10 m mangrove plot. Sampling in the field was carried out 5 repetitions. Macrozoobenthos infauna samples were taken using a 20 cm diameter PVC pipe that was inserted into the substrate to a depth of ±20 cm. Meanwhile, for epifauna macrozoobenthic samples, only the number of species in each quadrant transect was counted (Cochran, 1977; Wahab, 2019).

Identification and Assessment of Mangrove Density Change

Identification and assessment of changes in mangrove density is carried out by analyzing satellite imagery, which includes the following processing stages:

Identification of vegetation by Normalized Difference Vegetation Index (NDVI) transformation (Rouse et al, 1973). Application of NDVI transformation on Landsat-7-EM+ imagery uses bands 4 and 3 while for Landsat-8-OLI imagery uses bands 5 and 4 (Latifah et al, 2018).

Layer stacking using composite satellite imagery (RGB 564 for Landsat 7 EM+ and RGB 432 for Landsat 8 OLI) which refers to the Optimum index Factor (OIF) value (Chavez et al., 1982; Mannopo et al, 2015).

Mozaiking and cropping are carried out to cut and clarify areas of research work that refer to spectral values (Lii et al., 2019)

Classification of images using unsupervised using the isodata method which refers to clustering of spectral values based on average values. The results of image classification produce land cover classes in the form of mangroves, water bodies, and non-vegetation.

Classification of Mangrove Density based on the NDVI value for each image with reference to the Ministry of Forestry (2003) and Selamat et al., (2021) as in Table 2.

Referring to Puyravaud (2003), to see changes in mangrove cover between 2009 and 2021 a cross tabulation was carried out to determine the reduction and increase in mangrove area

Table 2. The standard criteria for mangrove density are based on the NDVI value

Mangrove Density Category	NDVI value for Landsat-7-EM+	NDVI value for Landsat-8-OLI
Sparse	0 ≤ 0,33	0,36 ≤ 0,61
Moderate	0,34 ≤ 0,42	0,61 ≤ 0,74
Dense	0,43 ≤ 1,00	> 0,74

Data Analysis

Data from field surveys and processing of satellite image data were analyzed to see the relationship between changes in mangrove cover area and macrozoobenthos abundance with the following analysis steps; Mangrove density is calculated to obtain the number of stands in a unit area (Ministry of Environment, 2004) with the equation

$$Di = \frac{ni}{A}$$

Where: Di = Mangrove density ; ni = Numbers of trees; and A = Area

Table. 3. Quality standard criteria for mangrove damage

Criteria		Density (trees/ha)
Good	Dense	> 1500
	Moderate	> 1000 – < 1500
Damaged	Sparse	< 1000

Source : State Ministry of Environment (KMNLH), 2004

The abundance of macrozoobenthos at study sites was calculated with reference to Odum (1971) and Analysis of the relationship between mangrove land cover and the abundance of macrozoobenthos using the linear regression method.

RESULTS AND DISCUSSION

Mangrove Density

Mangrove density is an indicator to see the level of damage to a mangrove forest area. Each station has a different density value, the more the number of mangroves, the denser the mangroves will be. The results of image classification for 2009 and 2020 with the categories of mangrove vegetation, water bodies and non-vegetation as shown in Figure 4, and changes in the area cover of each category as shown in Table 4.

Table 4. Land Cover Change Year 2009 and 2021

No	Type of Cover	land area (m^2)	
		2009	2021
1	Vegetation	445.500	500.400
2	Water Bodies	5.537.700	5.418.800
3	Non Vegetation	1.055.700	1.120.500

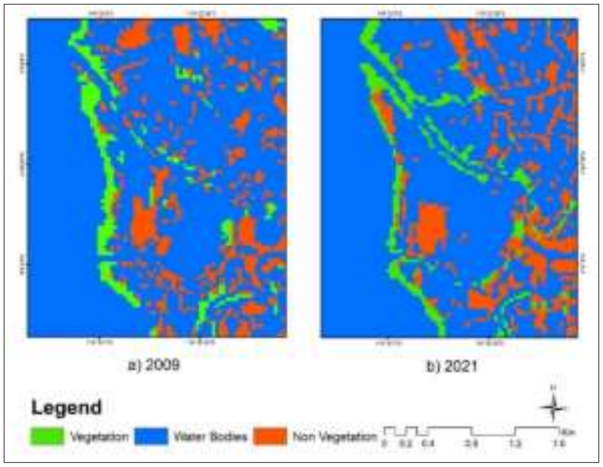

Figure 4. Landsat image classification results in 2009 (a) and year 2021 (b)

Figure 4 and Table 4 show that there is a tendency to increase the area of mangrove vegetation in Tekkolabbua by 54,900 m2 or around 5.49 Ha, and also the addition of an area of non-vegetation groups of 64,800 m2 or around 6.48 Ha. Based on the results of observations, the increase in mangrove area was due to the planting of mangroves in 2014. Meanwhile, the addition of non-vegetation areas was partly for settlement and aquaculture activities. According to Eddy et al, (2016), damage to mangrove ecosystems around the world is mostly caused by human activities. Setyawan and Kusumo (2006) also wrote about the conversion of mangrove forests into ponds with individual property right.

Further assessment of the condition of the mangrove ecosystem by calculating the density using the NDVI transformation. Mangrove density based on the results of satellite image classification as shown in Figure 5. The area for each category of mangrove vegetation density in 2009 and 2021 is presented in table 5.

The data in Figure 5 and Table 5 shows an increase in the density of medium category mangroves of 73.8 Ha and dense categories of 13.5 Ha. And specifically for the rare category, the area decreases by 32.4 Ha. This condition proves that there has been an increase in the quality of mangrove conditions in Tekkolabbua. The increase in mangrove density in Tekkolabbua is in line with the increase in mangrove cover area.

When compared to the results of direct measurements in the field at 5 (five) stations that have been determined according to Jumiarti (2009), the mangrove density criteria are obtained based on KMNLH criteria (2014) for each station, as presented in Table 6.

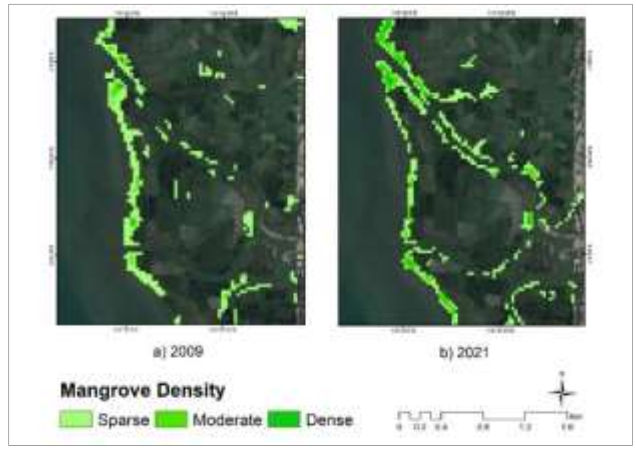

Figure 5. NDVI Value Transformation Results for 2009 (a) and 2021 (b)

Table 1. The area of each mangrove density category is based on the results of the NDVI transformation

No.	Mangrove Density Category	Land Area (m^2)		Tyoe of Area change
		2009	2021	
1	Sparse	399.600	367.200	Loss
2	Moderate	29.700	103.500	Gain
3	Dense	16.200	29.700	Gain
Total		445.500	500.400	Gain

Data from mangrove density measurements at each station have different values with the same density criteria based on KMNLH standard mangrove damage criteria in 2004, Station one with a density value of 7700 (trees/ha), station 2 with a density value of 4800 (trees/ha)), station 3 with a density value of 6800 (trees/ha), station 4 with a density value of 6100 (trees/ha), and station 5 with a density value of 6900 (trees/ha). All stations are in very dense density conditions.

Table 6. Mangrove density based on quality standard criteria

Station	Density (Trees/ha)	Density criteria
1	7700	Dense
2	4800	Dense
3	6800	Dense
4	6100	Dense
5	6900	Dense

Furthermore, a comparison of the results of measuring mangrove density from field surveys in 2021 and Jumiarti 2009 is presented in Figure 6.

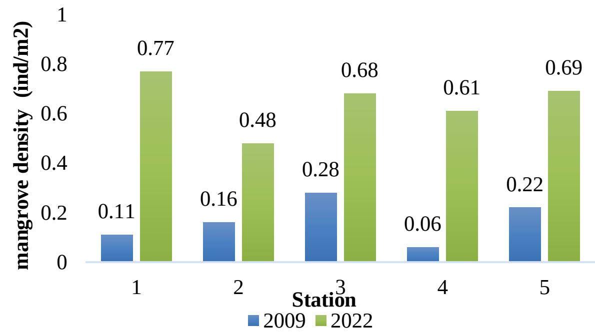

Figure 6. Mangrove Density (Di) at each station in the research location in 2009 (Jumiarti, 2009) and 2021

Based on the density of mangrove species, especially at each station, it shows that the density of mangrove species in 2021 is much better compared to the density of species in 2009 for all stations. replanting has been carried out in areas that have mangroves. According to Field (1999) that one way to rehabilitate mangrove forests is by embroidering techniques in locations that have sparse densities and successful rehabilitation is also supported by the type of mangrove planted (Macintosh et al., 2002)

Macrozoobenthos

Macrozoobenthos abundance is the number of individuals of a species in an area. The results of calculating the average abundance of macrozoobenthos found in substrate, roots and stems from the 2021 survey and the results of Jumiarti's research (2009) are presented in Figure 7.

The average macrozoobenthos abundance observed in 2021 was found in the highest substrate, roots and stems at station 4, following stations 2 and 1. Meanwhile, Jumiarti (2009) found that the highest abundance of macrozoobenthos was found at stations 1 and 5 and the lowest at station 3. If compared to the average abundance of macrozoobenthos in 2009 and 2021, the average abundance in 2021 is much higher than the average abundance in 2009. One of the factors causing the high abundance of macrozoobenthos is the high content of dissolved organic matter in the substrate (Awaluddin, 2018) and C-Organic (Basyuni, et al., 2018).

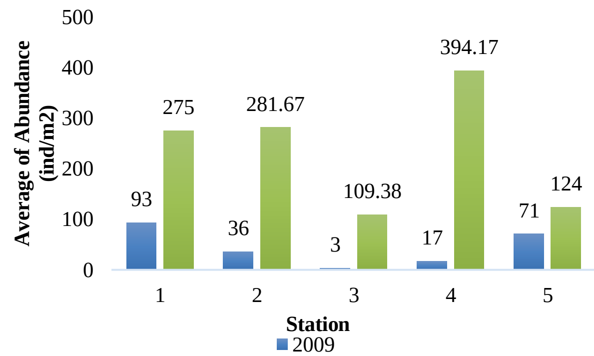

Figure 72. The average abundance of macrozoobenthos at each station in 2009 (Jumiarti, 2009) and 2021

The low abundance of Macrozoobenthos at station 3 in 2021 and 2019, is made possible by high anthropogenic pressure, because the distance between these stations and settlements is quite close. This was reinforced by KL et al, (2017) who wrote that mangrove habitat that is affected and under pressure from community exploitation activities can cause ecological damage and this also has an impact on the existence of macrozoobenthos, also reinforced by research conducted by Marpaung (2013) writing that The abundance obtained was relatively low, ranging from 107 – 1020 ind/m2 at stations 1 and 2 at Boe Beach, which are located close to residential areas.

Relationship between Mangrove Density Change and Macrozoobenthos Abundance

The relationship between Mangrove Density Changes and Macrozoobenthos Abundance is explained by the linear regression method. Changes in density values for stations 1 to 5 and the average macrozobenthos abundance per station are presented in Table 7.

Table 7. Changes in the average abundance value of macrozoobenthos (ind/m2) and land cover area values in 2009 and 2021

Station	Macrozoobenthos Average Abundance (ind/m^2)		Change of Abundance (ind/m2)	Info	Mangrove Density (ind/m2)		Change of Abundance (ind/m2)	Info.
	2009	2021			2009	2021		
1	93	275	182	Gain	0.11	0.77	0.66	Gain
2	36	281.67	245.67	Gain	0.16	0.48	0.32	Gain
3	3	109.38	106.38	Gain	0.28	0.68	0.4	Gain
4	17	394.17	377.17	Gain	0.06	0.61	0.55	Gain
5	71	124	53	Gain	0.22	0.69	0.47	Gain

The results of data compilation between 2009 and 2021 show that the average abundance of macrozoobenthos at each station has increased, as well as the density of mangroves has also increased for all stations. This shows that there has been a decade-long improvement in mangrove quality in Tekkolabbua, Pangkep Regency. Furthermore, to see how the effect of mangrove density on the abundance of macrozoobenthos, a regression test was carried out as shown in Figure 8.

The regression results for the abundance of macrozoobenthos in relation to the area of mangrove land cover are presented in Figure 9.

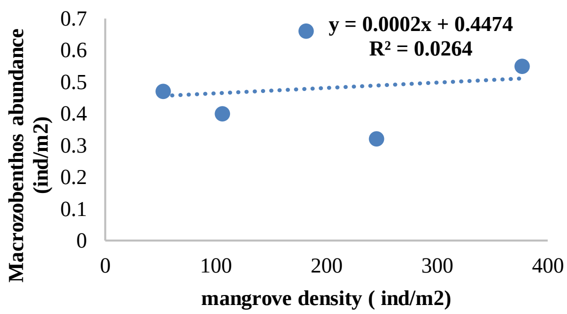

Figure 9. Graph of the relationship between changes in mangrove land cover and the abundance of macrozoobenthos

Based on simple linear regression analysis, the regression equation is Y = 0.0002x + 0.4474 with a coefficient of determination of 0.0264. This shows that the increase in mangrove density in Tekkolabbua causes an increase in macrozoobenthos abundance, although the determination value of this equation explains the possibility that many other factors influence macrozoobenthic abundance at the study site besides the mangrove density factor. The results of research by Octaviana et al., (2018) in Aceh Singkil showed that at a mangrove density of 0.8-1.1 ind/m2, an abundance of macrozoobenthos of 48-75 ind/m2 was found.

The small direct effect of mangrove density on the abundance of macrozoobenthos is supported by various other research results. Wardianto et al (2015) found that for some mancrozoobenthos species, sediment or substrate conditions are the main source of life for macrozoobenthos in mangrove ecosystems. Likewise the results of research by Marten et al., (2015) that the level of sediment roughness greatly determines the abundance of macrozoobenthos.

CONCLUSION

The image detects that the algae cover area changed from The results of the study concluded that in 1 decade (2009-2021) there was an improvement in the quality of mangrove ecosystem in Tekkolbbua, Pangkep Regency, where an increase in mangrove ecosystem cover was found of 5.49 Ha. The increase in cover was also accompanied by an increase in mangrove density. Improvement of ecosystem conditions also affects the increase in the abundance of macrozoobenthos in substrates, roots and stems in mangrove ecosystems even though with a small coefficient of determination.

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