ENVIRONMENTAL ASSESSMENT OF COASTAL ECOSYSTEM AND GOVERNMENT POLICY TOWARD PROTECTION

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ABSTRACT: Remote Sensing is a powerful tool for analyzing mangrove forests; it is suitable for monitoring the spatial and temporal evolution of mangrove ecosystems. Indonesia is the largest archipelago country which has the potential coastal marine resources which one of them is a mangrove ecosystem. The main objective of this study are to distinguish mangrove vegetation from other vegetation by applying NDVI and to discribe the implication of government policy toward mangrove protection. We used multi-temporal analysis of Landsat TM images from 1972 to 2019. Change of canopy density is one of the indication to monitor its quality. Based on the mangrove land cover change analysis, there has been a decrease and increase in the area from 1972 to 2019. The decrease of mangrove area was 21.65% on Satangnga Island, 0.51% on Sagara Island and 15.94% on Sabangko Island. Meanwhile, on Bauluang Island, there was an increase in mangrove land cover by 14.02%. Factors influencing loss of mangrove on the small island from the local people are conversion of mangrove for aquaculture, clearing of mangrove trees for charcoal production on a large scale, and utilization of mangrove trees for domestic use. The relationship between changes in remote sensing indices and implication of government policy for an efficient evaluation of the main environmental impacts, which can be used for coastal planning and management.

1. INTRODUCTION

Mangrove mapping is the process of identifying land cover changes using multi-date digital images that commonly acquired from satellite based multispectral sensors. Remote Sensing and GIS techniques are extremely effective in identifying these changes. Mangrove coverage degradation is a problem that occurs in several mangroves area around the world. Some related research tells that there has been an alarming decline in its quality and quantity globally. For approximately two decades starting from 1980 to 2000, there was 25% decreased of the total area (FAO 2007; Giri et al. 2011). According to Jones et al. (2016) degradation of the world's mangrove ecosystems has increased by 1 to 2% per year, as well as in Indonesia (Karyono et al. 2013).

Remote Sensing is a powerful tool for analyzing mangrove forests; it is suitable for monitoring the spatial and temporal evolution of mangrove ecosystems because it is cost-effective, time-efficient, and able to access remote regions and non-invasive (Kuenzer, et al. 2011). Remote sensing of mangroves provides important information for Habitat inventories (determination of extent, species and composition, health status); Change detection and monitoring; Ecosystem evaluation support; Productivity assessment (biomass estimation); Prompt information supply for disaster management; Aid delivery to gain a better understanding of ecological and biological relations and processes, functions, and dynamics (Manson, et al. 2001). Some of research have been identify coastal ecosystem successfully (Nurdin N, et al. 2015b, Levine AS, et al. 2015, Spaldinga M, et al. 2017). Remote sensing technology has already been successfully applied in the field of coastal vegetation research. Vegetation can be distinguished using remote sensing data from most other (mainly inorganic) materials by virtue of its notable absorption in the red and blue wavelengths of the visible spectrum, its higher green reflectance and, especially, it's very strong reflectance in the near-IR (Short, 2007).

Mangrove monitoring and management efforts need to be seriously considered by all stakeholders, the general public, agencies and academics. This is necessary to measure growth rates and identify areas for improvement (Monsef and Smith 2017). Access difficulty in the field is an obstacle in monitoring the condition of the mangrove ecosystem, therefore it requires appropriate technology and methods to obtain spatial-based data and mangrove information accurately and precisely . It is much needed for sustainable management of mangrove ecosystems. Monitoring by utilizing remote sensing satellite image data apart from using classification techniques can also be done by digitally transforming images using a vegetation index. The vegetation index used in this study is NDVI (Normalized Difference Vegetation Index).

The main objective of this study are to distinguish mangrove vegetation by applying NDVI and anthropogenic impact for land cover change. Mangrove mapping using remote sensing data from the last 47 years. We analyzed the temporal variability of vegetation activity (as NDVI) in mangrove areas located in Bauluang, Satangnga, Sagara and Sabangko Island, Spermonde Archipelago, Indonesia using a homogenized time series of Landsat images. Evaluated the effects of expansion aquaculture on the spatial distribution by the observed NDVI trends during the observation period and the implication of government policy toward mangrove protection.

2. MATERIALS AND METHODS

2.1 Study Area

The study were conducted among the mangroves in Bauluang, Satangnga, Sagara and Sabangko island, Spermonde Archipelago, Indonesia (Figure 1). Bauluang and Satangnga are small islands in the southern part of the Spermonde Archipelago which have the largest mangrove forests, while Sagara and Sabangko are small islands in the northern part of the Spermonde Archipelago which have the largest mangrove forests. The livelihoods of the people on Bauluang, Satangnga, Sagara and Sabangko are rice farmers, fish farmers, seaweed farmers and fisherman.

Fig.1 Map of the study area, Tanakeke Island in Spermonde Archipelago, South Sulawesi, Indonesia

2.2 Data Collection

The study was carried out using multi-temporal satellite images of Landsat. The Landsat images data was downloaded from USGS data archive (http://www.eros.usgs.gov) including A Landsat MSS images, Thematic Mapper (TM) images, Enhanced TM Plus (ETM+), and a Landsat 8 (Operational Land Imager, OLI) image, were used in this study (Table 1). Landsat image was processed using software ArcGIS 10.5. This software were needed to analyze and integrate spatial data. The data of Landsat image was projected to Universal Transverse Mercator (UTM) coordinate system, Datum WGS 1984, zone 50 South, Path:112/114 and Row:063/064. Bands combination of Landsat image was used to identify mangrove area.

Table 1. Satelite data from USGS data archive (http://www.eros.usgs.gov)

Satellite	Resolution	Path/row	Acquisition
Landsat MSS	60	122/064/63	10/28/1972
Landsat TM	30	114/064	8/26/1993
Landsat TM	30	114/063	7/21/1994
Landsat ETM+	30	114/063	6/24/2002
Landsat ETM+	30	114/064/63	7/21/2003
Landsat 8 OLI TIRS	30	114/064/63	4/27/2013
Landsat 8 OLI TIRS	30	114/064/63	4/25/2016
Landsat 8 OLI TIRS	30	114/064/63	1/1/2019

2.3 Pre-Processing Images

Time series data Landsat imagery were used in this research to obtain information about actual mangrove condition from each time series. We preferred to use Landsat TM, ETM+, and OLI after geometrically and radiometrically corrected. Visualize the image of the composite RGB 453 on Landsat (TM & ETM+) and 564 on Landsat 8. Satellite imageries was interpreted by unsupervised classification with the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features.

Accuracy assessment was being conducted by Kappa Coefficient (k) for accuracy assessment which relies on image training area. Training area was delineation based on ground observation with 50 samples of training area with random sampling method.
Kappa ‘ mathematical accuracy is :

$$K = \frac{N\sum_{i=1}^{r} X_{II} - \sum_{i=1}^{r}(X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{+i})}$$ (Congalton, et al. 2010)…….(1)

Where :
N : the total Number of cell in the matrix,
r : the number of rows in the matrix,
X_{ii} : the number in row i and column i
x_{+1} : the total observations for column i, and
x_{1+} : the total observations in row i

2.4 NDVI Measures

Normalized Difference Vegetation Index (NDVI) has been used by several authors as reliable estimates of vegetation health (Campbell, 2002). NDVI can be calculated as a ratio of red and the NIR bands of a sensor system, NDVI = (Infrared - Red)/(Infrared + Red). NDVI process produces new image with the value of pixel ranges from -1 to +1. The positive value of pixel indicates the existence of vegetation, while the negative value of pixel indicates non-vegetation object. To determine the value of mangrove canopy density using the results of calculations NDVI. Then the value of the NDVI classes in reclassification into 3 classes (Kepmen LH No. 120, 2014), high (0.43≤NDVI≤1.00), middle (0.33≤NDVI≤0.42) and low (0.43≤NDVI≤1.00).

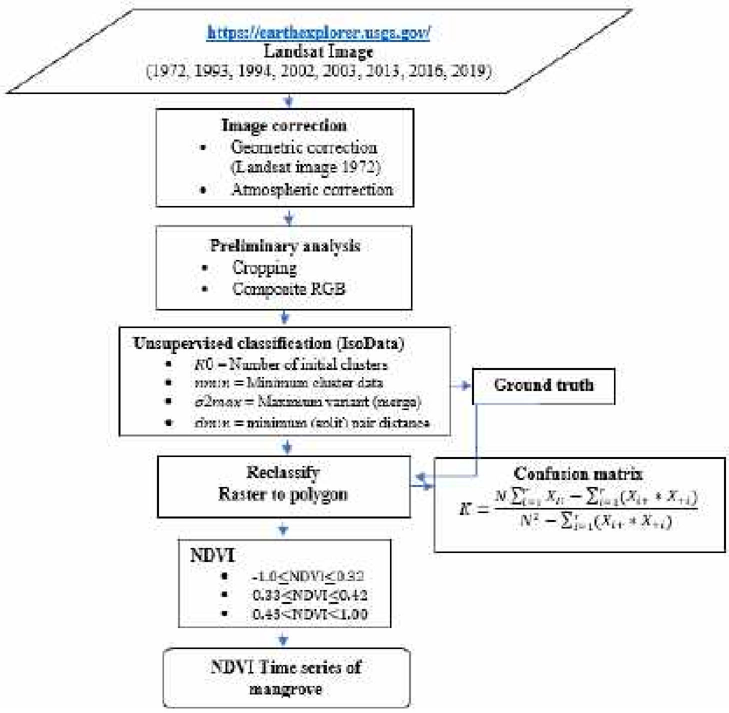

Fig. 2 Flowchart of research

3. RESULT AND DISCUSSION

Landsat imagery is an image that is often used to map mangroves (Lyons et al. 2012; Katie et al. 2019; Parida et al 2020), although Landsat satellite images are categorized as medium resolution images but many research results provide good mapping accuracy, one of them is Li et al. (2013) amounting to 92.3%. Satellite image classification requires an algorithm to produce certain desired classes and the use of the algorithm will also determine the accuracy of the classification. This study mapped mangroves using Landsat images and an ISO data algorithm with an accuracy of 86.78%.

3.1 Mangrove Cover Change

Identification of mangrove in Bauluang, Satangnga, Sagara and Sabangko island based on the result of image classification method. Based on the results of image analysis, there has been a change in mangrove land cover from 1972 to 2019. Mangrove coverage has been decreased by 21.65% on Satangnga Island, 0.51% Sagara Island and 15.94% on Sabangko Island. Meanwhile on Bauluang Island there was an increase in mangrove coverage by 14.02%. In this case, the change of mangrove cover in 1972 to 2019 in Figure 4. Factors influencing loss of mangrove on the small island from the local people are conversion of mangrove for aquaculture, clearing of mangrove trees for charcoal production on a large scale, and utilization of mangrove trees for domestic use.

Fig. 3 Degradation of mangrove for aquaculture, charcoal and settlement on Bauluang, Satangnga, Sagara and Sabangko island,

Changes of mangrove cover in 1994 to 2019 occured in Sagara and Sabangko Island, where mangrove was turned into aquaculture and settlement. In addition, because of a lack of information about environmental conditions, shrimp culture techniques and financial resources required, shrimp farming failed in some areas or shrimp ponds were used only in the short period. After few years, land has been degraded and farmers have continued to cut down mangrove forests and to make new shrimp ponds.

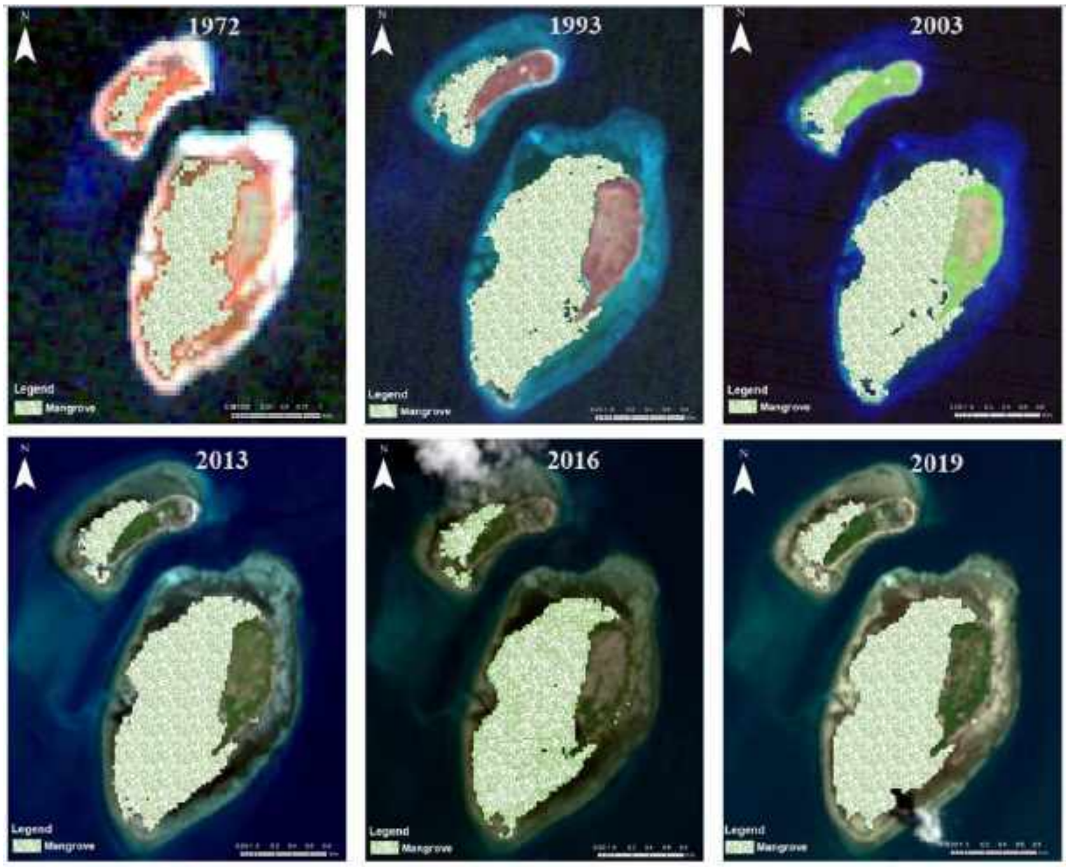

Fig. 4 Changes in the extent of mangrove cover in Bauluang and Satangnga island, Spermonde Archipelago. In this case, the loss of mangrove cover was 6.79 ha in Satangnga island and increased of mangrove cover was 34.41 ha in Bauluang island (1972 to 2019).

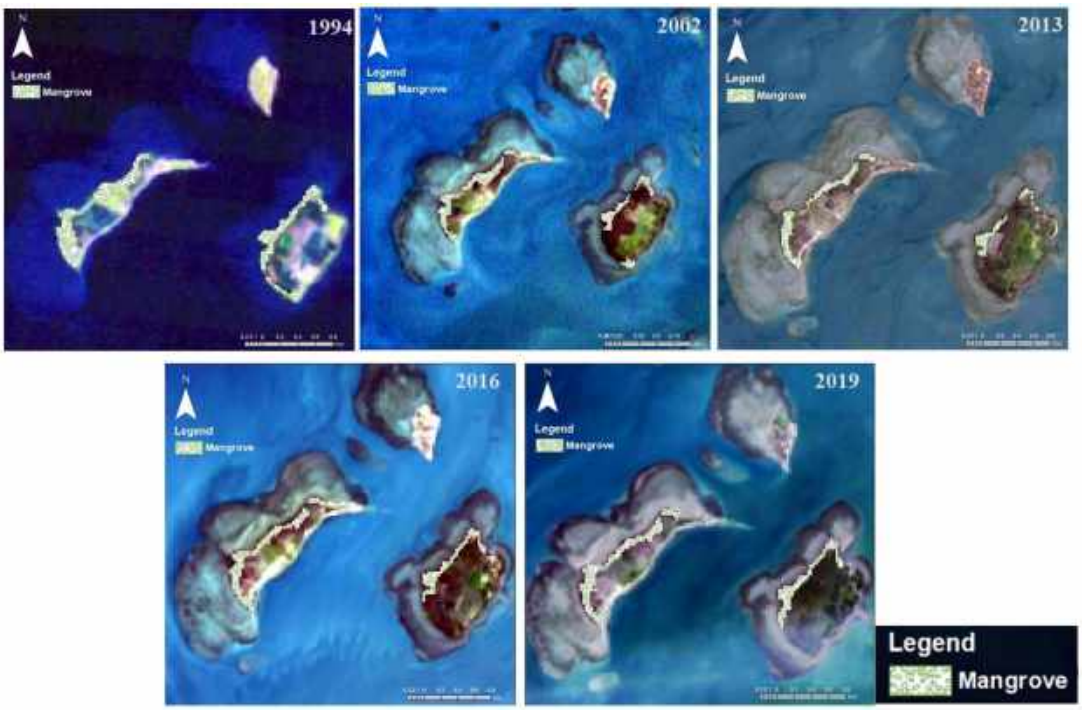

Fig.5 Changes in the extent of mangrove cover in Sagara and Sabangko island, Spermonde Archipelago. In this case, the loss of mangrove cover was 0.09 ha in Sagara island and 1.98 ha in Sabangko island (periode 1994 to 2019).

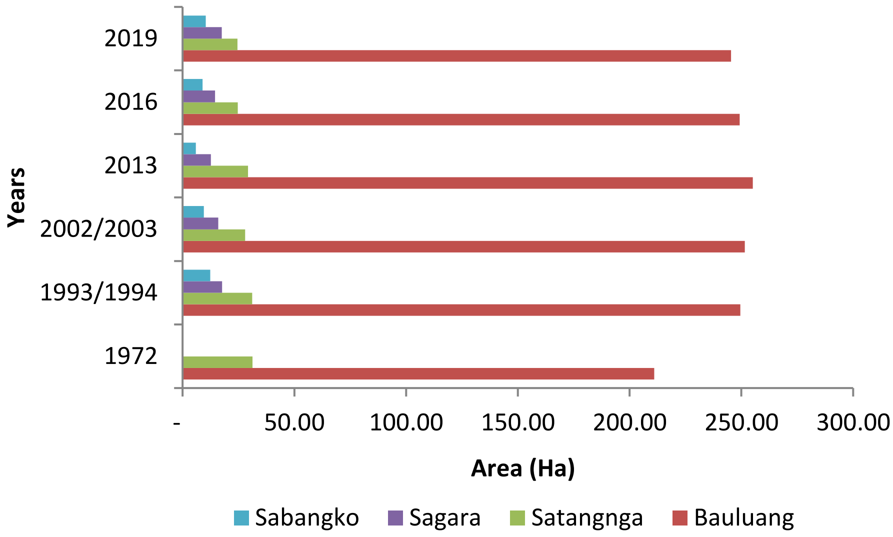

Fig.6 Graph trend line of mangrove on 1972, 1993, 2003, 2013, 2016, 2019 in Bauluang, and Satangnga island. On 1994, 2002, 2013, 2016, 2019 in Sagara and Sabangko island.

3.2 NDVI Time Series of Mangrove

The NDVI derived from Landsat images provide useful information to monitor coastal vegetation changes. The analysis of NDVI variations showed the qualitative information about the mangrove. From the NDVI analysis, we can predict the health of the mangrove and the impact of environmental factors on it. The time series of the annual averages of NDVI values showed a marked difference between distinctive mangrove covers in the study area, with the mangrove forest category showing the highest mean values (Figure 8). This progressive transition between the mean NDVI values of each of the categories could be related to the spatial distribution of the different mangrove covers inland from the coast. The high density category has increased on these four islands from 1972 to 2019 (Table 2).

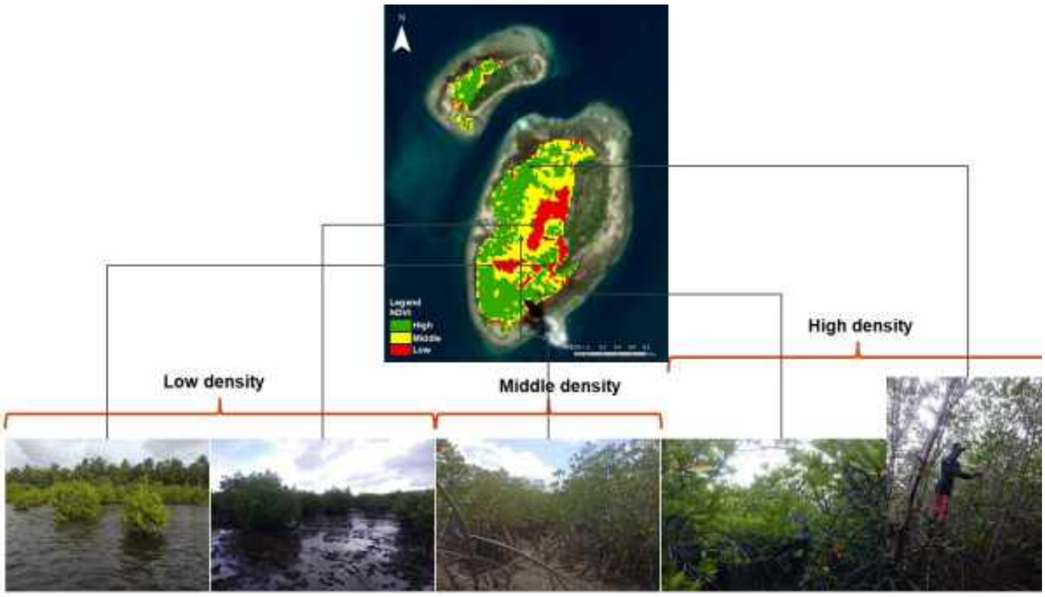

Fig.7 NDVI of mangrove in Bauluang and Satangnga island

During the study period, NDVI trends for all land cover categories showed a slightly negative trend, which was more evident in the categories of mangrove forest with pickleweed, pickleweed and bare soil. A negative NDVI trend in this category would be a symptom of the expansion of this type of degradation as the tree cover decreases and the presence of pickleweed increases (with comparative low values of NDVI). This study demonstrated the applicability of NDVI for the environmental assessment of mangroves. The relationship between changes in remote sensing indices and environmental variables allows for an efficient evaluation of the main environmental impacts, which can be used for coastal planning and management.

Table 2. Areal density of mangrove on 1972, 1993, 2003, 2013, 2016, 2019 in Bauluang, and Satangnga island. On 1994, 2002, 2013, 2016, 2019 in Sagara and Sabangko island. The mangrove category devided into law, middle and high density.

Island	**Years**	**Density of mangrove**			**Total**
		Low	**Middle**	**High**	
Bauluang	1972	36.52	88.54	85.96	211.02
	1993	87.39	122.49	39.69	249.57
	2003	126.54	87.48	37.53	251.55
	2013	22.14	79.83	153.18	255.15
	2016	52.20	101.52	95.49	249.21
	2019	39.96	88.65	116.82	245.43
Satangnga	1972	4.80	13.28	13.28	31.36
	1993	15.21	12.96	2.97	31.14
	2003	16.56	9.27	2.16	27.99
	2013	6.75	13.14	9.36	29.25
	2016	5.13	9.18	10.44	24.75
	2019	1.71	8.10	14.76	24.57
Sagara	1994	6.39	7.38	3.87	17.64
	2002	2.97	6.57	6.48	16.02
	2013	0.63	7.38	4.61	12.62
	2016	3.87	4.68	6.03	14.58
	2019	4.41	7.38	5.76	17.55
Sabangko	1994	4.50	6.03	1.89	12.42
	2002	3.24	2.52	3.78	9.54
	2013	0.27	4.19	1.51	5.96
	2016	2.52	3.51	2.88	8.91
	2019	2.88	3.78	3.78	10.44

On Bauluang Island, the high density category increased by 30.86 ha, Satanggnga Island by 1.48 ha, Sagara Island by 1.89 ha and Sabangko Island by 1.89 ha from 1972 to 2019. High mangrove density occurs on these four islands.

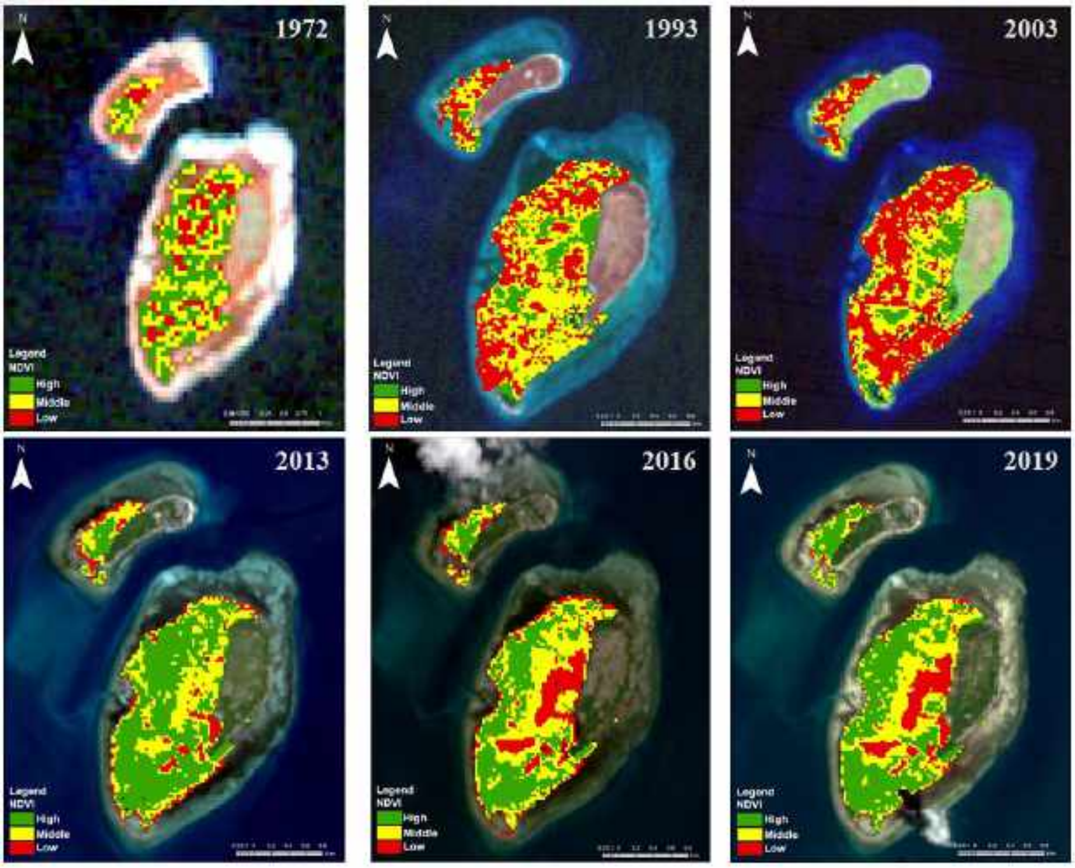

Fig.8 NDVI of mangrove on 1972, 1993, 2003, 2013, 2016, 2019 in Bauluang, and Satangnga island, Spermonde Archipelago. Red color is low density, yellow color is middle density and green color is high density.

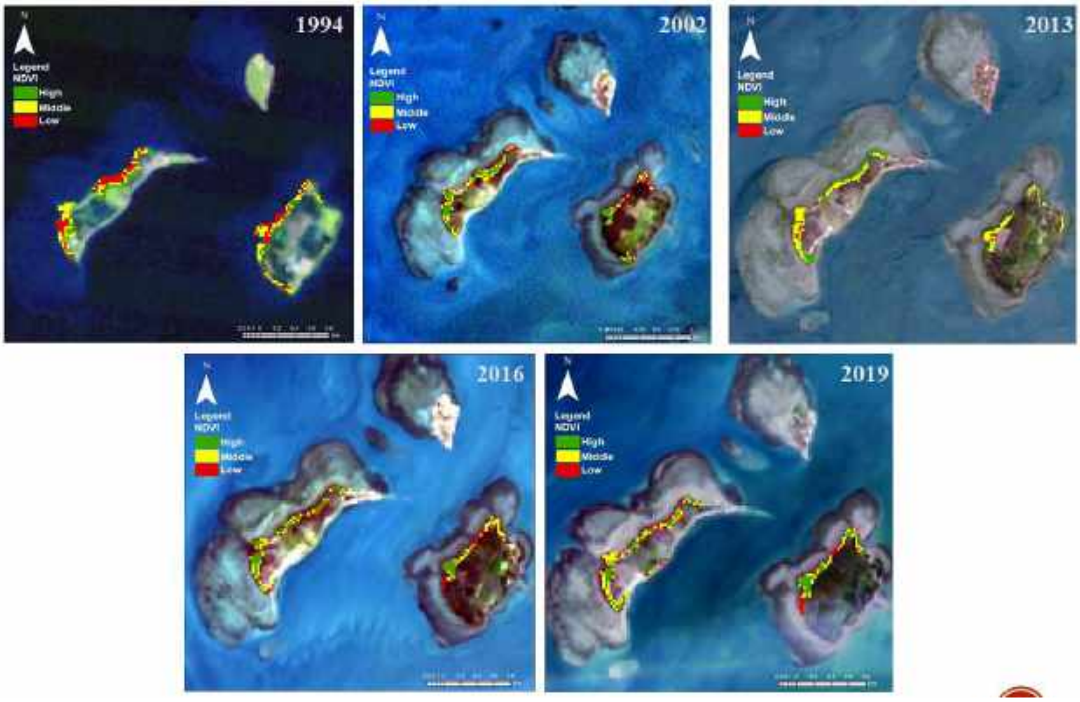

Fig.9 NDVI of mangrove on 1994, 2002, 2013, 2016, 2019 in Sagara and Sabangko island, Spermonde Archipelago. Red color is low density, yellow color is middle density and green color is high density.

3.3 The Implication of Government Policy toward Mangrove Protection

Land conversion is a threat to mangrove degradation which results in changes in the area of the ecosystem. Area that are threatened by mangrove degradation are Bauluang, Satangnga, Sagara and Sabangko Island. Mangroves are an important ecosystem for humans as well as biota and coastal ecosystems that are involved there (Giri et al. 2011). There have been many laws regulated the environment protection, specifically is Law Number 32 Year 2009 on Environmental Protection and Management explains that: (1) In order to maintain the preservation of the living environmental and public safety functions, every spatial layout planning shall be based on a Strategic Environmental Assessment. (2) Regional spatial planning as meant in paragraph (1) shall be determined by taking into account the carrying capacity and environmental responsibility. One sector in environmental management in Indonesia perceived as a lack of concern is the management of mangrove forests. Conservation International have been working in Indonesia since 1991, supporting conservation efforts to achieve sustainable development.

The strategic environmental assessment is a "systematic, comprehensive, and participative approach to ensuring that sustainable development has become an integrated and integrated basis in the development of an area and / or policy, plan and / or program. Tremendous and countinous effort must be done not only by central government but mostly local government where the damage of enviroment occurred. The works among stakeholders which is not only local government, fisherment, businessmen but the rule of law that must be keep seriously. The fact that there is increasingly declining has threatened the survival of human life and other living beings so as to require genuine and consistent environmental protection and management by all stakeholders. A systematic and integrated efforts undertaken to preserve the functioning of the living environment and prevent the occurrence of pollution and / or Environmental damage involving planning, utilization, control, maintenance, supervision and law enforcement.

Among all the kind of damages in mangrove environment, it is marine and coastal areas are one of the most susceptible environments with landfill waste that can cause pollution in the area. Local government need to endorse law enforcement to protects the sea. However, the result has not yet promising as every single year the damage increase. Public concern must be called through a massive media publication to call for more attention guarding the sea. Having the laws and local government apprratures will not enough. Public involvement would strongly matter that work side by side with the law enforcement. Therefore, local government should embedded with local laws (perda) to protects the ocean environment. Mangrove monitoring and management efforts need to be taken seriously by the general public, agencies and academics. This is necessary to measure growth rates and identify areas requiring rehabilitation.

4. CONCLUSION

We analyzed the temporal variability of NDVI in mangrove areas located in Bauluang, Satangnga, Sagara and Sabangko island island, Spermonde archipelago using a homogenized time series of Landsat MSS, TM, ETM and OLI_TIRS images (1972-2019). We identified temporal trends on NDVI and implication of government policy toward mangrove protection. The relationship between changes in remote sensing indices and environmental variables allows for an efficient evaluation of the main environmental impacts, which can be used for coastal planning and management. This study demonstrated the applicability of NDVI for the environmental assessment of mangroves. The spatial mangrove cover in small island is not always decrease but there is a positive trend as a good indicator for environment. Factors influencing loss of mangrove in Bauluang, Satangnga, Sagara and Sabangko island from the local people are conversion of mangrove for aquaculture, clearing of mangrove trees for charcoal production on a large scale, and utilization of mangrove trees for domestic use.

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