Spatial Analysis of Health and Physical Parameters of the Mangrove Forest with Sentinel 2A at Taman Hutan Raya Ngurah Rai, Bali

Abstract *Mangrove forest is a very valuable forest, but despite its benefits mangrove forest continue to be degraded due to human activities. The purpose of this study was to map the distribution and to analyze mangrove forests' health based on the NDVI vegetation index value and environmental quality. Distribution of mangrove forest health was obtained through the processing of sentinel 2-A satellite imagery in 2020 and field measurements. The environmental quality of the mangrove forest was obtained by processing the physical parameters which are water temperature, water salinity, water pH, and substrate texture using the Ordinary Kriging method. The health of the mangrove forest of Taman Hutan Raya Ngurah Rai is dominated by healthy category mangroves. The health of the mangrove forest worsens when closer to the shore and riverbanks. Mangrove vegetation with good conditions tends to have optimal environmental quality conditions and vice versa.*

Keywords: *environmental quality, mangrove forest health, NDVI, ordinary kriging, sentinel 2-A.*

Abstrak *Hutan mangrove merupakan hutan yang sangat bermanfaat, namun terus tertekan dan terdegradasi akibat dari aktivitas manusia. Tujuan dari penelitian ini adalah memetakan sebaran dan menganalisis kesehatan hutan mangrove berdasarkan nilai indeks vegetasi NDVI dan kualitas lingkungannya. Kesehatan hutan mangrove diperoleh melalui pengolahan citra satelit sentinel 2-A tahun 2020 serta pengukuran lapangan. Kualitas lingkungan hutan mangrove diperoleh dengan mengolah parameter suhu perairan, salinitas perairan, pH perairan, dan tekstur substrat menggunakan metode Ordinary Kriging. Kesehatan hutan mangrove Taman Hutan Raya Ngurah Rai didominasi oleh kategori sehat. Kesehatan hutan mangrove semakin buruk mendekati tepi pantai dan tepi sungai. Vegetasi mangrove dengan kondisi baik cenderung memiliki kondisi kualitas lingkungan yang optimal dan begitu pula sebaliknya.*

Kata kunci*: kesehatan hutan mangrove, kualitas lingkungan, NDVI, ordinary kriging, sentinel 2-A.*

1. Introduction

Mangroves are the most dominant coastal forests in tidal and saltwater areas in tropical and subtropical climates (Davidson, 2009). Mangrove vegetation lives by forming distinctive zones based on substrate type, tides, and salinity (Mughoffar, et al., 2018). Mangrove forests have high adaptability to a very diverse environment such as being able to grow and develop in coastal environments with extreme salt levels, water saturation, unstable soil conditions, and even anaerobic conditions (Pramudji, 2001). In addition to the high adaptability of mangroves, mangrove forests are also very beneficial, including being able to protect the coast from abrasion, support the livelihoods of coastal communities, and have an important role in global climate regulation (UNEP, 2014). Mangrove is one of the forests with high economic productivity and is a habitat for many types of flora and fauna, it can also act as a source of energy for the organism in its waters (Susiana, 2015).

Regardless of their ecological and economic value, mangrove forests continue to be depressed and degraded (Noor et al., 2006). Damages to mangrove forests can be caused by various factors, one of the main factors causing damage to mangroves is human activity which triggers the conversion of mangroves into residential areas and human activities around mangrove forests such as port construction, and the existence of aquaculture (Pawar, 2013). Water conditions, especially salinity, also affect mangrove quality (Noor, et al., 2006). Although this vegetation has high adaptability to changes in salinity, it's also susceptible to changes in the quality of other environmental parameters (Schaduw, 2018). If there's damage or disturbance to the quality of the coastal environment where mangroves live, it will result in a decline in the health of mangroves and can even cause the death of mangroves.

To avoid more damage to mangrove forests, conservation efforts are needed. Plants that have good health have a good growth rate, and the canopy or pile of leaves on these plants will be dense and dense (Oladejo, et al., 2018). NDVI can calculate the greenness of vegetation with the principle of radiation from visible red which is absorbed by chlorophyll and reflected (Williams, 2012). Based on these characteristics, mangrove health can be analyzed using the NDVI method (Maulidyah, et al., 2019).

Mangroves in the Taman Hutan Raya Ngurah Rai are also not immune from the threat of damage. According to the Bali Provincial Government in 2012, a permit was issued for reclamation activities in Tanjung Benoa by the Bali Governor's Decree No. 2138/02-C/HK/2012 which threatens coastal forests including mangrove forests. In addition to reclamation issue, the widening of Ngurah Rai airport, the construction of Benoa Harbor, and organic and inorganic pollution caused by the disposal of resident waste in the river that

empties into Benoa Bay also threaten the condition of the mangrove forest (BPKH Region VIII Denpasar, 2016). Mapping the distribution and health of mangrove forests is very important for monitoring, planning, and policy-making in mangrove forests.

The purpose of this study was to map the spatial distribution of Normalized Difference Vegetation Index (NDVI) values and the spatial distribution of environmental quality parameters of mangroves, as well as to analyze the health of mangrove forests in Ngurah Rai Grand Forest Park based on both. Several studies are used as references to examine the health of mangrove forests in this study, including research by Razali, et al (2019), Kawamuna, et al. (2017), Awaliyan and Sulistyoadi (2018) and Maulidyah, et al. (2019) which examines the health level of mangrove vegetation based on the value of the Normalized Difference Vegetation Index (NDVI) by VITO (2017) and validated by the value of species density in the field.

In addition to the method in analyzing the health of mangroves, previous studies used environmental quality data as a research variable. The data in question are pH, Temperature, Salinity (Schaduw, 2018), and Mangrove Forest Substrate (Imamsyah, et al., 2020; Razali, et al, 2019). In previous studies, mapping of water quality with parameters of temperature, pH, salinity (Nagalakshmi, et al., 2016), and substrate (Yasrebi, et al., 2009; Suhadirman, et al., 2013) was carried out using the kriging spatial interpolation method.

The novelty of this research is analyzing the health of mangrove forests by overlaying the Normalized Difference Vegetation Index (NDVI) vegetation index and analyzing the spatial distribution of environmental parameters using the kriging spatial interpolation method. The spatial distribution of environmental parameters consists of parameters of temperature, salinity, pH, and also the texture of the substrate in the mangrove forest. In addition, no research analyzes the health of mangrove forests based on the value of the vegetation Index and spatial environmental quality parameters in the mangrove forest of Taman Hutan Raya Ngurah Rai (Tahura).

2. Methods

2.1. Study Site

This research was conducted at the Taman Hutan Raya Ngurah Rai, located in Benoa Bay, Bali Province. Administratively, Taman Hutan Raya Ngurah Rai (Tahura) is located in the Badung Regency and Denpasar City which includes twelve coastal villages in three sub-districts. Namely South Kuta District, Kuta District, and South Denpasar District. The management of Taman Hutan Raya Ngurah Rai area is included in the UPT area, Tahura

Ngurah Rai, Bali Provincial Forestry Service. The land cover for the Taman Hutan Raya Ngurah Rai area includes Mangrove Forest covering an area of 1,132.00 Ha, Settlements covering an area of 16.27 Ha, Open Land covering an area of 49.35 Ha, and water body covering an area of 144.01 Ha (BPKH Region VIII Denpasar, 2016). Tahura Ngurah Rai is located in Benoa Bay which is a strategic location for both business and tourism which carried out the developments for that area. Developments that have occurred in Benoa Bay are the reclamation of Serangan Island, Benoa Harbor, and the Toll Road.

2.2. Variable and Data Collection

In this study, there are several research variables. The variables used are the NDVI value, the environmental quality consisting of parameters of temperature, salinity, pH, and substrate texture. These variables can be obtained through satellite imagery and data sampling from the field.

Data collecting for Normalized Difference Vegetation Index (NDVI) variable in the form of primary and secondary data. The primary data collected for the NDVI variable is collected from field sampling to know the number of greeneries in one unit area. The secondary data needed in this study are administrative data, and Sentinel-2A satellite image data on November 18, 2020, at Taman Hutan Raya Ngurah Rai, Bali.

Data collection for both samples of total vegetation number in the unit area and environmental quality was carried out at 40 selected sample points using the purposive random sampling method according to the level of vegetation health value based on the NDVI value classification and accessible roads in mangrove forests. The method of sampling the number of stands was carried out by previously making a plot of 10 x 10 meters.

2.3. Mangrove Forest NDVI Distribution Mapping

To map the distribution of mangrove forests, first, land cover classification was carried out using the supervised classification method. Supervised classification is the process of classifying image pixels into a certain class based on a pixel sample (training) that has been determined by the user as a reference (LAPAN, 2015). The accuracy test of the mapping results is done by making a confusion matrix or contingency matrix. The next stage of image data processing is NDVI transformation to determine the level of canopy density. The NDVI vegetation index value is between -1 to 1. To transform the NDVI vegetation index, the following formula is used (Green, et al., 2000):

$$NDVI = (NIR-RED)/(NIR+RED)$$

Where:

NIR = Near Infrared Band

RED = Red Band

After the data of a total of mangrove vegetation in one unit area were taken from 40 field samples, the data was then processed by calculating the vegetation density which could be done with the following equation formula (Gunawan, et al., 2011):

$$D_i = (n_{(i)})/(A(ind/m^2))$$

Where:

D_i = Species i Density

(i) = Total vegetation of species i

(ind/m^2) = total sampling area (class) or (unit/pixel)

2.4. Environmental Quality Distribution Mapping

The interpolation method is used for mapping the environmental quality of the mangrove forest. The steps taken to create an environmental distribution map of mangrove forests started from processing tabular data and then calculating experimental semi-variograms of environmental quality data (temperature, pH, salinity, and substrate texture) with the GS+ (Geostatistical Software). The experimental semi-variogram is then matched with theoretical semi-variogram models (Exponential, Spherical, Gaussian). An environmental parameter distribution map will then be made using the Ordinary Kriging method.

2.5. Mapping the Distribution of Mangrove Forest Health

The NDVI vegetation index data is used as one of the variables in assessing the condition of mangrove forests' health. Mangrove forest health data were processed by using the plant health classification by Vito (2017). Another variable that is processed is the environmental quality of the mangrove forest which is obtained from the interpolation of water temperature parameters, water salinity, water pH, and substrate texture which are then categorized according to the optimal range for mangrove health. The environmental quality

distribution map for each parameter is then overlaid to produce a distribution map of the environmental quality of the Taman Hutan Raya Ngurah Rai.

From the distribution of health of the mangrove forest based on the NDVI value and the distribution of the environmental quality of the mangrove forest, an overlay was performed. Map overlay can produce the distribution of mangrove forest health based on the NDVI value and the quality of the mangrove environment.

2.6. Data analysis

The analysis performed for the distribution of the Normalized Difference Vegetation Index (NDVI) is a statistical analysis of correlation and regression. Correlation analysis is used to determine the relationship between the variable x which is the transformation data of the vegetation index with the variable y, while the regression analysis is intended to determine the magnitude of the effect caused by changes in each unit of the independent variable x. The Normalized Difference Vegetation Index (NDVI) value was then analyzed descriptively by spatial analysis. The spatial distribution of the mangrove environment quality based on the parameters of water temperature, salinity, water pH, and soil texture was analyzed descriptively. The results of overlay data processing from the distribution of NDVI values and environmental quality of the mangrove forest were analyzed in a tabular and spatial descriptive manner. The unit of analysis in this study is the district in Taman Hutan Raya Ngurah Rai.

3. Result and Discussion

3.1. Mangrove Forest NDVI Distribution

Mangrove land cover spreads along with the coastal villages of Kuta District, South Kuta District, and South Denpasar District. The mangrove forest area generated from supervised classification was then tested for accuracy with a confusion matrix. The results of the accuracy-test with the confusion matrix show an overall accuracy of 94% which indicates that the classification can be used. The mangrove forest in the Taman Hutan Raya Ngurah Rai in 2021 has a total area of 1083.37 Ha. The largest area of mangrove forest is in South Denpasar District of 520.71 Ha, then South Kuta District of 347.7 Ha and the smallest is mangrove forest in Kuta District of 214.96 Ha.

The results of the statistical test showed that there was a real or significant effect between the NDVI value and the mangrove vegetation density value. The correlation value between the two NDVI value variables and the mangrove vegetation density is 0.818. The

magnitude of the correlation value (R) indicates a positive relationship between the NDVI variable and the density of mangrove vegetation. From the results of the distribution of the NDVI value in Figure 1, it can be seen that the NDVI value of mangrove forests in the Taman Hutan Raya Ngurah Rai area in 2020 has a range of 0.000754717 to 0.789031. The NDVI value in the mangrove forest of Taman Hutan Raya Ngurah Rai is quite high. The average NDVI value of mangrove vegetation is 0.5118. Low NDVI values can be found on the riverbanks and beaches facing directly to the sea. The NDVI value also appears to decrease at the fringe of mangrove forest which is close to housing and land.

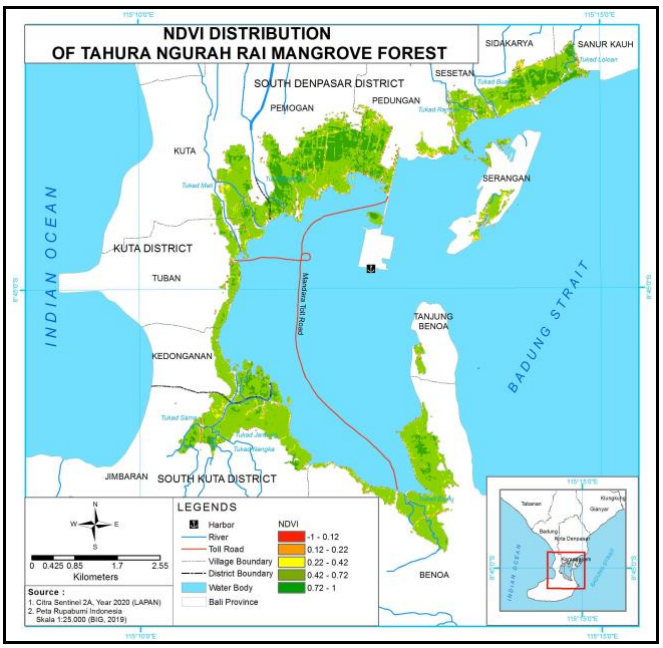

Figure 1. Distribution of Mangrove Forest NDVI Value

3.2. Environmental Quality Spatial Distribution

3.2.1. Water Temperature Distribution

Based on kriging results, mangrove forest water temperature is at least 28.63ºC with the maximum temperature is 33.32ºC. The temperature in South Denpasar District ranged between 28.63ºC-32.53ºC. Low-temperature waters are located in the northern part of Benoa Bay, precisely in Pemogan, Serangan, and Pedungan Villages in South Denpasar District where the temperature is in the range of 28.63ºC - 30.19ºC. In Sesetan Village, Sidakarya, Sanur Kauh, and Serangan Island, the waters of the mangrove forest have a temperature range between 30.2ºC - 31.75ºC. Kuta District, which is located in the western part of Benoa Bay, has a temperature range between 28.63ºC - 32.53ºC. The temperature in Kuta District from North to South is increasing.

According to the State Minister for the Environment (2004) which states that the ideal temperature for mangrove health is 28-32°C. Mangrove forest waters environmental quality based on temperature can be seen which can be seen in Figure 2. The environmental quality which is classified as unhealthy can be found in South Kuta District and Kuta District, precisely in Kedonganan Village and Jimbaran Village. The temperature is not optimal because the mangrove forest waters in this area flow from 3 different rivers, namely Tukad Jantung, Tukad Nangka, and Tukad Sama. Jimbaran Village is also one of the coastal villages with the highest population among twelve coastal villages in the Taman Hutan Raya Ngurah Rai area.

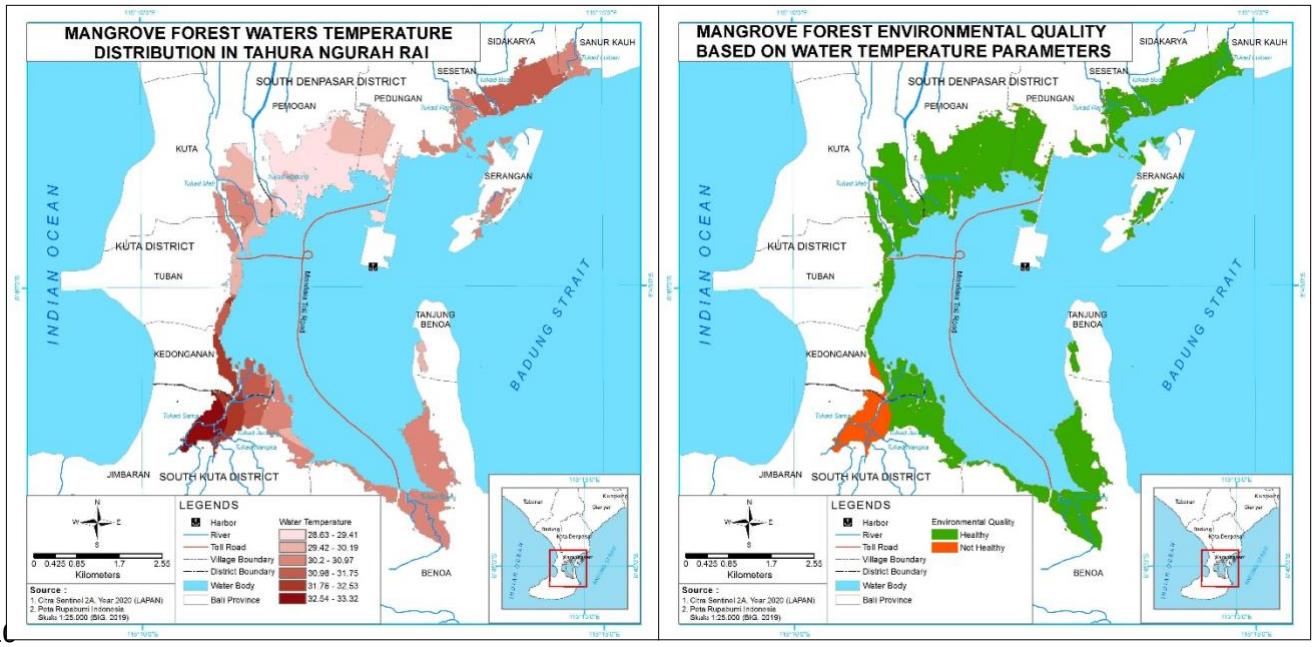

Figure 2. Distribution of Environmental Quality Based on Temperature Parameters

3.2.2. Water Salinity Distribution

Salinity in Taman Hutan Raya Ngurah Rai mangrove forest ranges from 5.12‰ - 32.82‰. The average salinity is 21.57‰. The distribution of salinity shows that high salinity values can be found in mangrove forests located on the coast and riverbanks of the mangrove area. South Denpasar District has a higher salinity than Kuta and South Kuta Districts, especially in the Sanur Kauh, Serangan, Sidakarya, and Sesetan villages which have salinity between 18.98‰ - 32.82‰. Pedungan and Pemogan villages have salinities ranging from 5.12 to 32.82. Kuta District has a salinity range of 14.37‰ - 29.21‰, and South Kuta District has a salinity ranging from 5.12‰ to 32.82 ‰.

The environment of mangrove plants that thrive in estuarine areas with a salinity of 10 -30 (Wantasen, 2013). In Figure 3, areas with un-optimal water salinity are located in Benoa

Village, Jimbaran Village, Pemogan Village, and Sesetan Village. In Benoa Village and Pemogan Village which is quite close to the mainland, the salinity value is the lowest. This is due to high sedimentation which causes the seawater cannot to flow properly through the area. In addition, other areas that have unhealthy water salinity parameters are located on the coast which has a salinity value of more than 30.

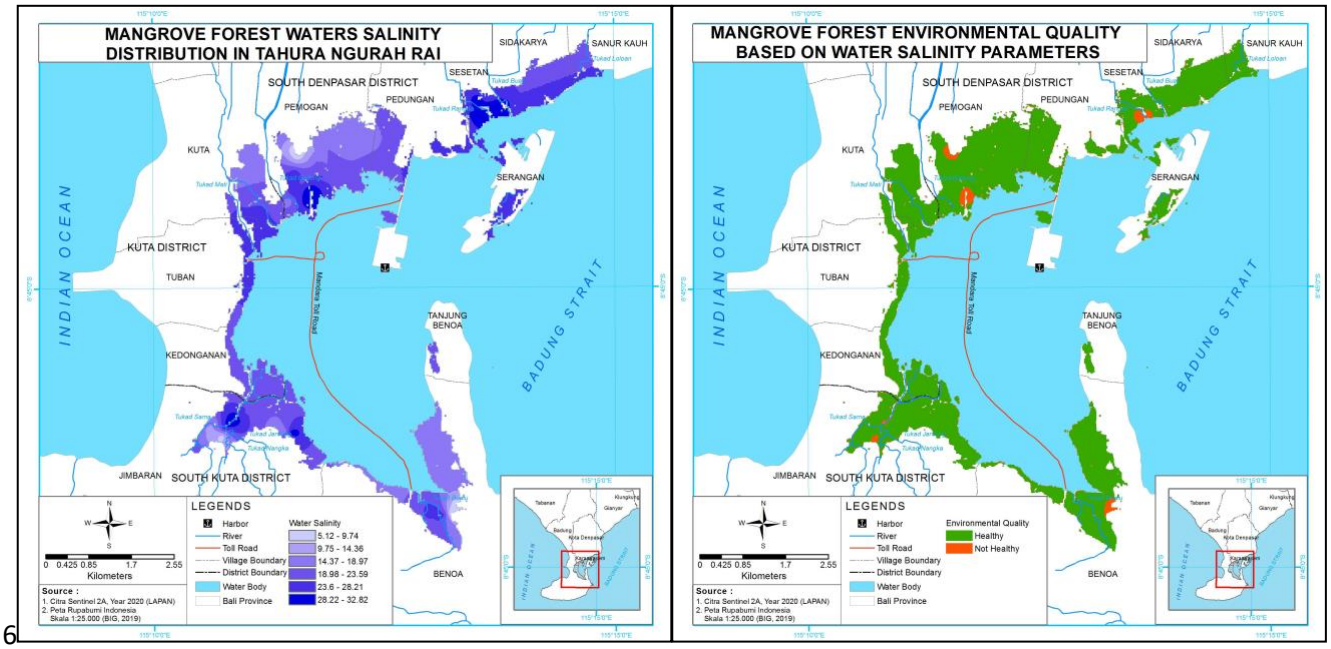

Figure 3. Distribution of Environmental Quality Based on Salinity Parameters

3.2.3. Distribution of Waters pH

Based on kriging results, the pH of the waters in the mangrove forest is at least 6.9 and the maximum is 7.5. The average pH value is 7.13. The area with low pH is located in the northern and southern parts of Benoa Bay, precisely in South Denpasar District and South Kuta District. South Denpasar District has a pH between 6.9 - 7.4. Kuta District, which is located in the western part of Benoa Bay, has a pH of 7.01 - 7.5. The distribution of pH in Kuta District from North to South is increasing. In South Kuta District, the pH distribution is higher in the west, precisely in Jimbaran Village and Benoa Village with a pH range between 6.9-7 and Tanjung Benoa Village has a pH range between 7.11-7.2.

Referring to the optimal pH range for healthy mangrove forests, which is around 7.0-8.5 (Wantasen, 2013), we can see the distribution map of environmental quality based on the pH value which can be seen in Figure 4. The pH that is not optimal for mangroves is in a small part of the South Denpasar District, namely Pedungan Village and Sesetan Village. It also can be found in South Kuta District, namely Benoa Village. The pH value in that area is between the range of 6.9 to 7. Mangrove forest waters pH values of Taman Hutan Raya

Ngurah Rai as a whole does not vary much. This is because there's a balance between the decomposition process of acidic mangrove litter and the influence of buffer capacity by salts in alkaline seawater.

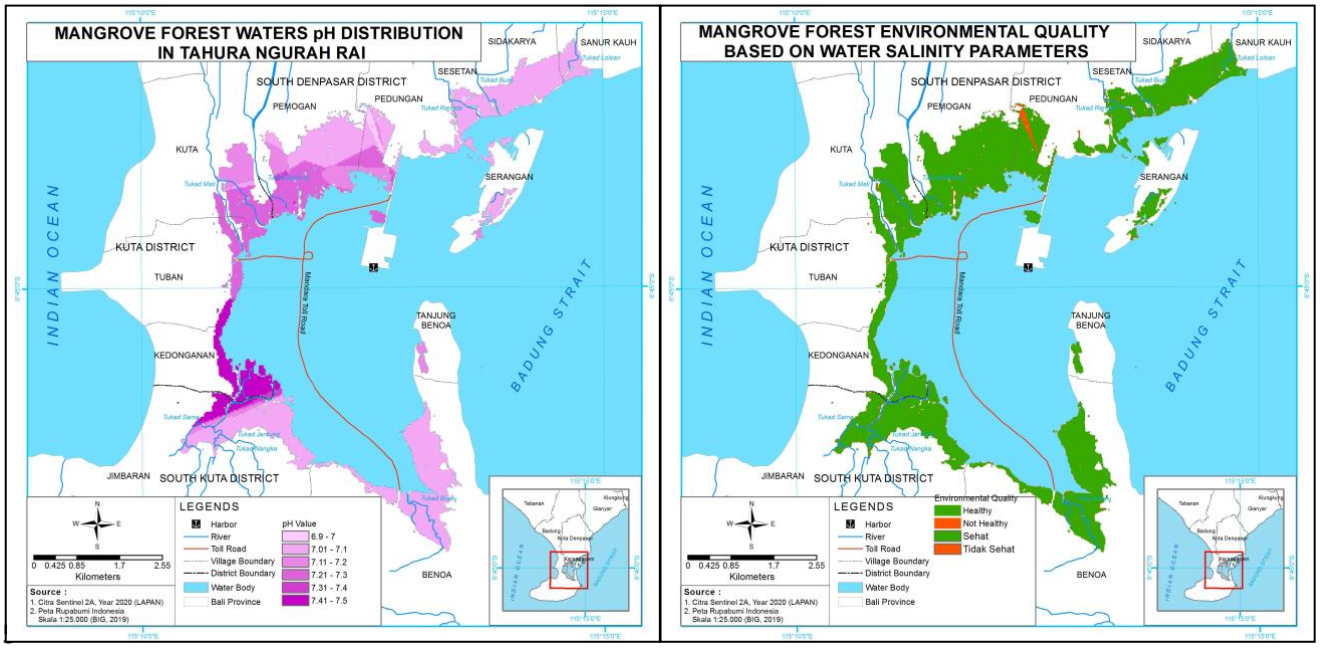

Figure 4. Distribution of Environmental Quality Based on pH Parameters

3.2.4. Distribution of Texture Substrat

The texture of the substrate in the South Denpasar District is dominated by sandy loam texture. There is a substrate with a clay texture and dusty clay in the mangroves near the mainland of Pemogan Village and sandy clay loam in the mangrove forest close to the coast on the border of Sesetan Village and Sidakarya Village. The substrate texture in Kuta District is a sandy clay texture. Substrate texture in South Kuta District is dominated by sandy loam texture. Several clay-textured areas in Benoa Village are close to Tukad Bualu.

The distribution of substrate textures in Ngurah Rai Forest Park shows that all types of substrate textures in this area are still in the optimal range for the health of mangrove forests. This is because the texture of the substrate in the mangrove forest is of the type of clay texture based on the content of the substrate fraction. The texture of the clay substrate affects the water content and nutrient conditions of the substrate where the mangroves live. Mangroves grow healthy on clay-textured soils that have a larger surface area so they can hold water and provide high nutrients (Mahmud and Bau, 2014). The distribution of the environmental quality of mangrove forests based on the texture of the substrate can be seen in Figure 5.

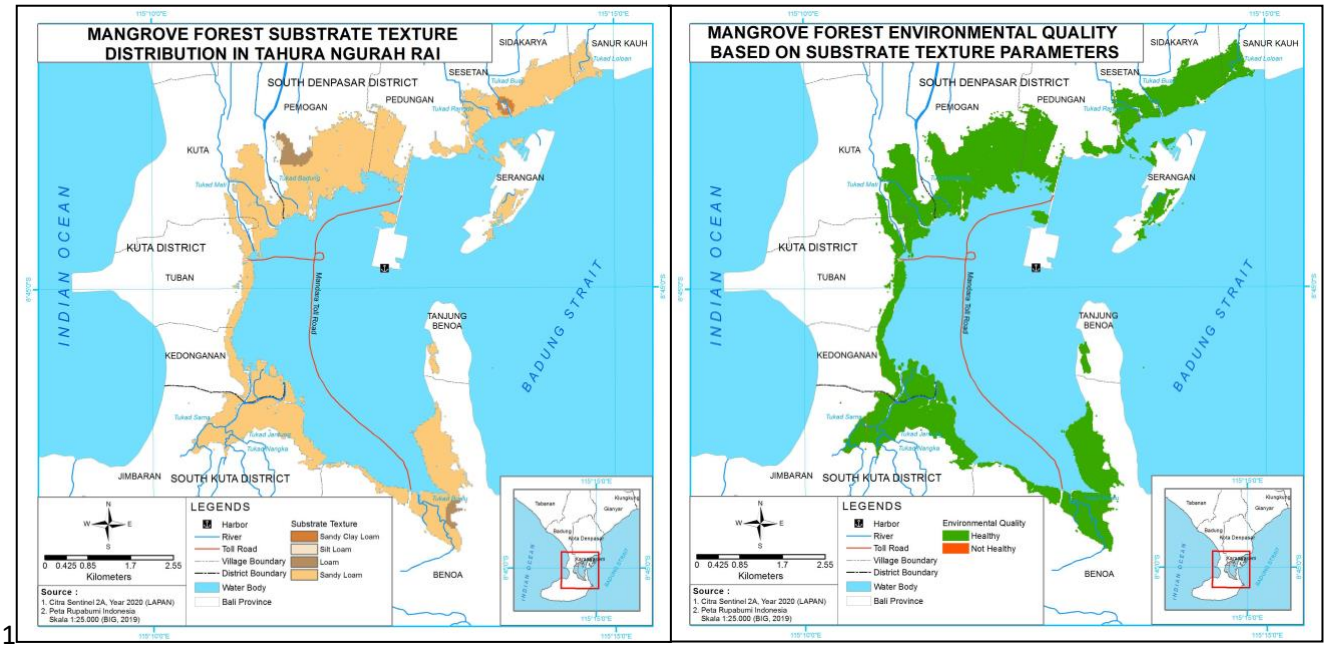

Figure 5. Distribution of Environmental Quality Based on Substrate Texture

3.3. Mangrove Forest Health Analysis

From the NDVI value and the environmental quality of the mangrove forest, an overlay is then carried to be able to see the distribution of mangrove forest health at Taman Hutan Raya Ngurah Rai in 2021 which can be seen in Figure 6. Area of mangrove health per district in Taman Hutan Raya Ngurah Rai can also be seen in Table 1.

Table 1. Comparison of Mangrove Forest Health Area by District

District	Vegetation Health	Pixel	Area (Ha)	Area (%)
Kuta	Healthy	20787	202.43	94.17
	Not Healthy	709	12.53	5.83
	Total		214.96	100
South Kuta	Healthy	27368	273.68	78.7
	Not Healthy	7402	74.02	21.3
	Total		347.7	100
South Denpasar	Healthy	49053	490.53	94.2
	Not Healthy	3018	30.18	5.8
	Total		520.71	100
	Grand Total		1083.37	

Source: secondary data processing

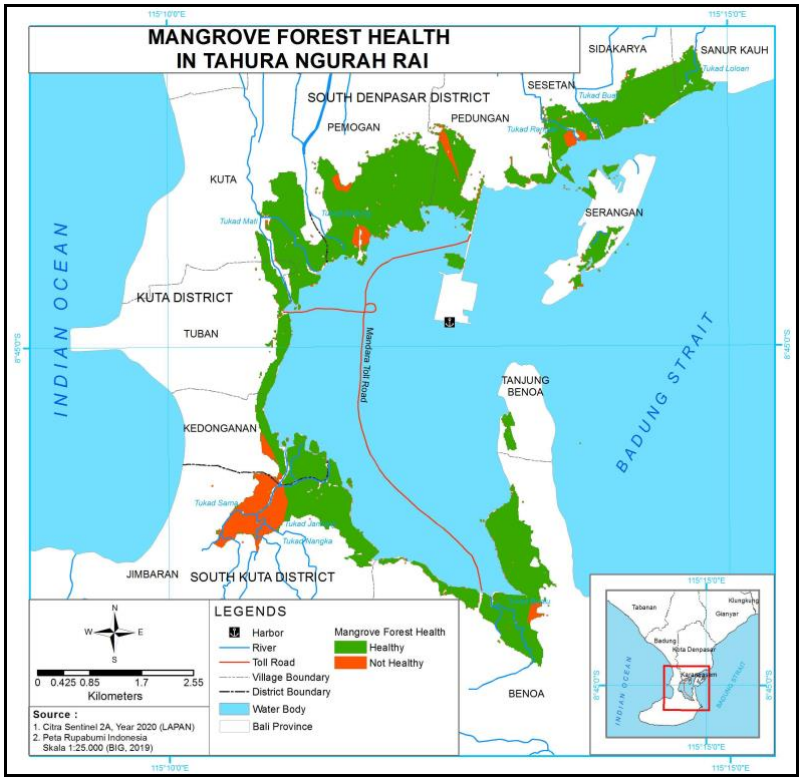

Figure 6. Distribution of Mangrove Forest Health Based on NDVI Value and Environmental Quality

Quality Mangrove forests based on NDVI values with very good, good, and normal classifications are included in the category of healthy mangrove forests and mangroves with bad and very bad categories are included in the unhealthy category. In South Denpasar District, the existing mangrove forest spans an area of 520.71 Ha consisting of 490.53 Ha in healthy condition and 30.18 Ha in unhealthy condition. Mangrove forest in South Denpasar District has the best condition among other districts in Taman Hutan Raya Ngurah Rai with a healthy category of 94.2% of the total area of mangrove forest in the district.

Mangrove forests that have unhealthy conditions are mostly found in Sesetan Village, Sidakarya Village, Pemogan Village, and Pedongan Village. Unhealthy mangrove forests in Sesetan and Sidakarya villages are located around Tukad Buaji and Tukad Rangda. This is due to the river flow community waste and the community density of Sesetan and Sidakarya villages is also very high among coastal villages in the Taman Hutan Raya Ngurah Rai area, it has a density of 6,806.90 and 5,242.93 people/km^2 respectively (Central Bureau of Statistics, 2020). Waste from the surrounding community and other community activities will affect the environmental quality of the mangrove forest which then affects the health of the surrounding mangrove vegetation.

The environmental quality of the affected mangrove forest waters is that the water temperature is not optimal for the health of mangroves. This can be found on the edges of the sea and coastal areas. The salinity value at the Tukad Rangda estuary on the border of Sesetan Village and Sidakarya Village and the coast of Pemogan Village is above 30 and the mangrove forest area near the mainland of Pemogan Village is below 10.

Kuta District has a mangrove forest that stretches across an area of 214.96 Ha consisting of 207.87 Ha in healthy condition and 7.09 Ha in unhealthy condition. Mangrove forest in Kuta District is the second-best forest in South Denpasar District with a healthy category of 94.17% of the total area of mangrove forest in the district. Mangrove forests with unhealthy categories are widely spread on the beach and the edge of Tukad Mati in the Kuta Village and at the estuary of three different rivers in Kedonganan Village that carries the wastes of communities around coastal villages. Tukad Mati is a large river that irrigates Kuta District and is designated as one of the tourism sites in the Taman Hutan Raya Ngurah Rai. Several areas of mangrove forest have water temperatures that are not included in the optimal temperature range mangrove which is in Kedonganan Village and the edge of Tukad Mati in Kuta Village. High-intensity human activities such as tourism and community waste entering from river water can damage mangrove forests.

From the total area of mangrove forest in South Kuta District of 347.7 Ha, 273.68 Ha is an area in healthy condition and 74.02 Ha in very bad condition. South Kuta district has the worst mangrove conditions among the three with 78.7% in healthy condition and 21.3% in unhealthy condition. Mangrove forests with unhealthy vegetation conditions are widely scattered on the shores of mangrove forests, the estuary areas of Tukad Sama, Tukad Jantung, and Tukad Nangka in Jimbaran Village, and mangrove forests close to the mainland in Benoa Village. The water flowing in this mangrove forest area is influenced by three different rivers, namely Tukad Sama, Tukad Jantung, and Tukad Nangka. This can be seen in the environmental quality of mangrove forest waters, namely the high temperature with a range of 32.54 - 33.32 °C which exceeds the optimal limit of the State Minister for the Environment (2004) who states that the ideal temperature for mangrove health is 28 - 32 °C. However, in Jimbaran Village, there is mangrove vegetation with poor health that is not on the riverbank or on the beach. The mangrove vegetation is influenced by the salinity level of the mangrove forest waters. The ideal salinity for the health of mangrove vegetation is salinity in the range of 10 - 30. (Wantasen, 2013). There are mangrove forest areas that have salinity in the range of 5.12 - 9.74. Lack of salinity is also found in the east of the mangrove forest in Benoa Village, which is close to Tukad Bualu. This low salinity level is caused by ocean currents

that cannot reach the area at high tide so that it cannot supply sufficient salinity levels. This is caused by the high sedimentation in the mangrove forest area. Moreover, in the same area, a large amount of plastic waste from surrounding settlements was also found.

Of the mangrove forests in three districts in Taman Hutan Raya Ngurah Rai, mangroves with unhealthy categories can be found on the edge of the mangrove forest. Both close to the mainland or close to the sea. This is due to human activities found in the mangrove forest and around the mangrove forest. This is supported by research by Pratama, et al (2019) who also examined the density of mangrove forests in Taman Hutan Raya Ngurah Rai, which found that the density of mangrove forests on both sides of the border with the sea and land is lower. This is due to human activities including the disposal of garbage, the widening of Ngurah Rai Airport and Benoa Harbor, and the construction of the Nusa Dua Benoa-Ngurah Rai toll road. According to Suteja and Dirgayusa (2018) in their research, it was also found that there was pollution from rivers dumped into Taman Hutan Raya Ngurah Rai. In addition to the mangrove forest in the Taman Hutan Raya Ngurah Rai, research by Hamuna, et al. (2018), in the mangrove forest of the Youtefa Bay Nature Tourism Park, Jayapura also shows the distribution of mangrove forests with low density or high mangrove damage in the outermost part of the mangrove forest.

4. Conclusion

The spatial distribution of the Normalized Difference Vegetation Index (NDVI) value of mangrove vegetation in the Taman Hutan Raya Ngurah Rai in 2021 indicates that the closer to the edge of the mangrove forest area, the lower the NDVI value. The spatial distribution of environmental quality parameters in the Taman Hutan Raya Ngurah Rai is dominated by the healthy mangrove forest category. Unhealthy environmental quality according to the parameters of temperature, pH, and salinity of the waters is found on the edge of river estuaries and mangrove forest areas bordering the mainland, while the substrate texture parameter indicates healthy environmental quality in all mangrove forests. Based on the results of the analysis, the health of mangrove forests, NDVI values, and the best environmental quality parameters are located in South Denpasar District then Kuta District, and South Kuta District which have the worst mangrove conditions among the three. The health of the mangrove forest is getting worse closer to the shore and riverbanks. Mangrove vegetation with good conditions tends to have optimal environmental quality conditions and vice versa, this is caused by the waste of the activities of the surrounding community.

Acknowledgment

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