Distribution and area changes of mangroves with remote sensing technology in Perancak Estuary, Jembrana, Bali

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Abstract. Mangrove vegetation has an important role for its functions and benefits to the coastal area and the society which lives in it. The purpose of this research is to know the distribution and the changes of mangrove vegetation area located in Perancak Estuary area within 10 years, and to know the green-ness level and the environmental parameters of mangrove vegetation; salinity and substrate condition. To observe the distribution and the changes of mangrove vegetation area, supervised classification is used on SPOT satellite imagery in 2007 and 2017. The result shows that the expansion of mangrove vegetation area in Perancak Estuary is 18.7 hectares along with the increasing of the green-ness level. In addition, the environmental parameters which are the salinity and the substrate conditions are also observed, where the average salinity value is 31.54 ppt and the substrate conditions are good (not much waste).

Keywords: Mangroves, NDVI, remote sensing, SPOT satellite imagery

1. Introduction
Indonesia is a maritime country with the water area of 6,315,222 km², with a 99,093 km² coastline and has many islands that have been named and coordinated [1]. The geographical position of Indonesia passed by the equator causes diversity of biological and non-biological resources, one of them is the resources in the coastal areas. Various kinds of coastal resources, of course, can be utilized for the life of the surrounding community. With good and integrated management, the potential of coastal resources can be utilized sustainably. One of the most useful resources for coastal life is mangroves.

Mangrove ecosystem that exist in coastal areas are quite important and should be protected because it has functions and benefits for humans, especially people who living in coastal areas. Mangrove ecosystem usually grows on coastline, delta or estuary [2]. Mangrove ecosystem functions include ecological functions such as retaining waves, windbreaks, flood controllers, as a habitat for aquatic biota and beneficial nutrients contributing to the surrounding waters. Approximately 3 million hectares of mangrove ecosystems grow along 95,000 km of coastal areas in Indonesia and this represents 22.6 % of the world's mangrove ecosystems [3]. According to the Food and Agriculture Organization (FAO), mangrove ecosystems decreased by 20 % from 1980 to 2005 [4], largely due to population growth and human activities in coastal areas, for example mangrove forest conversion to agriculture and aquaculture (shrimp ponds).

Perancak estuary located in Jembrana, Bali Province is an estuary with most of its land use are ponds and mangrove forests, where based on research conducted by Kartikasari et al. [5], mangrove in
Perancak Estuary in 2015 covering 651,200 m², consist of natural and planted mangroves. There is land conversion in Perancak estuary, where mangrove forest is used as aquaculture development in the form of shrimp ponds. Then the ponds gradually abandoned, and in the 1990s the land was used for mangrove planting. In order to mapping and monitoring of mangrove ecosystem that has a large enough area, remote sensing method or remote sensing was used, which is considered more efficient. With remote sensing method for mangrove monitoring, spatial and temporal analysis can be done. There are various applications of remote sensing technology that can be used to inventory and detect changes in mangrove area, for example the use of Landsat imagery has been done for mangrove management such as mangrove distribution mapping as well as analysing mangrove density based on NDVI vegetation index.

Based on the background above, how is the pattern of distribution, area changes and environmental parameters of mangrove vegetation in Perancak estuary, Jembrana, Bali. This research was conducted in order to analyse the pattern of mangrove vegetation distribution, to analyse the area changes of mangrove vegetation using remote sensing method and to know the environmental parameters such as condition of salinity and substrate of mangrove vegetation in Perancak Estuary, Jembrana, Bali.

2. Methodology

In this research, the distribution of mangrove vegetation in Perancak estuary, Jembrana, Bali, obtained through remote sensing method supported by field survey data validation. Remote sensing is used to obtain the distribution of mangrove vegetation in 2007 and 2017. The field survey aims to validate the results of satellite image processing and obtain salinity data as well as substrate conditions. The data obtained will be processed in tabular and map form.

Visual interpretation and image classification are performed on SPOT images in 2007 and 2017 by performing colour composite (RGB 143 on SPOT-4 and RGB 413 on SPOT-6) on images aimed at simplifying the interpretation process. Then supervised classification is done by making training area first to determine mangrove and non-mangrove vegetation, where the false color composite image provides visual that can distinguish mangrove vegetation with other vegetation. Then after the classification, the area of mangrove vegetation in 2007 and 2017 will be calculated. To get the density/quality level of mangrove vegetation is done image processing to get the value of vegetation index NDVI with existing algorithm on the results of mangrove vegetation distribution.

\[
NDVI = \frac{(NIR - red)}{(NIR + red)}
\]

where NIR is the near infrared band and red is the red band.

The index values of mangrove vegetation were then classified into three classes, low, medium and high density/quality. After obtaining all result of image processing, determination of sample point by purposive sampling technique, where the sample is determined based on the existence of the required sample based on image processing result in 2017 satellite imagery. The next step is to analyse the results of image data processing in two different years, in 2007 and 2017 and field survey results with the map distribution and value of vegetation index of mangrove vegetation in Perancak Estuary, Jembrana Regency, Bali Province as the output and comparative analysis in 2007 and 2017 (spatial and temporal analysis). In the field survey, sample of environmental parameters is the value of water salinity in mangrove vegetation and observation of substrate condition. The conclusion will be done by descriptive method.
3. Results and discussion

3.1. Distribution of mangrove vegetation in Perancak Estuary

Based on the results of SPOT-4 (2007) satellite image processing, mangrove vegetation in Perancak estuary in 2007 spread over the former pond area near the riverside. In addition, there is mangrove vegetation that grows on the banks of the river, growing following the flow pattern of the river. The shape of the distribution on the banks of the river is irregular, this may indicate that the mangrove vegetation is natural (not planted). While the existing mangrove vegetation on the pond area regularly, which can be indicated as planted mangrove. Mangrove vegetation are spread in some villages around Perancak estuary, where mangrove vegetation is in Perancak, Pengambengan, Loloan Timur, Budeng and Sangkaragung. Mangrove vegetation can be found in the former shrimp pond area mostly in Budeng and Perancak. Based on the results of image processing, in 2007, the area of mangrove vegetation is 59.74 hectares.

Mangrove vegetation in Perancak estuary in 2017 is mostly distributed over the former shrimp ponds, where mangrove vegetation in the former ponds is mangrove vegetation planted by the Jembrana Marine Research and Evacuation Centre and the local community. At the time of the field survey also found mangrove vegetation managed by PT. Angkasa Pura. On the banks of the river there is also mangrove vegetation that can be seen from the visual appearance of image and image classification results. Based on the results of image processing, the area of mangrove vegetation in 2017 is 78.44 hectares. To know the accuracy level of classification in the image, Kappa coefficient is calculated as below

\[
Kappa \ Coefficient = \frac{35(21 + 10) - ((23 \times 23) + (12 \times 12))}{(35)^2 - ((23 \times 23) + (12 \times 12))} = 0.75
\]

Kappa coefficient is a discrete multivariate technique used for accuracy assessment. Based on calculation of Kappa coefficient obtained that is 0.75, result of classification of image shows accuracy level in medium accuracy (table 1 and table 2).

3.2. Area changes of mangrove vegetation in Perancak Estuary

Based on the results of SPOT image processing (2007 and 2017), mangrove vegetation (in the picture, green colour is mangrove vegetation, figure 1) in Perancak estuary, Jembrana, Bali experienced a considerable change in 10 years. The result of supervised classification on SPOT-4 in 2007 shows the extent of mangrove vegetation is 59.74 hectares, while the supervised classification on SPOT-6 image 2017 shows the extent of mangrove vegetation is 78.44 hectares. This indicates that the addition of mangrove vegetation area is 18.7 hectares or increased by 31.3 % of the area in 2007.

The addition of mangrove vegetation area in Perancak estuary is caused by the change of function of shrimp pond into mangrove, which then the area becomes the conservation area. In the patches of shrimp pond that is not used anymore done mangrove planting. Based on interviews to local residents, the local community has a significant role in the addition of the area of mangrove vegetation, where the community from children to adults (men and women) participated through activities organized by the Jembrana Marine Research and Observation Centre (BPOL Jembrana), which is the activity of planting mangrove together. BPOL Jembrana also participated in mangrove planting activities with schools in Jembrana. The community participated in mangrove planting from nurseries to replanting the damaged mangroves. This is done by the local community also to increase income for their daily needs. So that most of the extension of mangrove vegetation comes from the planting done by the community. While on the banks of the river there is also a broad addition that can be seen quite clearly through visual image appearance and classification results.

3.3. Mangrove vegetation density based on NDVI

Based on SPOT-4 (2007) satellite image processing, the value of NDVI mangrove vegetation of Perancak Estuary in 2007 ranged from 0.05 to 0.19, with an average of 0.13. Based on SPOT-6 (2017)
satellite image processing, the value of NDVI mangrove vegetation in Perancak Estuary in 2017 ranged from 0.3 to 0.6 with an average of 0.54 as shown in table 3. The processing results are then classified into three classes, low, medium and high level. When the SPOT-4 and SPOT-6 satellite image processing results are compared, there is a change in the NDVI value. In the SPOT-4 processing result (recording date of June 2nd, 2007), the lowest NDVI vegetation index value was 0.05, while in SPOT-6 (April 30th, 2017), 0.3. In the SPOT-4 processing result in 2007, the highest NDVI value in SPOT-4 in 2007 was 0.2 while in SPOT-6 in 2017, it was 0.6. This indicates an increase in density/quality level of mangrove vegetation in Perancak estuary.

| Table 1. | Accuracy level of Kappa coefficient. |
|----------|--------------------------------------|
| Kappa coefficient | Accuracy |
| < 0.4 | Low |
| 0.4–0.8 | Medium |
| > 0.8 | High |

| Table 2. | The results of the survey. |
|----------|-----------------------------|
| Classification of Satellite Image SPOT-6 (2017) | Field data |
| | Mangrove | Non Mangrove | Total |
| Mangrove | 21 | 2 | 23 |
| Non Mangrove | 2 | 10 | 12 |
| Total | 23 | 12 | 35 |

Figure 1. Mangrove distribution based on image processing, (a) SPOT-4 2007 and (b) SPOT-6 2017.
Table 3. NDVI classification based SPOT-4 (2007) and SPOT-6 (2017) image processing.

| Density | NDVI Value |
|---------|------------|
| Low     | 0.05–0.25  |
| Medium  | 0.25–0.45  |
| High    | 0.45–0.6   |

According to Weier et al. [6], when the value of NDVI approaches one, the density/quality of the vegetation is better. To see the comparison of density level with the range of NDVI values in 2007 and 2017, we get a new classification of NDVI values, where class is divided into three (low, medium and high). When the density level compared with the NDVI value range 0.05–0.6, in 2007 the value of the NDVI vegetation index entirely entered into the low classification, because the NDVI value ranges from 0.05 to 0.2. While in 2017, the value of vegetation index NDVI included in the classification of medium and high, because the value of NDVI ranged from 0.3 to 0.6, which is dominated by high density levels, see figure 2.

3.4. Environmental parameters of mangrove vegetation in Perancak Estuary

The substrate of mangrove vegetation Perancak estuary is dominated by muddy soil substrate. Because mangrove vegetation in Perancak estuary has been used as a conservation area, substrate condition is quite good. At some point during the field survey, there was an organic waste but with little amount and no waste.

Based on the survey results, from 15 sample points there are four sample points contained waste. The waste is an organic waste in the form of household plastic waste (such as soap plastic, food wrap, Styrofoam) and the amount of waste found at the sample point is not much or accumulate as shown in figure 3. According Purwoko et al. [7] plastic waste is one of the main factors causing the destruction of mangrove vegetation, which causes air aeration in the mangrove root system. Plastic waste can also affect the flow of tidal in and out, which causes disruption of nutrient supply for mangrove vegetation. The least amount of waste in mangrove vegetation Perancak Estuary and increase of mangrove area indicate that mangrove vegetation substrate conditions are still in good condition. This muddy soil substrate is a good substrate for some mangrove species such as *Rhizopora* sp [8]. Muddy substrate can also be a good habitat for various animals that exist in the mangrove ecosystem. Animals that are often encountered during field surveys are crabs and lizards.

The lowest salinity value is 27.5 ppt, while the highest salinity value is 36.33 ppt. The average salinity value obtained at all sample points is 31.54 ppt (table 4). When compared with the quality standard for marine biota (mangrove) based on the decision of the State Minister of Environment No. 51, 2004, almost all salinity values from sample points are appropriate, up to 34 ppt, but only 1 sample salinity value not in accordance with the standard of marine biota (mangrove), with salinity value is 36.33 ppt.

The condition of salinity when associated with the theory of mangrove ecosystem characteristics according to Bengen, including into the category of saltwater [9]. Whereas when associated with the Nybakken theory [10], the salinity conditions fall into the estuary salinity category (5–30 ppt) and seawater (above 30 ppt). This shows that mangrove vegetation in Perancak Estuary has high adaptability under certain salinity conditions [11], where mangrove vegetation in Perancak Perancak is able to grow in salinity in the salty category. Based on the location of the sampling point of water sampling in mangrove vegetation, the highest water salinity location (sample point 1), also with the highest salinity value 2 (sample point 14) is close to the rivers (sample 1) and tributaries (sample 14).
Figure 2. Density comparison from NDVI value classification based on SPOT-4 (2007) and SPOT-6 (2017) after image processing.

Figure 3. Example of waste that found on mangrove substrate in Perancak Estuary.

While the location of water with the lowest salinity value of 27.5 ppt is located at a location further away from the mouth of the river. Closer to the river mouth, the higher the salinity value of water in mangrove vegetation. The further to the north (away from the river mouth), the lower the salinity value.
Table 4. Field survey data

| Sample | Date and Time       | Mangrove                          | Salinity | Waste on Substrate | Natural/Planted |
|--------|---------------------|-----------------------------------|----------|--------------------|-----------------|
| 1      | 19 May 2017, 09.03 WITA | *Rhizophora sp*                  | 36.33    | Yes                | Natural         |
| 2      | 19 May 2017, 10.06 WITA | *Rhizophora sp, Avicenia sp*     | 31.33    | Yes                | Natural         |
| 3      | 19 May 2017, 13.38 WITA | *Avicenia sp, Sonneratia sp*     | 31.17    | No                 | Natural         |
| 4      | 19 May 2017, 14.14 WITA | *Rhizophora sp*                  | 29.17    | No                 | Planted         |
| 5      | 20 May 2017, 08.44 WITA | *Rhizophora sp, Avicenia sp*     | 32.17    | No                 | Planted         |
| 6      | 20 May 2017, 09.05 WITA | *Rhizophora sp, Avicenia sp*     | 31.83    | No                 | Planted         |
| 7      | 20 May 2017, 09.25 WITA | *Rhizophora sp*                  | 32.00    | No                 | Planted         |
| 8      | 20 May 2017, 08.37 WITA | *Rhizophora sp*                  | 33.67    | No                 | Planted         |
| 9      | 23 May 2017, 09.00 WITA | *Rhizophora sp, Avicenia sp*     | 30.67    | No                 | Planted         |
| 10     | 23 May 2017, 09.58 WITA | *Rhizophora s, Avicenia sp*      | 30.00    | No                 | Natural         |
| 11     | 23 May 2017, 13.53 WITA | *Rhizophora sp, Avicenia sp*     | 27.50    | No                 | Planted         |
| 12     | 23 May 2017, 14.05 WITA | *Rhizophora sp, Avicenia sp*     | 31.33    | Yes                | Natural         |
| 13     | 23 May 2017, 14.14 WITA | *Rhizophora sp*                  | 31.33    | Yes                | Planted         |
| 14     | 23 May 2017, 14.50 WITA | *Avicenia sp*                    | 35.67    | No                 | Planted         |
| 15     | 23 May 2017, 15.15 WITA | *Avicenia sp*                    | 29.00    | No                 | Natural         |

4. Conclusion

Distribution pattern of mangrove vegetation in Perancak estuary in 2007 and 2017 grow to follow the river flow and clustered on the former shrimp pond. The pattern of mangrove vegetation in 2007 and 2017 tends to be the same, where in 2017 the clustering pattern is increasing. This is caused by the planting on the former shrimp pond.

The result of SPOT-4 satellite image processing in 2007 and SPOT-6 in 2017 shows that in 2007 the mangrove vegetation of Perancak Estuary is 59.74 hectares, while the mangrove vegetation area in 2017 is 78.44 hectares. The extent of mangrove vegetation increased by 18.7 hectares or increased by 31.3 % from 2007. The addition of mangrove vegetation area in Perancak estuary is caused by the role of the community in collaboration with the institution, where the community planted the mangrove together, to conserve and earn additional income. Salinity conditions in mangrove vegetation ranged from 27.5 ppt to 36.33 ppt, with an average of 31.54 ppt. The closer the mangrove vegetation with the river mouth the higher the salinity value. Mangrove substrate in Perancak estuary is muddy soil with clean condition from waste.
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