Study of potentials economic valuation of mangrove ecosystem for coastal communities using satellite imagery (case study: East Coastal Surabaya)

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Abstract. East Coastal Surabaya is one of the places planted with mangrove ecosystems. Given the important role of mangroves in human life, it is necessary to manage a good mangrove ecosystem. Mangrove at East Coastal Surabaya is one of the conservation areas which is in a good condition. From the results of the study, it was found that the correlation between NDVI and Nitrate, Phosphorus, Potassium, pH, Salinity showed a strong correlation of value (R) of 0.99, 0.99, 0.98, 0.98, 0.99. This shows that if the NDVI value is high, so does the NPK parameters of nutrients, pH, salinity. From an economic side, the mangrove ecosystem is expected to increase the economy of the people in the coastal areas. The estimated value of the mangrove uses economic value. The value is obtained from the total value of direct benefits, indirect benefits and the benefits of the choice of mangrove ecosystems. From the results of this research, the estimated value of the total mangrove economy is 19,157,539,347/year. The details consist of the annual direct value of mangrove benefits of Rp. 192,865,000, annual indirect benefits of Rp. 18,820,605,707 and annual preferred benefit value of Rp. 144,068,640.

1. Introduction
East Coast Surabaya is an area with the most extensive and diverse of mangrove ecosystem along the coastal of Surabaya. East Coastal Surabaya is one of the place which used as a conservation area. Mangrove have ecological and economic functions for living things. Mangrove forest is the most productive ecosystem and a source of nutrients for coastal fisheries. Mangrove support the lives of a large number of animal species by providing breeding grounds, spawning and eating. The species includes various species of birds, fish, shellfish, shrimp and crabs. The mangrove forest is a unique ecosystem and very potential as a natural resource, supporting the flora and fauna life of aquatic terrestrial communities which directly or indirectly play an important role in the survival of good humans in terms of economy, social and environment. Given the important role of mangroves for coastal areas, proper management is needed to maintain the existence of these mangroves.

As the development of science and information technology is increasing quickly, information needs must meet the requirements of relevant, on time, reliable, and up-to-date so that the information is optimally useful for the users in the decision-making process. Mapping of mangrove conditions
quickly and precisely can use remote sensing technology by utilizing high-resolution satellite imagery data. Considering the important role of mangroves in living life, the potential possessed by mangroves must be developed. To find out the value of the economic potential of mangrove ecosystems, it is necessary to study the mapping of the condition of mangrove ecosystems in the East Coast region of Surabaya. The economic potential of the mangrove ecosystem have been supporting the economy of the east coast community.

2. Methods

2.1. Research Location
This research was located in East Coastal of Surabaya. East Coastal Surabaya is one of mangrove conservation area which located in 7˚15’19.60” LS - 7˚17’13.25” LS and 112˚48’35.69” BT - 112˚48’40.72” BT.

![Figure 1. Research sites.](image)

2.2. Data and Equipment
The data and equipment used for this study include:

a. Landsat-8 Image  
   b. Pleiades 1A Image  
   c. RBI map scale 1: 25.000  
   d. GCP point measurement data  
   e. Parameter sample test data  
   f. Spectral ground data.  
   g. Economic value questionnaire data

2.3. Data Processing Phase
The phase in processing this research data are as follows:

a. Geometric Correction aims to determine the position of the image that matches the map coordinates or earth coordinates. In this study geometric corrections to Landsat-8 images were carried out with RBI maps in 1: 25.000 scale. While geometric correction on Pleiades 1A images is done by making a net design on the image and GCP measurement in the field. Geometric Correction is correct if the RMS Error value is less or equal to one pixel [4] meaning that the image has been geometrically corrected.

b. Radiometric Correction includes radiometric calibration and atmospheric correction. Radiometric calibration converts DN (Digital Number) to Reflectance. Then the atmospheric correction process is carried out using the Dark Object Subtraction (DOS) method.
c. Cropping is done to simplify image processing, and only covers the research area, namely the East Coast mangrove ecosystem area of Surabaya.
d. The vegetation index processing vegetation index is done by entering the vegetation index algorithm. In this study, we use the Normalized Difference Vegetation Index (NDVI) algorithm. The value of the NDVI algorithm is between -1 and 1. The NDVI algorithm is as follows:

\[
NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

Information:
NIR = Near Infrared spectral band value
RED = Red spectral band value
e. Furthermore, a supervised classification is carried out by including the range of values for each type of vegetation health.

| Class | NDVI Range     | Content Level |
|-------|----------------|---------------|
| 1     | 0 till 0.32    | Rare          |
| 2     | 0.32 till 0.42 | Average       |
| 3     | >0.42 till 1   | High          |

f. Field Observation include taking Sample Parameters (water and soil) and distributing the economic value questionnaire to the people in coastal areas. The parameter samples are soil and water physically and chemically.
g. Correlation tests are carried out on parameter samples. Correlation test is done by linking the value of the test results of the parameter samples with the vegetation index value in the image so that the form of the relationship can be known. If the pH value is high, salinity is low, with a high vegetation index value it has a positive relationship and vice versa.
h. Analysis. At this stage, the correlation value between the vegetation index and the parameter sample test in the field and the potential economic value of the mangrove are analyzed

3. Results and Analysis
From the results of processing, the data are as follows:

a. Geometric Correction
The results of the SoF net design calculation on the Pleiades 2015 image obtained a SoF value of 0.5938, it can be said that the SoF calculation fulfills the tolerance of ≤ 1. The Pleiades 1B image is rectified to determine how much the GCP point measurement error value is. The following are the results of the process of repairing the Pleiades 1B image using the 1st order and 2nd order polynomial methods:

| Point | Polynomial 1st Order | Polynomial 2nd Order |
|-------|----------------------|----------------------|
| GCP 1 | 0.328                | 0.231                |
| GCP 2 | 0.309                | 0.136                |
| GCP 3 | 0.293                | 0.173                |
| GCP 4 | 0.215                | 0.143                |
The average RMSE value for Pleiades 1B with 8 GCP points is 0.322 pixels for the 1st order polynomial method and 0.188 pixels for the 2nd order polynomial method. Thus, the process of repairing the Pleiades 1B image is acceptable because it fulfills the tolerance given ≤ 1 as suggested. The following is the result of processing the geometric accuracy test of Pleiades 1B satellite imagery:

### Table 3. Geometric Accuracy Test.

| Geometric Accuracy Test | Polynomial 1<sup>st</sup> Order | Polynomial 2<sup>nd</sup> Order |
|------------------------|---------------------------------|---------------------------------|
|                        | X Residue (m) | Y Residue (m) | X Residue (m) | Y Residue (m) |
| ICP 1                  | 0.310          | 0.573          | 0.393          | 0.479          |
| ICP 2                  | 0.285          | 0.243          | 0.263          | 0.236          |
| ICP 3                  | 0.177          | 0.126          | 0.366          | 0.305          |
| ICP 4                  | 0.562          | 0.874          | 0.265          | 0.815          |
| ICP 5                  | 0.650          | 0.447          | 0.130          | 0.130          |
| ICP 6                  | 1.501          | 0.727          | 0.623          | 0.286          |
| ICP 7                  | 1.068          | 0.343          | 1.032          | 0.212          |
| ICP 8                  | 0.002          | 0.752          | 0.134          | 0.436          |
| ICP 9                  | 0.079          | 0.089          | 0.372          | 0.008          |
| ICP 10                 | 0.187          | 0.064          | 0.303          | 0.057          |
| ICP 12                 | 0.482          | 0.169          | 0.505          | 0.175          |
| ICP 13                 | 0.681          | 0.301          | 0.656          | 0.885          |

**RMSE (m)**: 0.806 0.647

### Vegetation Index

The limitations of the species in that area, the vegetation index used in data processing is the NDVI algorithm. The range of the algorithm ranges from -1 and +1, where the value reflects the condition, characteristics and type of a vegetation [3]. The following is the result of calculating the algorithm such as Table 4:

### Table 4. NDVI Calculation Results

| Coordinate | NDVI |
|------------|------|
| X Y        |      |
| R1 683759.63 9204052.30 | 0.7595 |
| R2 683772.81 9204058.97 | 0.7089 |
c. Correlation Test
To find out the relationship between two variables, it is necessary to do a correlation test. Correlation test in this study was conducted to determine the strength of relationships between variables. The following is a table of measurement results of field parameter samples:

| Point | N  | P  | K  | pH | Salinity (ppt) |
|-------|----|----|----|----|----------------|
| R1    | 1.08 | 0.21 | 0.026 | 6.9 | 4.43           |
| R2    | 0.61 | 0.20 | 0.019 | 7.15 | 0.29           |
| R3    | 0.65 | 0.26 | 0.021 | 6.9  | 1.31           |

After calculating the NDVI vegetation index to determine the condition of the mangrove ecosystem in the East Coast of Surabaya, the correlation between the vegetation index and the sample parameters was conducted. The following is the result of a correlation test between vegetation index and sample field parameters:

\[
y = 9.531x - 6.1614
\]

\[
R^2 = 0.996
\]

**Figure 2.** NDVI and Nitrate (N) Relationship.

**Figure 3.** NDVI and Phosphorus (P) Relationship.
The test results of the correlation between NDVI and Nitrate, Phosphorus, Potassium, pH, Salinity show a strong correlation that is worth value (R) of 0.99, 0.99, 0.98, 0.98, and 0.99. This shows that there is a strong relationship between the value of NDVI and NPK nutrients, pH, Salinity. Correlation coefficient indicates a positive relationship between NDVI values and nutritional parameters related to one direction, if the NDVI value is higher then NPK, pH,
salinity is also higher because the mangrove ecosystem requires NPK nutrition for photosynthesis. Plants that contain N, P, K, pH, sufficient leaves of salinity will become greener. This greener leaf causes a higher reflectance value in the image.

d. Mangrove Economic Valuation

Economic valuation is an activity or business to measure and declare in monetary units (monetizing) all types of existing values from a natural resource. Economic valuation of all the benefits of mangrove forest resources uses the approach stage as done by [5]. The benefits and functions of the mangrove ecosystem include the value of direct benefits, indirect benefits, benefits of choice and inheritance benefits.

From the results of research in the field, residents around the East Coast of Surabaya (Wonorejo) utilize the potential of the mangrove ecosystem both directly and indirectly. The results of the interviews indicate that the local community uses the mangrove ecosystem as an ecotourism area, a place to find crabs, and is used as milkfish and shrimp ponds. In this study do not do calculations for inheritance values. The benefits of mangrove include:

1. Value of Direct Benefits

Direct benefit is the value generated from direct use of mangrove forests such as catching fish, crabs, firewood and tourism (Fauzi, 2002). From the fish catches carried out by local fishermen it produces an annual economic value of Rp. 70,560,000 and the benefit value per year per hectares is Rp. 7,056,000. Fishing is carried out about 2 times a month. While the annual economic value generated by catching mangrove crabs is Rp. 56,980,000 and the value of benefits per year per hectares is Rp. 7,122,500. Seasonal mangrove crabs take place at the highest tide. The number of mangrove crabs is inseparable from the mangrove ecosystem. The denser the mangrove ecosystem, the more abundance of these mangrove crabs.

For pond aquaculture in the field, namely milkfish and tiger shrimp ponds. From the results of tiger shrimp ponds harvested around 3-4 times a year, produce an annual economic value of Rp. 14,440,000 worth of benefits per year per ha of Rp. 3,610,000. Whereas for milkfish ponds are harvested every 6-8 months. The potential value of milkfish per year is Rp. 50,885,000 and the benefit value per year per hectares is Rp.12,721,250.

2. Indirect Benefits

Indirect benefits are perceived indirectly to goods and services produced by resources and the environment (Fauzi, 2002). The indirect benefits in the field include coastal abrasion, as a habitat for flora and fauna to spawning areas. The estimated cost of constructing a breakwater embankment with a coastline length of 26.5 km is valued at Rp. 18,123,655/year/hectares and an annual cost of Rp. 11,451,975,000. The economic value of flora and fauna habitat according to Fahruddin (1996) is US $ 767.20/hectares/year with a dollar price (October 16, 2018) worth Rp. 15,200, so that an estimated value of Rp. 11,661,440/hectares/year and annual costs of Rp. 7,368,630,707.

3. Benefits of Choice

The value of choice benefits in this study was approached using the value of biodiversity (biodiversity). According to [5] the value of biodiversity is US $ 15.00/hectares/year. If converted to Rupiah value (October 16, 2018) is Rp. 228,000/hectares/year. The value of the benefits of the mangrove multiplied by the area of the mangrove ecosystem, the total value of Rp. 144,068,640.

The value of the total economic benefits of mangrove forests is obtained from the sum of the value of direct benefits, indirect benefits and selected benefits. So that the total value of the economic benefits of mangroves is obtained as in the following table:

| Benefit Type       | Value per Year per Hectares | Total Value |
|--------------------|-----------------------------|-------------|
| Direct Benefits    |                             |             |
| Fish               | Rp. 7,056,000               |             |
| Crabs              | Rp. 7,122,500               |             |
| Pond Aquaculture   |                             |             |
| Milkfish           | Rp. 3,610,000               |             |
| Shrimp             | Rp. 12,721,250              |             |
| Indirect Benefits  |                             |             |
| Coastal Abrosion   | Rp. 11,451,975,000          |             |
| Flora and Fauna    | US $ 767.20                 | Rp. 15,200   |
| Total              |                             | Rp. 144,068,640 |
Table 6. Value of the economic benefits of mangrove.

| Types of Benefit          | Value of Benefits (/hectares/year) | Value of Benefits (/year) |
|--------------------------|-----------------------------------|---------------------------|
| Direct Benefit           | Rp 30,509,750                     | Rp 192,865,000            |
| Indirect Benefit         | Rp 29,785,095                     | Rp 18,820,605.707        |
| Benefit of Choice        | Rp 228,000                        | Rp 144,068,640           |
| Total Value of Economic  | Rp 60,522,845                     | Rp 19,157,539.347        |

4. Conclusion

The temporary conclusions obtained in this study are as follows:

a. The correlation test results between NDVI and Nitrate, Phosphorus, Potassium, pH, High Salinity with values (R) 0.99, 0.99, 0.98, 0.98, 0.99. This shows that there is a strong relationship between NDVI and NPK values, pH, Salinity. So if the NDVI value is high then NPK, pH, salinity is also higher because the mangrove ecosystem requires NPK nutrition for photosynthesis. Plants that contain N, P, K, pH, sufficient leaves of salinity will become greener. This greener leaf causes a higher reflectance value.

b. The total economic value of the economic potential of the mangrove is valued at Rp.19,157,539,347/year. This value consists of the direct benefit value of Rp192,865,000/year. Indirect benefit value of Rp.18,820,605.707/year and selected benefit value of Rp.144,068,640/year.

5. References

[1] Fachruddin A. 1996. *Analisis Ekonomi Pengelolaan Pesisir Kabupaten Subang, Jawa Barat*. Thesis. Postgraduate School. Bogor Agricultural Institute. Bogor.

[2] Fauzi A. 2002. *Valuasi Ekonomi Sumberdaya Pesisir dan Lautan*. Paper on the Training of Coastal and Ocean Resources Management. Diponegoro University. Semarang

[3] Ginting, Edina E BR. 2004. *Pemantauan Liputan Vegetasi Menggunakan Citra Satelit NOAA AVHRR (Studi Kasus P.jawa dan Madura)*. Final Project of the Faculty of Forestry. Yogyakarta: Gadjah Mada University.

[4] Purwadhi, F. Sri Hardiyanti. 2001. *Interpretasi Citra Digital*. Jakarta: PT. Grasindo

[5] Ruitenbeek, H. J., 1991. *Mangrove Management: An Economic Analysis of Management Option with a Focus on Bituni Bay, Irian Jaya*. Environmental Management Development in Indonesia (EMD) Project. EMDI Environmental. Reports No. 8., Jakarta.
