Economic valuation and lost value of mangroves ecosystem due to oil spill in Peleng Strait, Banggai and Banggai Islands Regency Central Sulawesi

S Putranto1*, N P Zamani2*, H S Sanusi2, E Riani3, A Fahrudin3
1Graduate Student of Marine Science, Bogor of Agriculture University, Bogor
2Marine Science and Technology Department, FPIK-IPB Bogor
3Management of Aquatic Resources, FPIK-IPB Bogor
*e-mail: sugeng.putranto@yahoo.com; np_zamani@yahoo.com

Abstract. The increase of sea transportation in the Strait Peleng, Banggai and Banggai Islands Regency, Central Sulawesi such as tankers are potentially causing environmental degradation, which in case of a tanker collision that may cause an oil spill. The event of oil spills in the marine environment when entry into the mangrove ecosystem can cause damage to mangrove ecosystems. The research aims to determine how much the loss value of mangrove ecosystem when the oil spill contaminates into the mangrove ecosystem, so it is necessary to do an economic assessment for the damage of mangrove ecosystems. Furthermore, some data is needed, there is important value index of mangrove, economic valuation of mangrove ecosystems, oil distribution patterns and the loss value of mangrove that caused by the oil spill. The research was conducted in nine districts in the Peleng Strait of Banggai and Banggai Islands, among others: South Batui, Batui, East Luwuk, Lamala, Masama, Balantak, Bualemo (located in the administrative area of Banggai) and the District Bulagi and Buko (located in the administrative area Banggai Islands). This research was conducted from August to November 2016 for taking the sample and interviews to the community and local government. Based on the results that showed, the mangrove ecosystem in Peleng Strait Coastal Water has a total area of ± 107 ha with a total value of economic value is US$1,702,605.73 /year. The biggest contributor comes from indirect value, that is as a buffer abrasion or as break water of US$1,237,277.78 /year. Base total economic value, the biggest effect of the oil spill could be losses per year is US$ 695,521.97 /year that occurred in the second transitional season (July – September).

1. Introduction

Banggai Regency and Banggai Islands Regency both are regions in Center Sulawesi Province which have several coastal ecosystems such as mangrove, coral reefs, and seagrass. The other site there are other potential resources in the mining sector, that is nickel mine producer (in an exploitation phase) and the natural gas in 3 locations, the Matindok Block, Senoro Block and Donggi Senoro LNG. This condition will have an impact on sea transportation thus increasing the traffic level. In case, oil tanker will provide a lot of coming into Banggai coastal area. It has the potential to cause some environmental degradation such as
disposal of liquid waste, ballast water, and other incidents such as a tanker collision or leakage/pipe cracking on loading arm.

Indonesia has encountered several oil spill incidents, one of which occurred in Montara Well Head Platform in the Timor Sea in 2009. Although the oil spill location was in Australia's ZEE territory, however, the impact felt to the Indonesian region in 8 districts in East Nusa Tenggara province [1]. The Government of Indonesia claimed for environmental damage caused by the oil spill in the US $ 2.4 billion, or Rp 21.6 trillion. Unfortunately, it was rejected by PT TEP Australasia because of the claim was not supported by enough data.

The impact of an oil spill can cause the degradation of sea water quality in short-term effect or more harmful impact over a long term. Physically, the contamination of oil will be obvious because the sea surface will be covered with oil or tar balls. Chemically, the petroleum is classified as a hydrocarbon aromatic compound, it can be toxic to marine organisms and causes the damage to coastal ecosystems. Biologically, the liquid waste and oil spill incident affect to marine organisms living and humans both directly or indirectly. Because of it, the management of coastal areas is a very important thing. Referring to the concept of sustainable development, the focus is balancing between economic growth and natural resource quality.

Based on this background, the purpose of this research is to determine how much the loss value of mangrove ecosystem when the oil spill contaminates into the mangrove ecosystem, so it is necessary to do an economic assessment for the damage of mangrove ecosystems. Furthermore, some data is needed there is important value index of mangrove, economic valuation of mangrove ecosystems, oil distribution patterns and the loss value of mangrove that caused by the oil spill.

2. Method

2.1. Location and time

The location of data observation is mangrove ecosystem area in Banggai Regency and Banggai Islands Regency, Central Sulawesi. The research was held in August - November 2016. Data were collected from 9 District; South Batui, Batui, East Luwuk, Lamala, Masama, Balantak and Bualemo (Banggai Regency), Bulagi and Buko (Banggai Island Regency).

2.2. The technique of data collection

2.2.1. Mangrove. Mangrove density was measured by Line Transect Plot method with a size of transect 10x10 m2 on each vertical/horizontal stratification zone (3 plots to data retrieval and repetition). The distance between each plot is about 20 m and coordinate points recorded by GPS locations. The measurement of diameter for individual mangrove refers to Ministry of Environment No. 201 the year 2004 regarding Standard and Guideline of Mangrove Degradation. The species identification refers to [2].

2.2.2. Valuation of economic. The sampling method is an accidental sampling, that will be taken from the people who live in around the mangrove area as the respondents. Base on pre-research, about 81 people as the respondent are working as: fishermen, Woodman and some people who related to mangrove resource. Primary data obtained by deep interview and questioners (directly collected the data from the local community) and secondary data collected from a local government office and other resources.
2.2.3. Oil spill. Oil spill model uses Oilmap software. This model can predict the spread of oil spills. This software uses a geographic information system which combines the environmental conditions and the oil characteristics (Table 1). Secondary data used for the distribution of oil spill, there are daily/monthly tide and annual tide, currents, waves, wind, and humidity. These data were obtained from the Luwuk Climatology and the North Oceanic Atmospheric Administration (NOAA) database.

Table 1. Characteristic of marine fuel oil [3].

| Parameter                          | Value/Units |
|------------------------------------|-------------|
| Specific gravity at 60/60 °F       | 0.87        |
| Melting point                      | 30-50 °C    |
| Boiling point                      | 150 °C      |
| Flash point                        | 70-230 °C   |
| Solubility in water                | No soluble in water |

2.3. Data analysis

2.3.1. Economic Valuation of Mangrove Ecosystem. Economic valuation of mangrove ecosystem resources or Total Economic Value (TEV) is calculated from the sum of economic value based on utilization, which includes direct value, indirect value and option value [4]. Following is analysis method for economic valuation of mangrove ecosystems bellows:

A. Total Economic Value (TEV)

Total economic value of mangrove forest estimated from the sum of direct value, indirect value and option value can be written in the mathematical equation as follows:

\[ TEV = DUV + IUV + OV \] .................................(1)

where;

- **Total Economic Value (TEV)** = Measured in terminology as a willingness to pay (WTP)
- **Direct Use Value (DUV)** = Goods and services provided by a resource that can be directly utilized.
- **Indirect Use Value (IUV)** = the value is derived from the goods and services which provided by a natural resources that used indirectly.
- **Option Value (OV)** = Potential direct or indirect value of a natural resource which can be utilized in the future with assuming that the resource is not destroyed or permanently damaged.

B. Direct use value

Direct use value (DUV) is the economic value that derived from the direct utilization of an ecosystem. In the context of mangrove ecosystems, these economic values include the mangrove utilization as a material, cordwood and the value of fishery resources. Mangrove wood as a material (par value of wood) is estimated by the number of mangrove volume/ha/year multiplied by the price of mangrove wood [5]. The species which has potential wood value is Rhizophora, thus the calculation only involve this species. This type of wood usually uses as building material and Fish Aggregate Devices (FADs) by the local community.

\[ \text{par value of wood} = (V \times \text{quantity}) \times \text{selling price} / \text{m}^3 \] .................................(2)

\[ V = \pi r^2 t \] .................................(3)
where:

\[ V = \text{volume (m}^3\text{)} \quad r = \text{radius of a tree (m)} \]
\[ \pi = 3.14 \quad t = \text{height (m)} \]

Mangrove value as cordwood (par value of wood fuel) is estimated by the amount of wood produced multiplied by the selling price [6].

\[ \text{par value of wood fuel} = (V \times \text{quantity}) \times \text{selling price /m}^3 \] ........(4)

Mangrove crab catching value (par value of crab) is estimated by the number of catches/year multiplied by the selling price.

\[ \text{par value of crab} = (T \times B) - B (\text{US$ / ha /year}) \] .................................(5)

where:

\[ T = \text{Total of crab catches (kg /ha /year)} \quad B = \text{Operational price (US$)} \]
\[ H = \text{Selling price (US$ /kg)} \]

C. Indirect use value

Indirect use value is the economic value that derived from the indirect use of an ecosystem both biologically and physically. The biological function of mangrove indirectly as a spawning ground for fish. Biological value (biological par value) is estimated by the number of fish catches around mangrove area by fish price/kg, then reduced the investment and operational cost. The numbers of fish caught at offshore area are not included, which is not considered the function of mangrove forest.

\[ \text{Biological par value} = (T \times H) - B (\text{US$ / ha /year}) \] .........................(6)

Physical function, the mangrove ecosystem also serves as coastal protection from the ocean waves. The initial par value is calculated through the wesel approach by making the concrete which equivalent to mangrove function of resisting the coastal from abrasion. According to Minister of General Services No. 28 the year 2016 which mention, to build a breakwater with 150 m length, 20 m width, and 5 m height and 20 years withstand that cost is 2,921,147,000 IDR or approximately 19,474,313 IDR/meter.

\[ \text{Physical par value} = \frac{B \times PGP}{10 (\text{US$ /m/year})} \] ..............................................(7)

where:

\[ B = \text{Wesel standard beton (US$)} \]
\[ PGP = \text{long coastline (m)} \]

D. Option value

Option value (par value of option) is the value calculated by the possible use of ecosystem goods or services in the future by yourself and others too; it's also called inheritance value [7]. This optional benefit value can be discovered by using direct method. The results of [8] research in Bintuni Bay, US $ 1,500 / km2 / year can be used as biodiversity benefit value on this research too; assuming that the mangrove forests ecologically are important and well maintained.

\[ \text{Par value of option} = US \frac{B \times \text{Area of mangrove forest}}{10 (\text{US$ /m/year})} \] .............................................(8)
2.3.2. *The spread of an oil spill.* Calculation of oil spill area in mangrove ecosystem is determined by using stochastic model. Stochastic model estimates the magnitude of marine fuel oil which entered or stranded to the mangrove then predicts the travel time of oil can reach the shoreline and amount the percentage of stranded oil on to the shore.

2.3.3. *Determination of losses value.* To calculate the losses value refers to the research result from [9]:
1) Par value of mangrove tree is calculated by the oil spill which impacting the mangrove plant with less than 3 m height
2) Par value of mangrove crab is calculated by considering the death impact on 0-15 day so that the annual percentage of death is 100% per year
3) Par biological value is calculated by the number of biota death which living around mangrove forest with the death impact on 0-15 day so that the annual percentage of death is 100% per year.
4) Par physical value is calculated by the existence of mangrove forest, so this is equal to the par value of mangrove tree calculation
5) Par value of option calculation similar to the par value of mangrove tree and par physical value

2.3.4. *Spatial simulation model of losses value.* This simulation will integrate the Oil Spill Trajectory and Economic Values that will be displayed in the form of a thematic map containing the value of the damage. This thematic map uses the GIS and Oilmap Arcs that combined with the formulation of economic valuations. Oil trajectory data was made simulated by incorporating oceanographic and climatologically parameters. The view of this spatial simulation will contain information on the Cost of Mangrove Ecosystem Damage at four seasons.

3. Result and discussion

3.1. *The condition of a mangrove ecosystem*

Referring to [10] regarding Standard and Guideline of Mangrove Degradation, the result shows that Banggai Regency and Banggai Island Regency have mangrove from good until bad criteria. Mangrove with good criteria located in Balantak with density is 3,183 ind/ha, Bualemo with 1,639 ind/ha, Bulagi 1,450 ind/ha, South Batui 1,222 ind/ha, Masama 1,160 ind/ha, and Lamala with 1,117 ind/ha. Based on the result of research, Balantak has the highest mangrove density among others due to many rivers that supply richness nutrient and sedimentation. Mangrove with bad criteria located in Batui with density is 750 ind/ha, Buko 675 ind/ha, and East Luwuk 550 ind/ha.

Degradation of mangrove area in East Luwuk caused by the area has been acquitted by the local community. Population growth is not accompanied by land available for residence area, thus becoming a trend that people to cut down the mangrove to build the house. The database mentions that East Luwuk is the district with the highest population density than other research area. In 1990, there was a permitting for the company from Taiwan to do logging and export the mangrove and no rehabilitation program until now [11]. The consequence is mangrove ecosystem becomes almost extinct in Banggai Coastal.
Figure 1. Map of mangrove distribution at the research location.
3.2. Economic Value

3.2.1. Direct use value. Direct use value on this research is estimated from the value of mangrove wood utilization for material (par value of wood), and the value of mangrove utilization as crab habitat (par value of crab). The value of mangrove as cordwood is not included in the calculation, because the people use it only for household needs and not for sale. Par value of wood is only calculated for Rhizophora sp. due to only its wood which utilized by local people. The value is obtained by multiplying the volume of tree log with a selling price of US$ 26.32/m³. Balantak has the highest par value of wood US$ 101,512.98/year while contradictory par value of wood in East Luwuk because there is no found Rhizophora tree in this location. The total log of the par value of wood from nine District is 438,137.4/year or 25.73% of the total economic valuation number.

Par value of crab is obtained by multiplying the number of crabs catches in one year with the selling price of US$ 3/kilogram then subtracted with the operational cost in one year. The number of crab catches and the amount of operational costs is obtained from the interviews with crab seekers. The highest par value of crab is in Bualemo (US$ 2,442.11/year), while the lowest result is in Bulagi (US$ 649.62/year). The total par value of crab from nine District is US$ 10,641.94/year or 0.63% of the total economic value. The small value of crab is due to not optimal by people for utilizing mangrove ecosystem for crab fishing or aquaculture area.

3.2.2. Indirect use value. The indirect use value of mangrove ecosystem is estimated from biological and physical par values. The biological par value is obtained by multiplying the number of fish catches in one year with the selling price of US$ 2.26/kilogram then subtracted with the operational cost in one year. Fish catches value which included into the calculation is fishing around the mangrove forest area by using a fishing rod and a net (sero). The highest biological par value is located in Buko with US$ 2,426.92/year while the lowest is in Masama with US$ 970.83/year. The total biological par value in the 9 District is 14,943.64/year or 0.88% of the total utilization value.

The mangrove ecosystem has indirect value as a natural barrier, stabilizes the delicate sediment and prevents the shoreline from erosion. Mangroves also reduce the effects of storms and floods, maintain water quality and support the lives of various wildlife [12]. Indirect use of mangrove forests physically to be retention of abrasion thus a value estimated through replacement cost by building the breakwater. According to Minister of General Services No. 28 the year 2016 which mention that to build a breakwater with 150 m length, 20 m width, and 5 m height and 20 years with stand, the cost is US$ 219,635.10 or approximately 1,464.23/meter. Banggai Regency and Banggai Islands Regency have a total coastline which protected by mangrove forest are 16,900 m length, then the cost required to replace the physical function of mangrove ecosystem as a physical par value for 20 years withstanding is US$ 24,745,556 or equivalent to US$ 1,237,278/year.

3.2.3. Option value. The option value in the existing mangrove ecosystems in Banggai and Banggai Islands coastal areas can be approached using the benefits transfer method, by assessing the estimated value from other places (where the resources are available) and then the value is transferred to obtain a rough estimate of the value of the environment. The method is approached by calculating the value of existing biodiversity in this mangrove area. According to [8], Indonesia has biodiversity value of US$ 1,500 US$/km² or about US$ 15/ha/year. This value can be used in all mangrove forests throughout the Indonesia if the ecosystem of mangrove forest is ecologically important and naturally protected.
3.2.4. Total Economic Value. Total Economic Value (TEV) in this research is obtained by summing of direct value, indirect value and option value so that the result is amount US$ 1.702.606/year or approximately US$ 15.912/ha/year. The highest TEV is located in East Luwuk with US$ 368,775.45/year while the lowest is in Batui with US$ 33,610.09/year. Although East Luwuk has degradation of mangrove ecosystem however it has a high utilization value. Moreover, East Luwuk also has a long coast line which covered by mangrove forest to protect from abrasion.

Table 2. The result of calculation of a value of exploiting of mangrove ecosystem at the research location (in US$).

| District      | par value of wood | par value of crab | biological par value | physical par value | OV   | TEV       |
|---------------|-------------------|-------------------|----------------------|--------------------|------|-----------|
| South Batui   | 76,692.37         | 855.19            | 1,550.83             | 73,211.70          | 150.00 | 152,460.09 |
| Batui         | 2,370.53          | 799.25            | 1,125.64             | 29,284.68          | 0.03  | 33,610.09  |
| East Luwuk    | 0.00              | 770.18            | 1,721.76             | 366,058.52         | 225.00 | 368,775.45 |
| Masama        | 5,552.89          | 1,257.14          | 970.83               | 146,423.41         | 150.00 | 154,354.27 |
| Lamala        | 70,203.68         | 1,515.79          | 1,506.54             | 109,817.55         | 225.00 | 183,268.57 |
| Balantak      | 101,512.89        | 933.87            | 1,691.20             | 109,817.55         | 225.00 | 214,180.52 |
| Bulalo        | 88,312.68         | 2,442.11          | 1,970.90             | 183,029.26         | 375.00 | 276,129.90 |
| Bulagi        | 46,293.16         | 649.62            | 1,979.02             | 146,423.41         | 150.00 | 195,495.21 |
| Buko          | 47,199.21         | 1,418.80          | 2,426.92             | 73,211.70          | 0.75  | 124,331.63 |
| **Total (US$/thn)** | 438,137.37       | 10,641.94         | 14,943.64            | 1,237,277.78       | 1,605.00 | 1,702,605.73 |
| **Percentage (%)** | 25.73            | 0.63              | 0.88                 | 72.67              | 0.09  | 100.00    |

The indirect use value takes the highest portion of TEV of 74.55% (indirect use value), while the lowest is the option value of 0.09% (option value) and the rest is from direct option value of 26.36% (direct use value). The highest of indirect use value is derived from the mangrove value as a breakwater. This below the comparison of TEV with other location (Table 3). Generally, the higher contribution of TEV is come from IUV (Indirect Use Value), due to the have long coast line which covered by mangrove forest to protect from abrasion.

Table 3. The economic value of mangrove ecosystem some regions in Indonesia (US $)

| Banggai dan Banggai Islands | North Minahasa | Tanjung Pinang | Kendal |
|----------------------------|---------------|---------------|-------|
| (US$) (%)                  | (US$) (%)     | (US$) (%)     | (US$) (%) |
| DUV 448,779 26.36          | 13,180 1.61   | 3,994,846 60.20 | 46,796 42.94 |
| IUV 1,252,221 73.55        | 802,378 98.01 | 2,634,586 39.70 | 61,518 56.45 |
| OP 1,605 0.09              | 3,105 0.38    | 6,833 0.10    | 668 0.61 |
| TEV 1,702,606 100          | 818,663 100   | 6,636,265 100  | 108,983 100 |

Based on tabulation in hectare, the TEV of mangrove in this research is 15.912 US$ per hectare or 1.59 US$ per meter square. This research is much bigger than [16] research in Blanakan Bay West Java, Indonesia with 782,34 ha of plots mangrove sampling and 6,800 m length of coastline which the result of ecosystem
services is amount US$ 286,901.50/year or approximately US$ 366.72/year/ha or US$ 0.04/m2. The difference of both research due to the Indriyani research is not to calculate the direct use value such as the wood utilization and fishery and the coastal line.

3.3. Oil spill spreading

This model is made with simulation of oil spill location in DSLNG Port (coordinate of 1° 15,104’ S; 122° 35,630’ E). The location is LNG loading and unloading activities area. The results of model simulation provide data information about the percentage of oil spills which are stranded on the shore. The results are displayed in the geographic information system (map) in each month in one year and for impact analyze in one year. The monthly data is grouped into four seasons; there is the west season (Dec-Feb), transitional season 1 (Mar-Apr), eastern seasons (May-Sep) and transition season 2 (Oct-Nov). This model simulation used MFO type of oil. The amount of spill is 700 ton or 4375 barrel with API index (American Petroleum Institute) is 33.7 with density is 0.87 gr/cm3. According to [9] this oil is categorized to the second group which has the characteristic of (1) volatile, (2) have residue after the end of evaporation, (3) spread rapidly, (4) does not have stable form emulsion and (5) more bioavailable than light oils, hence it more likely will affect animals in water and sediment.

Oil spill spreading in the west season is mostly influenced by the west season, and the oil spill moves towards to the east as shown in figure 2 (a). Oil will be stranded in the coastal of along Batui, Kintom, and Nambo. Mangrove in Batui Coastal is in bad criteria (with 750 ind /ha), while there is no mangrove habitat in Kintom and Nambo which is a sandy beach and settlement area. Oil spill also spread to the north of Peleng Island, precisely in Bulagi, which has mangrove forest with good criteria (1,450 ind/ha).

In the transition season 1, the wind tends to fluctuate not only from one direction, but it is from the north and northwest. Figure 2 (b) shows the oil spread to the southeast or towards Peleng Island. The oil spreads east ward along the coast of Banggai towards to the north, but its limited spreading and not reaches to Luwuk City. Oil will be stranded in the coastal of Batui, Kintom, and Nambo which is only Batui coastal has mangrove area with bad criteria. Oil is spreading towards to Peleng Island, precisely in Buko which has no mangrove area, it's rocky sand beach without settlement area.

Oil spreading in the east season is mostly influenced by the east season, and oil spill moves towards to the southwest as shown in figure 2 (c). The mangrove areas affected by the oil spill are located along Batui and South Batui. In May and June oil spills around Batui Beach then extends to South Batui in July and finally began to decrease in August and September.

In the transition season 2, the influence of the western season is beginning and added with pressure from the west wind. The result of oil spreads to the east as shown in figure 2 (d). The thin layer of oil began to spread eastwards along the coast of Banggai towards to the north. However, its finite spreading and not reaches to Luwuk city and will be stranded along the coast of Batui and Kintom.

3.4. The lost value due to the oil spill

[9] mention that mangroves are particularly vulnerable to oil exposure and then can cause the death within weeks to months. This level of sensitivity depends on the type of mangrove and the type of oil. Light oils are more toxic compared to heavy oils. Oil with slow decomposition will be more toxic than fast decomposed. Poly Aromatic Hydrocarbon (PAH) is a toxic compound which causes the death of mangrove. The death begins with yellowing leaves then defoliation and ultimately cause to death of the tree. The accumulation of hydrocarbons in the substrate disrupts mangrove function. The results of research in Panama mention that the effects to mangrove growth are different in diverse concentrations of hydrocarbons [16].
Figure 2. The oil spreading and lost value of the simulation in the four seasons (a) west season, (b) transitional season 1, (c) east season, (d) transitional season 2.
Table 4. The value of oil spill loss.

| District     | Loss Value by Season (US$) | West Season | Transition 1 | East Season | Transition 2 |
|--------------|----------------------------|-------------|--------------|-------------|--------------|
| South Batui  | -                          | -           | 35,868.07   |             | -            |
| Batui        | 2,594.71                   | 2,346.30    | 3,748.05    | 3,843.11    |
| Bulagi       | 79,775.27                  | -           | -           | -           |
| TOTAL        | 82,369.98                  | 2,346.30    | 39,616.13   | 3,843.11    |

The total lost value due to the oil spill can be calculated = TEV (in affected areas) x affected mangrove area (%) x Response to damage/death (within one year). The simulation results (table 5): the biggest cost of an oil spill if occurs in the west season is US$ 79,775.27 in Bulagi while the lowest is in transition season 1 with US$ 2,346.30 in Batui.

4. Conclusion

There are 13 mangrove species found in Banggai and Banggai Islands Regency which *Rhizophora mucronata* is dominated almost found in all locations. Based on Ministry of Environment No. 201 the year 2004 regarding Standard and Guideline of Mangrove Degradation, the 6 locations which have a good category there are Balantak, Bualemo, Bulagi, South Batui and Lamala, while there is 3 location which has a bad category: Batui, Buko, and East Luwuk. Total Economic Value (TEV) result of mangrove ecosystem utilization is US$ 1,702,606/year. The highest of economic valuation is derived from the mangrove benefit as breakwater which takes 72.67% of TEV, followed by the value of mangrove benefit as building materials is 25.73% and the lowest TEV as fishery products. It means that mangrove utilization as fishery resources has not been optimal by local community such as aquaculture and fishing. Oil spill simulation results by loss in scenario 1 is only US$ 82,369.98 which occurring in the west season.

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