Economic valuation of mangrove ecosystem in Cilamaya Wetan, Karawang, West Java

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Abstract. Cilamaya Wetan has 738 hectares (ha) mangrove forest which provides real functions and benefits to the local community ecologically, physically and economically. The ecosystem is typically crucial, hence the benefits and values need to be identified and estimated economically. The purpose of this study was to estimate the economic value as the basis of the conservation program. Research on economic valuation was conducted in March-May 2019. The method was applied to estimate total economic value (TEV) consisted of direct-use value (fuelwood collection, seed collection, and nearby fishing activities); indirect-use value (natural barrier to shoreline erosion, food source for animal and carbon potency for sequestering CO2), option value (biodiversity benefits), and existence value (willingness to pay). Results showed that the TEV of mangrove ecosystem in Cilamaya Wetan per year accounted for 419 billion rupiah or equivalent to IDR 568,067,635/ha/year or equivalent to 39,753 USD/ha/year.

Keywords: Cilamaya Wetan, economic valuation, mangrove

1. Introduction

Indonesia has a mangrove forest that grows along 95,000 km in the coast with a total mangrove area of 3 million ha, this area represents 20% of the total world mangrove ecosystem (Giri et al 2011). Mangroves deforestation in Indonesia have a big impact on climate change mitigation, which contributes 42% of total global emissions (Murdiyaso et al 2015). The rates of mangrove deforestation in Indonesia is quite high for several decades, as big as 52 thousand ha/year.

Mangrove forests can be found in Cilamaya Wetan, Karawang Regency, but its existence is threatened. According to data from Dinas Perikanan dan Kelautan Karawang (2017) mangroves forest in Karawang Regency are in a damaged condition about 5,400 ha. Community activities on the coast, such as agriculture, aquaculture, urbanization, sand mining are increasing. Low awareness community towards the important function of the mangrove ecosystem is also the cause of a large number of mangrove ecosystems that are threatened with deforestation (Widiastuti et al 2016).

Public awareness of the value of mangrove forests is still low. Coastal communities still percept that mangrove forest is owned by the public so it can be explored free, regardless the sustainability. The ecosystem is threatened, hence the benefits and values need to identify and estimate economically.
Therefore, research on values the economy and carbon potential on the coast of Cilamaya Wetan need to be done. The purpose of this study was to estimate the economic value as the basis of the conservation program. The research needs to be done so that the information can be used as basic data and become material consideration in planning management and utilization of mangrove.

2. Materials and methods

The study sites included the mangroves ecosystem of Cilamaya Wetan, Karawang, West Jawa (figure 1). The research conducted on March-May 2019. Determination of the observation was done by purposive sampling, based on the presence of mangroves.

![Figure 1. Study site, Cilamaya Wetan.](image)

2.1. Materials

Global positioning system (GPS, Garmin), roll meter, wooden stick 1.3 m, transect, shovel, plastic, plant scissor, cutter, pipe 60 cm, diameter 5 cm, thermometer, camera, mangrove identification book, scale (SF-100), oven (Memmert UF-110) and scientific calculator (Casio fx-350ES) were used during the field survey. Data observation was done by line method.

2.2. Methods

The study used the TEV as its framework for estimating the values of different uses of mangroves. TEV classified the values of a resource or ecosystem into use and non-use values (Pearce and Moran 1994). The use-values were further classified into direct use, indirect use and option values. On the other hand, non-use values include existence values.

Direct use values were estimated based on the market values of the various product derived from firewood, charcoal, and fishery. Interviews conducted by the purposive method to the community which has the criteria of having activities and obtaining income from direct utilization of mangrove with a minimum age of 17 years.

The Indirect use values include carbon potency, breakwater, and nursery, spawning and feeding ground. The Carbon potency was estimated based on field observation. Line transect drawn along 60 meters, consists of three quadrants, with a distance between quadrants 15 m. Each quadrant consisted
of a square plot. The size of the plots was diverse into 2 × 2 m plot for seedlings, 5 × 5 m for stakes and 10 × 10 m for a tree. DBH (Diameter at Breast Height) measurement was carried out on stakes and tree meanwhile seedlings were carried out using the destructive method by sampling the whole plant. The seedlings were weighed in total wet weight in the plot area (leaves and stems), sub-samples were dried in an oven at 80°C for 48 hours or until it reached a constant weight. The environmental data such temperature was taken at each station. Soil substrate samples carried out at the depth of 10 cm, 20 cm, and 30 cm, then dried at 80°C until a constant weight was obtained then the volume of soil substrate also measured. All data were recorded for further analysis.

The mangrove ecosystem as a breakwater was valued by estimating costs for making the breakwater at the coastal area, referred to the standard of *Kementerian Pekerjaan Umum* multiplied by the length of coastline Cilamaya Wetan. Fishery, nursery, and spawning ground were measured by multiplying the value of nursery, spawning, and feeding ground by Kusumastanto (2000) of the Cilamaya Wetan mangrove area.

Option value was evaluated by multiplying biodiversity value by Ruitenbeek (1992) to the area size of mangrove Cilamaya Wetan. Existence values were estimated by interviewing respondents about how much they were expected to pay for a mangrove conservation program, this method known as a willingness to pay.

3. **Results and discussion**

Mangrove ecosystem in Cilamaya Wetan consisted of species *Avicennia marina, Rhizophora apiculata, R. mucronata, Suaeda maritima,* and *Hibiscus tiliaceus* (table 1).

| Table 1. Mangrove vegetation in Cilamaya Wetan. |
|-----------------------------------------------|
| **Familia**        | **Species** | 1 | 2 | 3 | 4 | 5 | 6 |
| True Manrove      | *Acanthaceae* | *A. marina* | - | + | + | + | + |  |
| True Rhizophoraceae | *R. apiculata* | - | - | + | - | + | + |  |
| True Mangrove     | *Rhizophora mucronata* | + | - | - | - | - | - |  |
| Associate Amanaraceae | *S. maritima* | - | + | - | - | - | - |  |
| Associate Malvaeeae | *H. tiliaceus* | + | - | - | - | - | - |  |

The carbon potential values consisted of biomass, carbon stock, and CO₂ sequestration. Biomass value is related to carbon stock value and CO₂ uptake, so the value of carbon stock and CO₂ uptake is highly dependent on biomass value (table 2). High and low biomass values can be differently influenced by several factors, such as stem diameter. The greater stem diameter stored the higher carbon content. The stem diameter also indicates the age of a plant level. Cilamaya Wetan was dominated by stakes and tree-level (adult age). Cilamaya Wetan has a total stakes density of 63.89 ind/ha and total tree density 863.89 ind/ha and density of seedlings (young age) were very low which only 9.89 ind/ha. The highest biomass was occurred at station 5, followed by high tree density and high stakes density. While the lowest biomass was followed by a low stake and tree density.

Growing habitats can affect the value of biomass. Mangrove biomass in coastal areas was higher when compared to mangroves near the estuary (table 2). Station 2 was the only mangrove vegetation located next to a small river. It suspected due to differences in nutrients and differences in physical environmental conditions between coastal mangroves and estuarine mangroves (Hori and Kuwae 2019). This was also in accordance with the study of Donato et al (2011) for 25 mangrove forests in the West-Indo Pacific, the study showed that the carbon content in estuarine mangroves was lower
(mean = 7.9%) compared to marine mangroves (mean = 14.6%). The amount of carbon stock value is also influenced by the number of carbon sources method. This study took samples of carbon sources not only from upper and lower plants (seedlings) but also from soil.

| Location | Species       | Biomass (ton/ha) | C-Stock (ton/ha) | C-Sequestration (ton/ha) |
|----------|---------------|------------------|------------------|-------------------------|
| St. 1    | R. mucronate  | 36.34            | 16.86            | 61.89                   |
|          | Total         | 36.34            | 16.86            | 61.89                   |
| St. 2    | A. marina     | 1.33             | 0.62             | 2.27                    |
|          | Total         | 1.33             | 0.62             | 2.27                    |
| St. 3    | R. apiculate  | 27.16            | 12.60            | 46.25                   |
|          | A. marina     | 719.89           | 334.03           | 1225.88                 |
|          | Total         | 747.05           | 346.63           | 1272.13                 |
| St. 4    | A. marina     | 482.52           | 223.89           | 821.67                  |
|          | Total         | 482.52           | 223.89           | 821.67                  |
| St. 5    | R. apiculate  | 1.07             | 0.50             | 1.82                    |
|          | A. marina     | 966.57           | 448.49           | 1645.95                 |
|          | Total         | 967.64           | 448.98           | 1647.77                 |
| St. 6    | R. apiculate  | 4.32             | 20.00            | 73.48                   |
|          | A. marina     | 407.57           | 189.11           | 694.05                  |
|          | Total         | 411.89           | 191.12           | 701.39                  |
| Average  |               | 441.13           | 204.68           | 751.19                  |

Table 2. Carbon potency on stakes and tree in Cilamaya Wetan mangrove ecosystem.

The soil carbon has the highest carbon content when compared to other carbon sources (table 3). The soil was able to store 49-98% of carbon from the total deposits of the whole carbon (Hori and Kuwaee 2019). The soil carbon content was high because mangrove soils have different thickness suboxic layers, which support the anaerobic decomposition process (Donato et al. 2011).

The soil carbon, based on table 3, has a higher soil carbon stock value, it was suspected due to the accumulation of organic material and decomposition processes that have been going on for a long time so that more organic materials were accumulated (Donato et al. 2011).

| Source      | Biomass (ton/ha) | C-Stock (ton/ha) | Sequestration (ton/ha) |
|-------------|------------------|------------------|-----------------------|
| Stakes and Tree | 441.13           | 204.68           | 751.19                |
| Seedling    | 1.24             | 0.58             | 4.56                  |
| Soil        | -                | 1604.61          | -                     |
| Average in total | 442.37           | 1269.36          | 755.75                |

Table 3. The total carbon potential of the Cilamaya Wetan mangrove ecosystem.

The result showed that mangrove ecosystem of Cilamaya Wetan has total average biomass, carbon stock and CO₂ uptake of 442.37 tones/ha, 1269.36 tones/ha and 755.75 tones/ha. This value was considered high when compared to the value of carbon potency at Muara Gembong, Bekasi by Rachmawati et al (2014) with only 108.66 tones/ha of biomass and CO₂ Sequestration of 55.35 tonnes/ha but not higher than the carbon potency value in Palawan, Philippines with 757.7 tones/ha of biomass and 356.1 tones of carbon stock/ha (Abino et al 2014).
The total economic values of the Cilamaya Wetan mangrove ecosystem was obtained by summing direct-use values, indirect-use value, option value, and existence values. The highest economic value came from indirect use value, while the lowest value came from the existing value.

Table 4. The indirect use value of the Cilamaya Wetan mangrove ecosystem

| No. | Type of benefit       | Total (IDR/Year)   |
|-----|-----------------------|--------------------|
| 1.  | Wave retention        | 15,183,688,000.00  |
| 2.  | Nursery ground        | 1,504,284,293.00   |
|     | Spawning ground       |                    |
|     | Feeding ground        |                    |
| 3.  | Carbon sequestration  | 398,507,730,750.00 |
|     |                       | 415,195,703,043.00 |

The indirect use-value is evaluated by summing wave retention, nursery, spawning, and feeding ground and carbon sequestration value. Among these values, carbon sequestration has the highest value. The carbon sequestration value of Cilamaya Wetan was high due to its large mangrove forest area which is equal to 738 ha. The greater the area of mangrove forests the greater the ability mangrove ecosystem as CO₂ sequestration. On the other hand, the second-highest value obtained from making a breakwater, the value was high because Cilamaya Wetan has a very long coastline which reaches 13,000 meters. Meanwhile, the use-value of mangroves as feeding, nursery, and spawning ground reached 1,504,284,293 IDR/year, this value indicates the role of mangroves as habitat and foraging for small fish and some other small animals that live within mangrove ecosystem. The result showed that indirect use value was 415,195,703,043 IDR/year. Indirect use values considered high indicates the role of mangroves in generating economic value even though those benefits cannot be directly perceived by the local community.

Table 5. The direct use value of Cilamaya Wetan mangrove ecosystem.

| No. | Resource     | Total (IDR/year) |
|-----|--------------|------------------|
| 1.  | Firewood     | 22,500,000.00    |
| 2.  | Mangrove Seed| 1,200,000.00     |
| 3.  | Crab         | 1,717,600,000.00 |
| 4.  | Fish         | 1,849,225,500.00 |
| 5.  | Squid        | 259,200,000.00   |
| 6.  | Shrimp       | 30,000,000.00    |
|     | Total        | 3,879,725,000.00 |

The second-highest economic value came from direct use-value. The value of catching fish and crabs was the highest value when compared with the other value. The value of catching fish was high because most residents of Cilamaya Wetan work as fishermen. Meanwhile, the crab was a superior commodity because it can be caught anytime and not depending on the season, so the number of catches per year obtained was high. Local community still use mangrove wood as firewood. Local community preferred to use mangrove as firewoods than other fuels for cooking due to financial reasons. It was known that 27% of the Cilamaya Wetan local community was still classified as a pre-prosperous family (BPS 2016), besides mangrove wood was better than other types of wood as firewood. The direct use value obtained illustrates the economic value that has been directly benefited by the community.
The third highest economic value came from the option value. The option value refers to the value of other potential used of mangrove forests in the future obtained from the existence of sources of biodiversity and habitat conservation (Pearce and Moran 1994, Widiastuti et al 2016). The Cilamaya Wetan mangrove ecosystem has an option value of 158,190,300 IDR/year. This value was considered higher when compared to option value of mangrove in Dompak Island, which only 90,877,800 IDR/year. The option value depended on the size of the mangrove area.

The lowest economic value came from existence value. The existence value of Cilamaya Wetan mangrove ecosystem was obtained from the value of willingness to pay. The willingness to pay value illustrated the minimum cost that a person can afford to pay a conservation program for mangrove as a form of satisfaction with a resource (Widiastuti et al 2016). Based on the results of interviews with 30 respondents, 87% were willing to pay for the mangrove conservation program, while 13% of them refused. This indicated that not all Cilamaya Wetan communities have a concern in maintaining the sustainability of mangroves. This was allegedly due to financial reasons. The Cilamaya Wetan community consisted of 27% pre-prosperous groups and the rest have entered into prosperous groups. (BPS 2016). The value of willingness to pay can be described the community's concern for a resource, in this study was mangrove forest. The higher the value of WTP showed the higher community's concern.

Table 6. The total economic value of Cilmaya Wetan mangrove ecosystem.

| No. | Types of value | Total (IDR/year) |
|-----|----------------|-----------------|
| 1.  | Direct use value | 3,879,725,000.00 |
| 2.  | Indirect use value | 415,195,703,043.00 |
| 3.  | Option value | 158,190,300.00 |
| 4.  | Existence value | 296,000.00 |
| Total economic value | 419,233,914,343.00 |

Based on the results, Cilamaya Wetan mangrove ecosystem has a total economic value (TEV) of IDR 419,233,914,343/year or equivalent to IDR 568,067,635 /ha/year. If the value was converted to dollars, the value was 29,337,573 USD/year or 39,753 USD/ha. This value was very high when compared to research conducted by Widiastuti et al (2016) on mangrove forests in the coastal area of the Arafura Sea, which resulted in IDR 21 million/ha/year but not so high when compared to the Zen and Ulfah (2013) study on Dompak Island, Tanjung Pinang City which resulted TEV of IDR 169.7 million/ha/year. Different TEV values depend on several factors, such as the amount of economic value that valued.

Based on these values, Cilamaya Wetan mangrove ecosystem provided functions and benefits that very important to the communities. The functions and benefits are inseparable from the threat of damage by the community itself. The total economic value evaluated is an illustration of the value of the loss obtained if the mangrove is damaged. This value can be used as a basis for consideration in the management and utilization of mangroves so that the benefits can be obtained sustainability.

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