Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(6): 1333 – 1347 (2025)
www.ejabf.journals.ekb.eg

Economic Valuation of Mangrove Forest in Biringkassi Beach, Pangkajene and Kepulauan Regency, South Sulawesi Province

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ARTICLE INFO

Article History:
Received: March 20, 2025
Accepted: Aug. 20, 2025
Online: Nov. 29, 2025

Keywords:
Mangrove,
Direct and indirect use Value,
Option use and existence value,
Total economic valuation

ABSTRACT

Mangroves play an essential role in coastal areas, therefore evaluating their economic value is crucial for optimizing their conservation and utilization. This study aims to identify the various uses of mangrove forests in Biringkassi Beach and to analyze the total economic value of the identified mangrove forest benefits. This study involved systematic surveying, measurement, and data collection on aspects related to mangrove, succeeded by quantifying all utilization services to its obtain economic value. This purpose was achieved through local market price-based calculation methods and commodity prices in the global market, replacement cost-based calculation methods and determining economic value through benefit transfer and the cost of willingness to pay or willingness to accept as compensation related to the protection and conservation of Biringkassi mangrove forest. The utilization value of mangrove forests in Biringkassi Beach includes direct use value, indirect use value, optional use value, and existence value where the economic value of each utilization is US$315.597 per year for direct use value; the indirect use value is US$172.762 per year, and the optional use value and existence value of Biringkassi mangroves is US$838 per year. The total economic value of the Biringkassi mangrove forest for the 4 hectares is US$489.197 per year. The utilization of the Biringkassi mangrove forest area can be improved by expanding and developing the mangrove forest area.

INTRODUCTION

The west coast of South Sulawesi Province has a length of about 270 kilometers starting from Jenneponto Regency at coordinates 5°32'47.87" South Latitude and 119°25'12.42" East Longitude to Pinrang regency at coordinates 3°42'9.08" South Latitude and 119°27'2.66" East Longitude. Regencies and cities located on the west coast of South Sulawesi include Jenneponto Regency, Takalar Regency, Gowa Regency, Makassar City, Maros Regency, Pangkajene and Kepulauan Regency, Barru Regency, Pare Pare City and Pinrang Regency. The west coast of South Sulawesi is directly adjacent to the Makassar Strait. The Biringkassi coastline at the research site spans approximately 4 hectares and is home to several mangrove species, including *Avicennia alba*, *Rhizophora*, and *Sonneratia*.

Saru (2013) stated that mangrove ecosystems are generally dominated by several species of mangroves such as *Rhizophora* sp., *Avicennia* sp., *Bruguiera* sp., and *Sonneratia* sp. These mangrove species can grow well in shallow coastal areas because the root form can adapt to the aquatic environment from both the influence of tides and other environmental factors such as temperature, salinity, dissolved oxygen, sediment, pH, nitrate, phosphate, currents, and waves. Furthermore, **Saru (2013)** stated that ecologically mangroves have a function as nursery grounds, feeding grounds, and spawning grounds for various types of marine life. Mangrove forest areas can be inhabited by various fauna, including land animals such as insects, leaf-eating monkeys that prefer living in the shade of trees, snakes, and other slithering groups.

Tahang *et al.* (2018) stated that mangrove ecosystems have extensive benefits and environmental services for humans and other living things. In addition to ecological benefits, it also has various economic benefits for the community. For this reason, it is necessary to assess the overall economic benefits of mangrove ecosystems for humans so that management and utilization actions can be carried out more wisely and have an optimum impact on people's lives, especially communities in coastal areas. **Mappasomba *et al.* (2024)** detailed that mangrove forest areas in the Biringkassi coastal area have been degraded due to land conversion into ponds and other agricultural activities. Currently, there are only a few mangrove forests that grow naturally.

Bahar (2007) defined ecotourism in mangrove ecosystems as activities that are interconnected with one another so that each ecotourism activity can use the same facilities, for example, photographing and natural interpretation activities that can be carried out simultaneously, such as observation towers. This facility can serve multiple functions, so that it allows efficiency in reducing the provision of ecotourism facilities in mangrove forest areas, but is still expected to be an interesting experience for tourists in efficiently utilizing facilities and infrastructure. The optimal Biringkassi coastal area currently hosts mangrove ecotourism activities known as Mangrove Dewi Ecotourism. According to **Mashoreng (2022)**, one of the key ecological functions of mangrove ecosystems is supplying organic matter through fallen litter. This litter is largely decomposed by sediment bacteria, with some exported to adjacent ecosystems and a smaller portion directly utilized by local biota. The amount of organic matter in the sediment is believed to be influenced by the age of the mangrove vegetation. Given the extensive benefits provided by mangrove ecosystems, including direct and indirect uses, option values, and existence values, it is essential to thoroughly identify the functions, and services offered by mangrove forests, particularly for communities around the

Biringkassi Beach research area. In addition, it is crutial to assess the total economic value of these benefits. Therefore, a scientific study is required to determine the economic value of mangrove ecosystem services along the Biringkassi coast in Bulu Cindea Village, Bungoro District, Pangkajene and Islands Regency, South Sulawesi Province.

MATERIALS AND METHODS

1. Study area

The research was conducted from September 2024 to January 2025 in the coastal area of the mangrove forest of Biringkassi Beach, Bulucindea Village, Bungoro District, Pangkajene and Kepulauan Regency, South Sulawesi Province, Indonesia. The research area of the mangrove is approximately 4 hectares.

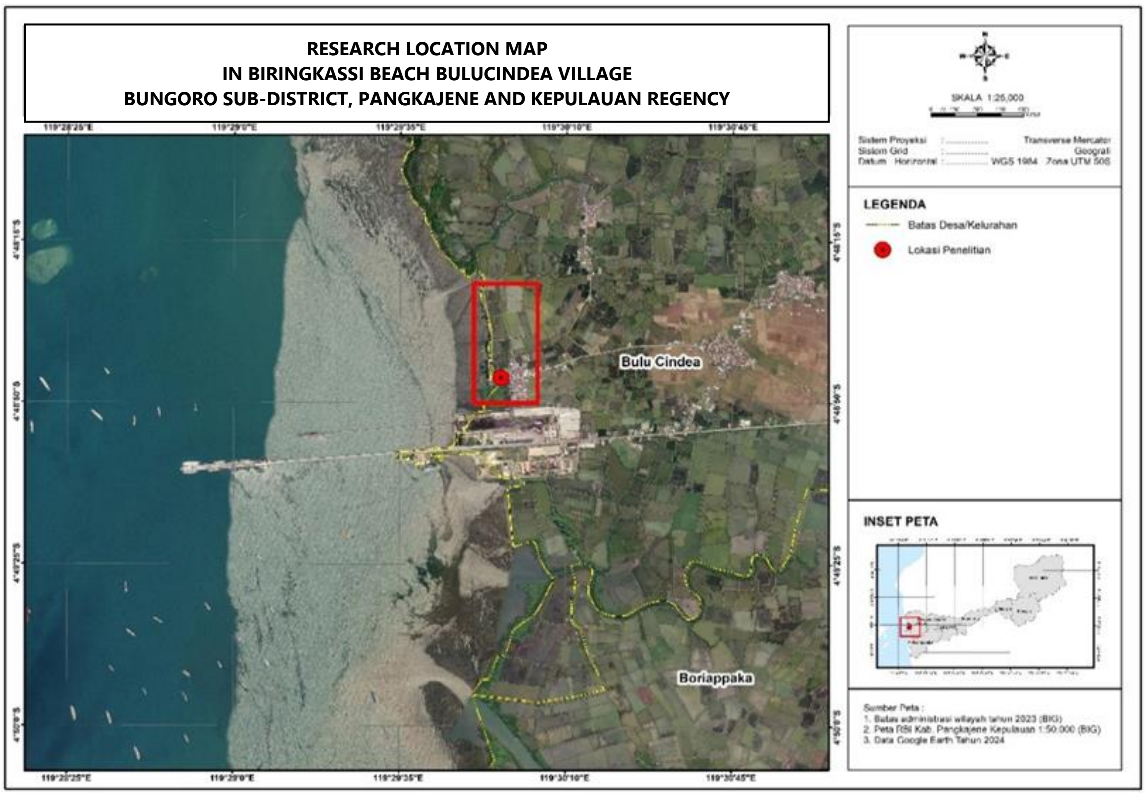

Fig. 1. Map of the research location

The focus object of the research is on the mangrove forest area, directly adjacent to a number of 109 residential houses with coordinates as depicted in Fig. (2).

Fig. 2. Focus on the mangrove research area

2. Research instrument

The research instrument used is listed in Table (1).

Table 1. Research instruments

No	Research Instrument	Function
1	Writing stationery	Note all necessary data and information
2	Questionnaire sheet	Guide the data collection of all necessary information at the time of survey/interview with respondents
3	Elasticated meter and rope	Measure the circumference of the mangrove trunk at breast height (1.3 metres) and form a rectangular plot measuring 20 m x 20 m.
4	Smart phone camera	Taking photos of research objects by activating the location coordinate feature so that it can function as a GPS
6	Anemometer	Measuring wind speed at the research site
7	Drone	Taking aerial photos and videos above the research site objects
8	Laptop	Compile database of research
9	Software (*Microsoft Word, Microsoft Excel, Google Earth Pro, Google Earth Engine*)	Obtain, process, analyse, and write down the data of the research results

3. Research design and procedure

The research design and procedure of data collection are shown in Figs. (3, 4).

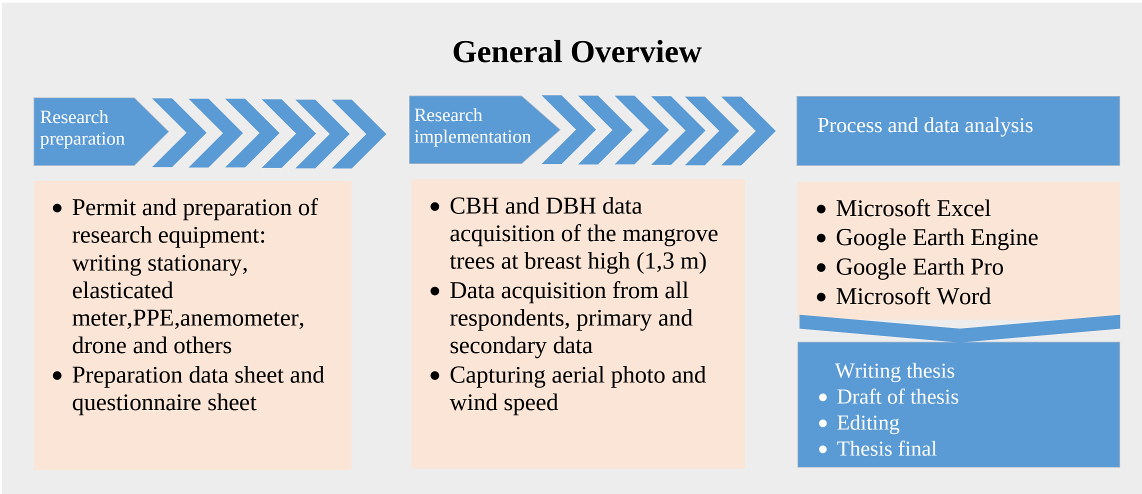

Fig. 3. General overview of the research

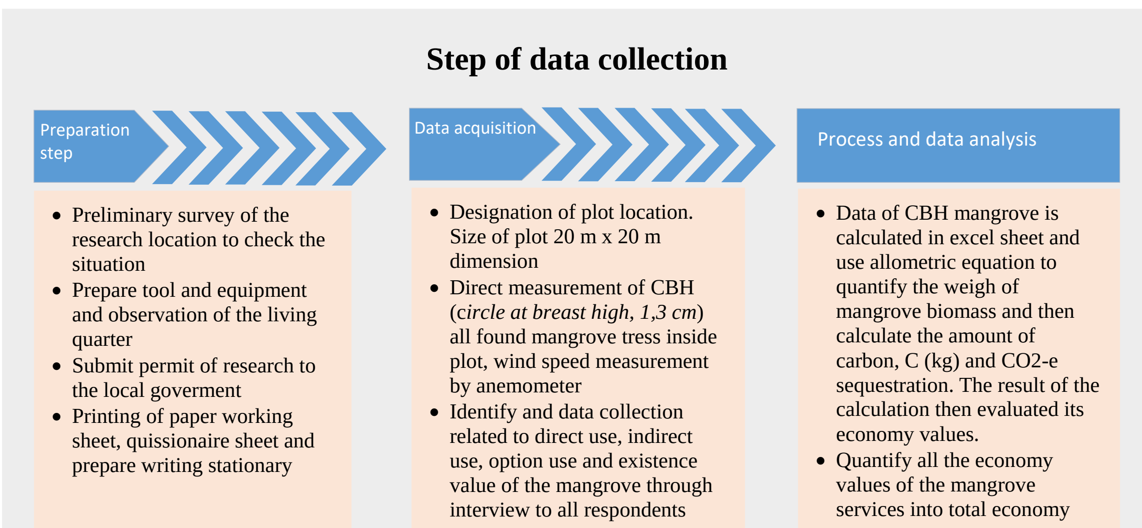

Fig. 4. Step of data collection of the research

4. Data analysis

Respondents amount is determined based on the total amount of houses that are available near the mangrove forest. The amount of houses was used as references assuming that this party is impacted directly or having mangrove services all the time. **Slovin**'s **(1960)** formula for sampling technique was used to determine the amount of respondents:

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{N}\,((\mathbf{d})^2) + \mathbf{1}}$$

Where, n is the number of samples of respondents, N is the population size (houses, 200), and d is the error level (10%). The Slovin formula is used to determine the total amount of respondents, which is related to further analysis of the utilization of mangrove Biringkassi. The number of respondents is 67 persons obtained from the calculation: 200 / (200 x (0,01)2)+1 = 68. The respondent related to the mangrove ecotourism observation is calculated by referring to the average number of visitors monthly to the mangrove Biringkassi ecotourism. Based on the information from the local government in Biringkassi village, 50 persons visit the mangrove ecotourism per month. To determine the respondent amount, the formula calculated: 50 / (50 x (0,01)2)+1 = 33.

Field measurement of the mangrove trees is commenced by determining the location and amount of plots in the mangrove forest area. 7 plots with size 20 m x 20 m were determined. The purposive sampling method is used to determine the number of plots, which is the number of 7 plots as a plot sample for research. Plotting area at the site of the mangrove forest was conducted by using a rope and an elasticated meter, and hence a direct measurement of CBH (Circumference at Breast High) of the mangrove trunk is obtained. All amounts and species of mangroves were noted in the work paper sheet. Photos and videos of the mangrove area and its structure were documented. Calculation of mangrove biomass weight above ground (*Wtop*) was determined for all mangrove trees through field measurement. An allometric equation was used to determine the biomass weight of mangrove species found at the survey site. Four major species of mangroves were found during field measurement, and the allometric equation of each mangrove species was applied to calculate the Wtop. The mangrove species found in Biringkassi Beach included *Avicennia marina*, *Rhizophora mucronata*, *Rhizophora apiculata*, *Avicennia alba* in addition to a small amount of *Sonneratia alba*. To calculate the weight of each mangrove species aboveground as a biomass weight (Wtop, kg), the allometric equation applied for each species gave the following values: Wtop = 0.043*DBH2.63 **(Amira, 2008)** for *Rhizophora apiculate,* Wtop = 0.1848*DBH2.3624 **(Dharmawan & Siregar, 2008)** for *Avicennia marina* mangrove, Wtop = 0.1466*DBH2.3136 **(Dharmawan, 2010)** for *Rhizophora mucronata* mangrove, and Wtop = 0.079211*DBH2.470895 **(Tue *et al*., 2014)** for *Avicennia alba* mangrove.

For the calculation of C (carbon, kg), the formula C = 0.47 x Wtop was used, where C is the weight of carbon (kg) as stock carbon in mangrove biomass, and Wtop is biomass weight of mangrove per tree above ground in kg. While CO_2e (carbon dioxide equivalent) sequestration is calculated using the formula WCO_2-e = 3.67 x C, where WCO_2-e is the carbon dioxide equivalent which is sequestrated in ton/hectare. The number 3.67 is the weight ratio of compounds or atoms between CO_2 and C, namely 44/12 = 3.67. To calculate the economic value of the benefits of the mangroves absorbing carbon dioxide (CO_2e) and carbon C (kg) stocks, the formula NMSK = C x international carbon trading price was used, where NMSK (Nilai Manfaat Serapan Karbon) is the beneficial value of carbon sequestration in rupiah/ton for a year. To determine the economic values of the natural services, the structure of natural resource economic valuation is shown in Fig. (5).

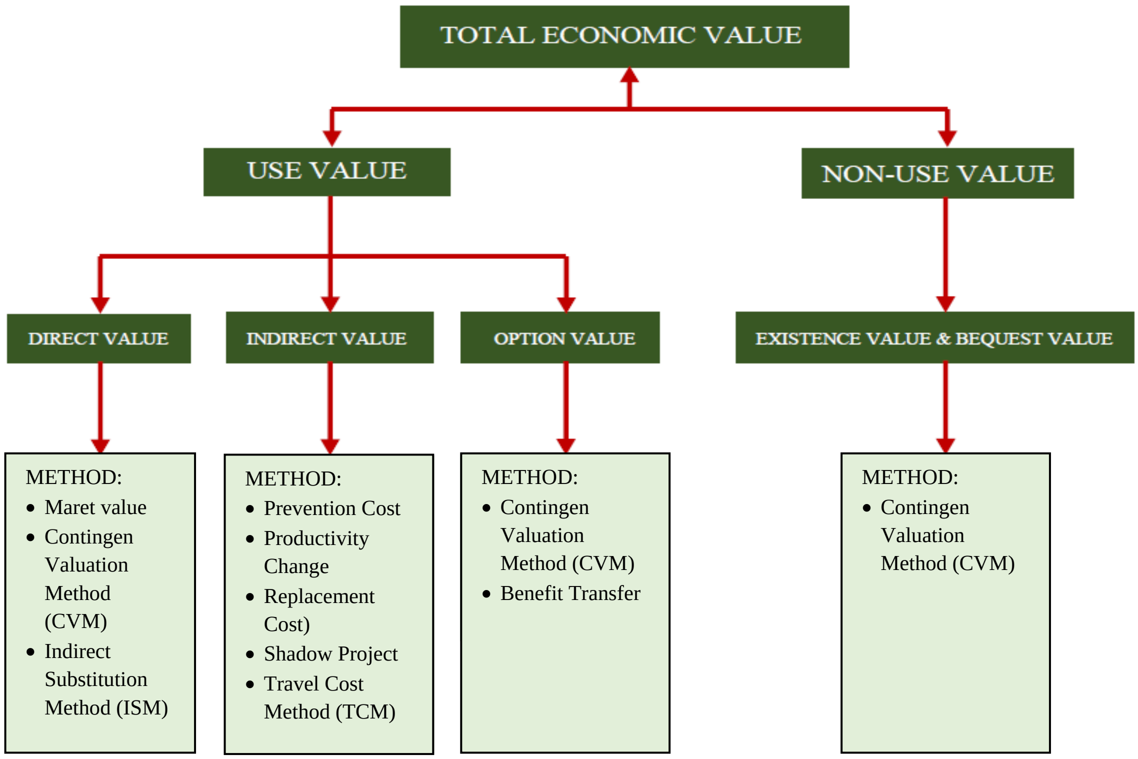

Fig. 5. The structure of natural resouce economic valuation

The total economic value of the mangrove forest in Biringkassi is analyzed from the direct use value, indirect use value, and option and existence value of the mangrove benefit for the community. The direct use value of the Biringkassi mangrove forest is closely linked to the benefit it provides to coastal fisheries. Local fishermen harvest crabs, oysters, fish, and shrimp on a daily basis. Additionally, women, particularly fishermen's wives, collect oysters during low tide periods. However, shrimp and oyster yields are relatively limited.

The indirect use value of the mangrove forest includes carbon sequestration and carbon storage within biomass. The economic value of these services was estimated through carbon credit trading, based on measurements of carbon stock C in kg and CO_2 equivalent sequestration tons per hectare. International carbon credit prices were used to determine the monetary value.

Mangrove ecotourism benefits in Biringkassi are evaluated using the Travel Cost Method TCM. A total of 33 visitors were interviewed to collect data on the expenditure incurred during their visit, including transportation, fuel, and food. Most visitors originate from Pangkajene and Makassar, with the majority being young local residents working as civil servants or private employees.

There are 109 houses located adjacent to the mangrove forest which benefit directly from reduced wind exposure. Mangrove vegetation, approximately 200 meters in width, can reduce wind speed by 60 to 85 percent. The Biringkassi research area has a coastline of about 903 meters, covered by roughly 4 hectares of mangroves with varying stand widths.

Another significant indirect use value is coastal abrasion protection. Without mangroves, waves can erode and damage the coastline. To estimate the economic value of mangroves as natural coastal defenses, the replacement cost method was used. This assumes the cost of constructing artificial structures such as seawalls or revetments to provide equivalent protection.

Mangroves also help minimize seawater intrusion into terrestrial areas. When mangrove vegetation is present along the shoreline, it acts as a natural barrier that protects freshwater aquifers from salinization. This value can likewise be estimated using the replacement cost method, based on domestic freshwater consumption and associated expenditure by households living near the mangrove forest.

The option value and existence value of the Biringkassi mangroves are assessed through biodiversity valuation using the benefit transfer method. In addition, the CVM is employed to determine the community's willingness to pay for mangrove conservation and protection, as well as willingness to accept compensation, providing insight into local perceptions and expectations regarding the Biringkassi mangrove ecosystem.

RESULTS AND DISCUSSION

Economic valuation of mangrove forests in Biringkassi Beach, Pangkajene, and Kepulauan Regency, South Sulawesi Province consists of economic values from direct use value, indirect use value, option use value, and existence value. Direct use value is related to fishing product catch collected by the fisherman on a daily basis. The local market price is used to evaluate the transaction. The economic value of the direct use benefits is US 315,597 per year, derived from the sale of crabs, oysters, and fish at local market prices. The detailed economic value of these direct uses is presented in Table (2).

Table 2. Economic value of the direct use of mangrove forest

Crab trading	Oysters trading	Fish trading
US$372/day	US$3/day	US$502/day
US$11.146/month	US$90/month	US$15.063/month
	US$315.597 per year	

The majority of the residents of the coastal region of Biringkassi are fishermen with only an elementary school education. Others are casual laborers at the cement factory of PT Semen Tonasa, which is located near the port of the state-owned enterprise, near the mangrove area. The waterways that are already a slightly farther from the mangrove region are where these fishermen capture fishery items. They plant their crab fishing gear every day by submerging it at the sea's bottom, and they harvest it every morning. Crabs often earn between two and three kilograms per day, or more during some seasons.

According to the findings of the economic value of indirect use of the Biringkassi mangrove forest area, the benefits of mangroves include their ability to absorb carbon dioxide (CO_2), their role in storing carbon stocks in tree biomass, their usefulness for mangrove ecotourism areas, their ability to reduce wind speed in 109 houses close to the mangrove forest area, their ability to minimize seawater intrusion, and their ability to protect the coastline from erosion or abrasion caused by currents and waves. The indirect economic benefits of the 4- hectare mangrove area at Biringkassi Beach amount to US 173 per year. The detailed values of these indirect benefits are presented in Tables (3, 4).

Table 3. Economic value of the indirect benefit

CO_2e sequestration (IDR/ton)	Carbon stock, C (IDR/ton/)	Mangrove ecotourism (IDR/year)
US$24.544 (4 hectares)	US$67 (4 hectares)	US$32.287
(I) US$57.099 per year		

Table 4. Economic value of the indirect benefit

Intrusion reducer (IDR/year)	Wind speed reducer val(IDR/year)	Abrasion reducer (IDR/year)
US$10.466	US$98.613	US$6.584
(II) US$115.663 per year		
Total (I + II) US$172.762 per year		

The research results of the indirect benefits of the Biringkassi mangrove forest as listed in Tables (2, 3) specifically for carbon dioxide (CO_2) sequestration in tonne/ha and carbon stock, C (kg) in biomass begin with calculating the weight of tree biomass above the surface (Wtop, kg) using the allometric formula. The number of plots was 7 plots measuring 20 x 20m. The results of the weight of biomass (kg) of mangrove trees at the top of the surface were then quantified to further obtain the weight of carbon (kg) in each tree, followed by calculating the value of carbon sequestration. The economic value of carbon sequestration or carbon stock is obtained by multiplying the price of carbon credits on the global market. In this study, a maximum price of 35 USD per tonne of carbon credit was used. The economic value of mangrove benefits as mangrove ecotourism is based on the results of a travel cost method calculation survey for 33 respondents. The number of respondents was determined using the Slovin formula:

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{N}\,((\mathbf{d})^2) + \mathbf{1}}$$

Where, n is the number of respondents, N is the population and d is the error rate of 10% or 0.01. Population data were taken based on the average number of visitors per month of 50 people, based on the results of interviews, and a total of 33 respondents for the valuation of the economic value of mangrove areas as mangrove ecotourism.

The benefits of the Biringkassi mangrove forest as a barrier to seawater intrusion were quantified using the replacement cost method. The replacement cost was calculated based on total household expenditures for raw water used for cooking and drinking, bathing, washing, and toilet needs. A total of 68 respondents provided data on their water use and procurement costs, and the aggregated expenditure was used as the replacement cost representing the value of mangroves in reducing seawater intrusion.

The economic value of the mangroves as a reducer of wind speed was also quantified using the replacement cost method. In the absence of mangrove trees, strong winds exceeding 63 kilometers per hour blowing from west to east can damage house roofs, walls, windows, or doors. Literature indicates that winds above this speed can cause significant damage to wooden houses, with estimated repair costs of about US 905 per housing unit. This estimate was supported by several online references. With 109 houses directly exposed, the economic value of mangroves as a wind barrier is calculated as 109 multiplied by US 905, resulting in a total value of US 98,645. Field measurements during the survey showed that existing mangrove stands reduce wind speed by approximately 60 percent to 83 percent.

The economic value of the Biringkassi mangroves as coastal protection was also quantified using the replacement cost method. It was assumed that if mangrove trees were absent along the coastline, coastal protection would need to be provided by constructing stone revetments. According to the cost reference issued by the Ministry of PUPR of the Republic of Indonesia in 2022, the cost of revetment construction is US 35 per square meter. The estimated length of the Biringkassi coastline based on Google Earth Pro measurements is 903 meters. A revetment structure with a width of 10 meters would require a construction area of 9030 square meters. The total construction cost is therefore US 319,185. Considering Indonesia's annual inflation rate of 1.57 percent, this cost must be adjusted accordingly. Based on government standards, coastal protection structures are designed with an operational life of 50 years, so the annual economic value of mangroves as coastal protection is calculated by dividing the total replacement cost by 50, resulting in US 6,584 per year. This value represents the annual benefit over the next 50 years.

The economic value of the option use and existence value of the Biringkassi mangroves was assessed using the benefit transfer method and the contingent valuation method through estimates of community willingness to pay and willingness to accept compensation for conservation and protection of the mangrove ecosystem. The calculated values are presented in Table (4).

Table 4. Option use and existence value

Benefits of biodiversity (US$/ha)	Average WTP value (*Willingness to Pay*) (US$/year)	Average WTA value (*Willingness to Accept*) (US$/year)
US$59	US$1	US$10
	US$70	
	US$838 per year	

The economic valuation of biodiversity in the mangrove forest area was conducted using the benefit transfer method. Based on the study by Ruitenbeek HJ (1992), the biodiversity value of Indonesian mangrove forests is estimated at 15 USD per hectare. Using an exchange rate of IDR 16,580 per USD on 13 March 2025, the biodiversity value of the 4- hectare Biringkassi mangrove forest at the research site is calculated at 59 USD.

The economic value of the existence benefits of the Biringkassi mangroves was obtained using a shadow survey based on the contingent valuation method. Respondents were asked about their willingness to pay for mangrove maintenance and preservation, as well as their willingness to accept compensation if the Biringkassi mangroves were to be converted and thus lose their ecological functions. Survey results indicated that the community in Biringkassi Hamlet is generally willing to contribute financially, with an average willingness to pay of approximately 1 USD per person for mangrove conservation, and nearly all respondents expressed readiness to participate or donate. Meanwhile, most residents were not willing to accept compensation for mangrove conversion, indicating a strong community desire to prevent any change in the existing mangrove area.

The total economic value of biodiversity and existence benefits for the 4- hectare Biringkassi mangrove forest is estimated at 838 USD per year.

CONCLUSION

Direct utilization of the Biringkassi mangrove area primarily involves the harvesting of crabs, oysters, fish, and shrimp. Other forms of direct utilization are minimal or nearly non-existent. The economic value of direct utilization for the 4-hectare Biringkassi mangrove research site is estimated at US 315,597 per year.

Indirect benefits, in the form of environmental services such as carbon dioxide absorption and carbon storage in mangrove biomass, have an economic value of US 24,812 per year. The value of mangroves as a basis for ecotourism at Biringkassi Beach is estimated at US 32,287 per year. Additional indirect benefits, including protection against seawater intrusion, reduction of strong wind speed, and coastal abrasion protection, amount to US 115,663 per year. Therefore, the total economic value of indirect utilization of the Biringkassi mangrove area is US 173,000 per year.

The value of biodiversity and the existence benefits of the mangrove forest is estimated at US 838 per year. Combining all direct and indirect benefits, the total economic value of the 4-hectare Biringkassi mangrove forest research site is US 489,197 per year. The majority of this total value is derived from mangroves as a source of fisheries production, which serves as an important income source for the local community.

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