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Fauna diversity, production potential and total economic value of mangrove ecosystems in Mentawir Village, East Kalimantan, Indonesia

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Abstract. *Kristiningrum R, Lahjie AM, Masjaya, Yusuf S, Ruslim Y, Ma'ruf A. 2020. Fauna diversity, production potential and total economic value of mangrove ecosystems in Mentawir Village, East Kalimantan, Indonesia. Biodiversitas 21: 1940-1953.* Mangroves play important role in life. The benefits of the mangrove ecosystem consist of ecological and socio-economic values. However, it is a challenge to discern how the mangrove ecosystem provides a comprehensive economic value. This research is aimed to analyze the Total Economic Value (TEV) of mangrove ecosystems in Mentawir Village, North Penajam Paser District, East Kalimantan Province. This aim will be achieved by conducting fauna inventory, analysis of mangrove wood production potential, social-economic interviews, and infrastructure cost analysis as the inputs to calculate four elements (i.e. Direct Use Value, Indirect Use Value, Option Value, and Existence Value) to sum up the TEV. The research used a mixed-method combining both qualitative and quantitative methods. Fauna inventory was conducted using boat survey method and interviews with local fishermen. Data on mangrove wood production was obtained using the systematic random sampling method by establishing two plots with an area of one hectare for each plot to calculate mean annual increment (MAI) and current annual increment (CAI). The economic value of the mangrove ecosystem was calculated using market price values, replacement costs, and the Contingent Valuation Method (CVM). The results of fauna inventory consisted of 3 species of mammals, 1 species of reptile, 16 species of birds, 25 types of fish, 8 species of crustaceans, and 7 species of mollusks. The economic valuation resulted in the contribution of direct use value with 39.56% in the form of wood (94,875,000,000 IDR) and fishery products (103,500,000,000 IDR); indirect use value with 53.47% in the form of breakwater (38,028,881,407 IDR), abrasion resistance (218,549,528,110 IDR), and carbon sequestration (11,580,313,067); option value with 6.92% in the form of biodiversity (34,690,085,038 IDR); and existence value with 0.05% (241,500,000 IDR). All these resulted in the total economic value (TEV) of the mangrove ecosystem in Mentawir Village of 501,465,307,621 IDR. Therefore, this value can be the basis for policymakers in managing natural resources so that the ecosystem is more protected and sustainable, and can continue to provide environmental services for the welfare of the community.

Keywords: Biodiversity, economic valuation, fauna, growth, mangrove, Mentawir

INTRODUCTION

Mangrove is an evergreen, salt-tolerant plant community that grows in inter-tidal coastal zones of the tropical and subtropical regions of the world (FAO 2008). Mangrove ecosystems are ecologically important for many fauna species as they are rich in food resources and consist of many different vegetation structures. They serve as ideal foraging and nursery grounds for a wide array of species such as birds, mammals, reptiles, fish, and aquatic invertebrates (Zakarian and Rajpar 2015). Mangrove ecosystems also serve as buffer zones and provide protection from coastline erosion (Lundquist et al. 2017).

Besides having an ecological function, the mangrove ecosystem also has considerable economic benefits. Mangrove ecosystems contribute significantly to increasing community income as well as supporting regional and state economy. Goods produced from mangrove ecosystems include firewood, building materials, fertilizers, paper raw materials, food ingredients, beverages, household appliances, candles, honey, recreation, fishing grounds, and more (Walters et al. 2008; Saenger 2011; Oktawati and Sulistianto 2015). Nonetheless, despite the high importance of mangrove ecosystems, they are often regarded as public property resources that can be used by anyone without regard to their sustainability aspects. This view triggers over-utilization of mangrove resources, causing the depletion of such resources and the degradation of the ecosystems in providing environmental services (Darmawan 2015).

Wijaya (2018) states that one of the leading research themes in 2019-2023 will be the quantification and valuation of coastal ecosystem services. Coastal and marine ecosystems use many estimates of ecosystem service assessments (Vegh et al. 2014). Economic valuation is an attempt to provide quantitative value to goods and services produced by natural resources and the environment, both on the basis of market value and non-market value. Economic valuation is defined as a process of attaching monetary value or price to non-marketed environmental goods and services (Rao 2000). Economic valuation plays an important role in decision making although it is often fraught with limitations. The economic value is generally defined as a measurement of the maximum number of people wanting to sacrifice goods and services to obtain other goods and services (Fauzi and Anna 2005). This estimate reflects various economic valuation methods. Barbier et al. (2011) state that some of these economic valuation methods depend on the value of ecosystem services and some depend on the non-market approach. Ecosystem services are said to be important if they can be valued or quantified in monetary terms.

One way to conduct a monetary valuation of ecosystem services is to use a comprehensive assessment from a total economic valuation (TEV) method. TEV considers the benefit of transfer as an important platform for appreciating and analyzing sustainability values in the decision-making process. The TEV is valued by revealed preference or stated preference. The TEV tries to adopt entirely marginal values for ecosystem services, according to the additional values derived from the total estimation of willingness to pay and willingness to accept some environmental commodities. TEV is the combination of direct, indirect, option, existence and bequest value, altruistic value, quasi option value (which are based on use value), and non-use ecosystem values of services (Price 2007). The TEV of world mangrove ecosystem services is around USD 200 billion (Vo et al. 2012).

Balikpapan Bay is a strategic port in the province of East Kalimantan. As a consequence of development in Balikpapan Bay, it caused damage to the mangrove ecosystems of about 47.6% and a decrease in the area of mangrove forests by around 12.5% in the last 15 years (Lahjie et al. 2019). Warsidi (2017) stated that mangrove forests in the Balikpapan Bay area consist of primary mangrove forests and secondary mangrove forests, which are generally dominated by *Rhizophora apiculata* species. Given the low appreciation of the local community for the potential of mangrove forests as an economic asset, it is necessary to do an economic valuation of the magnitude and benefits of mangrove forests. This research is aimed to analyze the Total Economic Value (TEV) of mangrove ecosystems in Mentawir Village, Penajam Paser Utara District, East Kalimantan Province. This aim will be achieved by conducting fauna inventory, analysis on mangrove wood production, social-economic interviews, and infrastructure cost analysis as the inputs to calculate four elements (i.e. Direct Use Value, Indirect Use Value, Option Use Value and Existence Use Value) to sum up the TEV.

MATERIALS AND METHODS

Study area and periods

This study was conducted in Mentawir Village, North Penajam Paser District, East Kalimantan Province (Figure 1). The rationale of selecting this village is the utilization of mangrove ecosystems that is still very natural and as one of the mangrove tourism villages in East Kalimantan. The research period lasted for four months from November 2019 to March 2020.

Data collection

The research used a mixed-method by combining qualitative and quantitative methods (Masrizal 2011). Observations of species of fauna were conducted using boat survey along 2.5 km with the track following the river flow (Salter and MacKenzie 1985; Atmoko et al. 2007; Ridzwan Ali et al. 2009; Atmoko et al. 2011). The total distance of exploration during the study was 13.3 km, including the Mentawir River, Tiram Tambun River, Penyanggulan River, Sekambing River, and Loop River. Site identification and recognition including river names and tributaries were based on information from local communities. Observations were started in the morning at 6: 30 am until 2 pm. The aquatic faunas were caught using fishing rods and cast nets while aquatic invertebrates were collected via swap nets. We also gathered data from fish catches by local fishermen.

Data collection on mangroves were conducted using systematic random sampling by establishing two plots, namely Plot 1 (mangrove stands with an estimated wood volume of around 100 m^3) and Plot 2 (around 60 m^3). Each plot has an extent of one hectare in which four sub-plots with size of 2500 m^2 (50m x 50m). 4 times with data collection methods in the form of systematic random sampling.

Social-economic data was collected using purposive sampling (Sugiyono 2015) by conducting direct interviews with selected fishermen and communities around the mangrove.

Data analysis

Analysis of mangrove wood production

This study used Microsoft Office Excel to perform calculations and generate graphs. Analysis of mangrove wood was done by calculating the total volume of standing stock as follows:

$$V = \frac{1}{4}\Pi d^2 htf$$

Where: V: standing volume, d: diameter at breast height, h: branch free height, f: form factor

We also analyzed the growth increment of mangrove. The increment is an increase in tree dimension growth (height, diameter, base area, and volume) associated with tree age or a particular period. Based on the measurement period, there are mean annual increment (MAI) and current annual increment (CAI) (Van Gardingen et al. 2003), and formulated as follows:

$$MAI = \frac{V_t}{t}$$

Where: MAI: mean annual increment, Vt: total standing volume at age t, t: tree age.

$$CAI = \frac{V_t - V_{t-1}}{T}$$

Where: CAI: current annual increment, Vt: total standing volume at age t, Vt-1: total standing volume at age t-1, T: time interval between each measurement age.

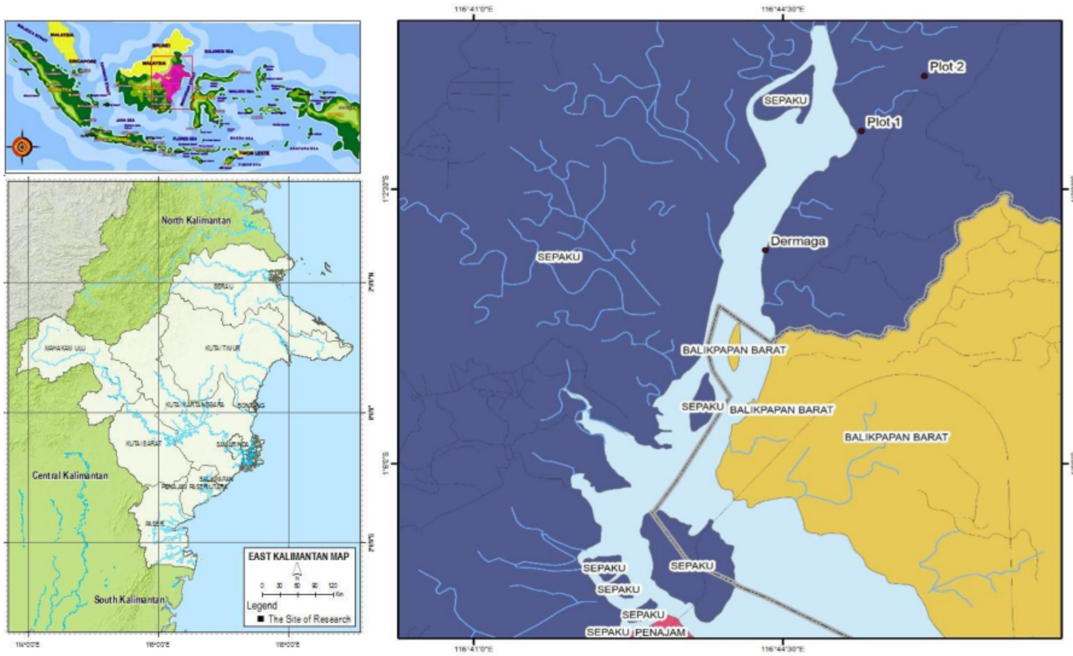

Figure 1. Research location in Mentawir Village, Sepaku Sub-district, North Penajam Paser District, East Kalimantan, Indonesia

The relationships between variables were analyzed using simple linear regression to determine the coefficient of regression determination (R^2).

Analysis of total economic value

The analytical methods related to the calculation of total economic value of mangrove ecosystems in Mentawir Village based on:

Direct use-value. The direct use-value is the economic or social value of the goods or benefits derived from the services provided by an ecosystem that can be used directly by an economic agent. Determination of the types of direct benefits can be seen based on the market price approach for marketable goods and services such as fisheries productivity. Measurement of direct use value based on market prices according to Tuwo (2011) can be formulated as follows:

$$MLi = (HPI \times Pi) - Bpi$$

Where: MLi: Direct use value of commodity i (IDR yr^{-1}), HPI: Commodity Market Price (IDR. Kg^{-1}), Pi: Commodity Production i (Kg yr^{-1}), BPI: Operational costs (IDR), i: type of commodity (for example: shrimp, fish, crab, etc.),

So that the value of the direct benefits of the mangrove ecosystem can be formulated as follows:

$$ML = ML1 + ML2$$

Where: ML: Direct benefits, ML1: Direct benefits of wood, ML2: Direct benefits of fisheries

Indirect use-value. Indirect use-value is the value of utilization based on an indirect function of the existence of mangrove ecosystems, such as a breakwater, an abrasion restraint, and carbon sequestration. The formulation of the calculation of benefits as a breakwater, according to Kurniawati and Pangaribowo (2017), is as follows:

$$MTL = PGP \times B$$

Where: MTL: Indirect benefits (IDR yr^{-1}), PGP: coastline length (m), B: standard concrete cost (IDR)

The standard cost of concrete breakwaters was referred to the Regulation of the Minister of Public Work and Housing No. 28 of 2016. The cost to make a breakwater building with a length of 150 m, width 20 m and height 5 m with a durability of 20 years requires 2,921,147,000 IDR m^3 or equal to 194,743 IDR m^{-1}. To accommodate inflation, the cost in 2016 was updated to 2019 with the formula according to (Osmaleli 2013) and formulated as follows:

$$V_{2019} = V_{2016} (1+ i)^n$$

Where: V: value in respective year (IDR), i: interest rate (6.5%), n: amount of time (years)

The indirect value of mangrove forests as an abrasion barrier can be estimated using replacement costs or the cost of building breakwater structures (Marhayana et al. 2011; Anissa 2012; Samsul 2013). The cost for building a breakwater with a size of 70 cm x 300 cm x 150 cm with a durability of 10 years according to Fidyansari and Hastuty (2016) requires a fee of 1,272.38 IDR m^{-3}. For the length of 1 meter, the building uses 3 m^3 of the mixture of the construction material of the breakwater so that it costs 2,703,817 IDR m^{-3}. If the compound is updated to 2019, it becomes 12,145,884 IDR m^{-3}.

The formulation of the calculation of benefits as a carbon sink according to Prayogi et al. (2016) is multiplying the amount of carbon with the selling price of carbon. Where the carbon price is 7 USD ton^{-1}, if it is compounded to 2019, the carbon value will be 8.5 USD ton^{-1}.

Option use-value. The assessment of the benefits of choice refers to the biodiversity value of the mangrove ecosystem. The value used referred to Ruitenbeek (1992) in Bintuni Bay, West Irian, which is US $ 15/ha/year. This value is updated to 2019 to accommodate interest rate using the following formula (Osmaleli 2013):

$$V_{2019} = V_{1992} (1+ i)^n$$

Where: V: biodiversity value (IDR), i: interest rate (17%), n: amount of time (years)

The compound values that have been obtained need to be adjusted to the purchasing power and prices in the Mentawir Village so that the calculation results obtained are more accurate using the formula below:

$$NP = V \times M \times \text{Dollar Exchange}$$

Where: NP: total value of mangrove biodiversity in Mentawir Village in 2019, V: biodiversity value of mangrove ecosystems in Mentawir Village that has been compounded, M: Area of mangrove ecosystem (ha)

Existence use-value. Existence Use Value is the benefits felt by the community related to the existence of mangrove ecosystems. The calculation of economic valuation uses the contingent valuation method (CVM), which is the willingness to pay (WTP) to calculate the value of wood and willingness to accept (WTA) to calculate catches. If the WTP and WTA values are known, then the balance of the WTP and WTA can be calculated. According to Halkos and Galani (2013); Malik et al. (2015); Wahyuni et al. (2014); Widiastuti et al. (2016); Wuthiya (2016); Sina et al. (2017), value assessment of WTP for services provided by coastal ecosystems is usually done to provide value appreciation for the existence of coastal ecosystems such as mangroves, reefs coral, seagrass and fish resources (Rizal and Dewanti 2017). Therefore, Hanley and Spash (1993) state that WTP is a value of potential uses of natural resources and environmental services. According to Kristiningrum et al. (2019), CVM is a survey-based approach that involves developing a hypothetical market by directly asking an individual to state his or her willingness to pay (WTP) for the environmental services provided in a particular location and willingness to accept (WTA) as the compensation for any damages. In this research, Mitchell and Carson 1989; Turner and Pearce 1990; and Suprapto 2016, CVM were used for valuing mangrove ecosystem and it aims to assess the willingness to pay of communities for the mangrove ecosystem. The marginal willingness to pay was calculated by the differences in the coefficients between the two attribute levels. Households were asked about how much they would pay for a given service level, describing at which level they were willing to contribute to experience a transformation of something (Kamaludin et al. 2018). This study refers to the research of Kristiningrum et al. (2019) that the calculation of WTP and WTA was derived from the calculation of the total income from mangrove wood production and yields from fisheries catches. Where both form a point of intersection called the margin (balance). However, in this research, the approaching model with WTP of wood was assumed as the ability of the community to pay for natural and environmental services in mangrove conservation activities whose value is obtained from the mangrove wood. While the WTA of fish catch approach model is assumed as a willingness from the community to receive compensation (in the form of funds) derived from fisheries catches. The value of the margin (profit) from both the WTP and the WTA was made as to the balance value and calculated as follows:

$$AW = \frac{TW}{t}$$

Where: AW: average willingness, TW: total willingness at age t, t: age

$$MW = \frac{W_t - W_{t-1}}{T}$$

Where: MW: marginal willingness, Wt: total willingness at age t, Wt-1: total willingness at age t-1, T: time interval between each measurement age, both to pay and to accept (MWTP or MWTA) i.e Marginal willingness to pay (MWTP) from wood and marginal willingness to accept from a catch.

Total economic value. This value is the sum of all the values of direct, indirect, choice and existence. The formulations according to Price (2007) and Vo et al. (2012) are as follows:

$$NET = ML + MTL + NP + NE$$

Where: NET: Total economic value, ML: Direct use-value, MTL: Indirect use-value, NP: Option use-value, NE: existence use value

RESULTS AND DISCUSSION

Diversity of fauna species of mangrove ecosystems

The mangrove ecosystem in the Mentawir Village is part of the Balikpapan Bay mangrove ecosystem. In addition to the beauty of the natural scenery, the mangrove ecosystem in Mentawir Village has a rich biodiversity in the form of mangrove species. According to Kristiningrum et al. (2019), there are 12 species of mangroves in Mentawir Village, while according to Warsidi (2017) they found as many as 20 species of mangroves in Balikpapan Bay. These results are higher than the research by Oktawati and Sulistianto (2013) in Kariangau village, Balikpapan Municipality, which only found 4 species of mangroves. Besides biodiversity, it turns out that mangrove ecosystems also have a diversity of protected wildlife such as Bekantan (*Nasalis larvatus*), sea dolphins (*Orcaella brevirostris*), dugongs (*Dugong dugon*), green turtles (*Chelonia mydas*), and other exotic animals (Hutapea 2016). According to Lhota (2010), Balikpapan Bay and the surrounding mangrove forests have almost 300 species of birds including endangered species such as Storm storks (*Ciconia stormi*), vulnerable birds such as Tontong storks (*Leptoptilos javanicus*), and a small fish eagle (*Ichthyophaga humilis*) which is near threatened. Mammals that live in the area include various types of bats, squirrels, weasels, and otters, while the types of reptiles present also have some endangered species, namely the green turtle (*Chelonia mydas*).

Based on the identification, the species of fauna that exist in the mangrove ecosystem of Mentawir Village include 3 species of mammals, 1 species of reptile, 16 species of birds, 25 species of fish, 8 species of crustaceans, and 7 species of mollusks (Figure 2, 3, 4, 5, and 6). The species of mammals in the Mentawir mangrove ecosystem include *Nasalis larvatus, Macaca fascicularis,* and *Tupaia minor,* and the reptile species is *Cuora amboinensis* (Figure 2)**.**

According to Lhota (2010), Balikpapan Bay and the surrounding mangrove forests have almost 300 species of birds. Based on the research that we did in Mentawir, we identified 16 species of birds illustrated in Figure 3. Sari (2012) found as many as 12 species of birds, of which three overlapped with those in the mangrove ecosystem of Mentawir Village: *Haliastur indus, Egretta eulophotes*, and *Pelargopsis capensis* at Bina Ovivipari Semesta Company and its surroundings in West Kalimantan Province.

The 8 species of crustaceans found in the Mentawir mangrove ecosystem can be seen in Figure 4. The 25 species of fish found in the Mentawir mangrove ecosystem can be seen in Figure 5. There are also 7 different species of mollusks as shown in Figure 6.

The high diversity of mammal, reptile, avian, fish, and aquatic invertebrate species illustrates that the mangrove ecosystem of Mentawir Village has attracted a wide array of fauna species. It has been stated that mangrove habitats may harbor a wide range of animals such as birds, mammals, reptiles, fishes, and aquatic invertebrates. According to Zakaria and Rajpar (2015), the presence of a higher diversity of fauna could be due to the habitat's pristine condition (i.e., no disturbance), complex vegetation structure and composition, the availability and richness of food resources such as fish, mollusks and crustaceans, and low predation risk. The vegetation structure and composition, occurrence of mudflats, and richness of food resources are the major driving factors that influence the distribution and diversity of animals directly or indirectly. Vegetation heterogeneity, the abundance of food resources, and habitat diversity may increase avian richness and diversity, i.e. they provide suitable foraging and rearing grounds, and protection from harsh weather and predators.

The high number of fish species suggests that the mangrove ecosystem of Mentawir Village areas serves as a nursery ground for various juvenile fish communities. This area is likely rich in invertebrate assemblages such as crustaceans (crabs, prawns, and shrimps) and mollusks (*Nerita lineata, Cerithidea djadjariensis, Chicoreus capucinus, Crassostrea* spp, *Anadara granosa*, *Placuna placenta*, and *Telecopium telescopium*). In addition, the extensive root systems of mangroves create habitat heterogeneity and complexity (Correa and Oliveria 2008, Wang et al. 2008), offering suitable foraging sites for juvenile fish and protecting them from predators by reducing their visibility (Zakaria and Rajpar 2015). Habitat heterogeneity and complexity is a major factor that influences fauna diversity and distribution.

In addition to fish species, it turns out that birds also dominate the mangrove ecosystem of Mentawir Village. These bird species utilize the area to fulfill their daily requirements of habitat, water, food, and protection from predators and harsh weather. Therefore, the mangrove ecosystem must be protected in a sustainable way to protect its diverse aquatic and terrestrial fauna species for future generations.

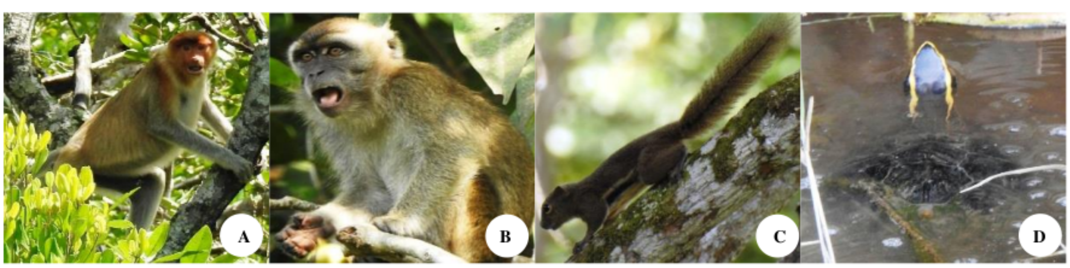

Figure 2. Species of mammals and reptiles in the Mentawir mangrove ecosystem, East Kalimantan, Indonesia. A. *Nasalis larvatus*; B. *Macaca fascicularis*; C. *Tupaia minor*; D. *Cuora amboinensis*

Figure 3. Species of Aves/birds in the mangrove ecosystem of Mentawir Village, East Kalimantan, Indonesia. A. *Lonchura fuscans* female; B. *Lonchura fuscans* male; C. *Dicaeum* sp.; D. *Todirhamphus sanctus*; E. *Haliastur indus*; F. *Passer montanus*; G. *Acridotheres javanicus*; H. *Rhipidura javanicus*; I. *Egretta eulophotes*; J. *Pycnonotus plumosus*; K. *Pycnonotus goiovier*; L. *Pelargopsis capensis*; M. *Dendrocopus canicapillus*; N. *Aplonis panayensis*; O. *Alcedo meninting*; P. *Streptopelia chinensis*

Figure 4. Species of crustaceans in the mangrove ecosystem of Mentawir Village, East Kalimantan, Indonesia. A. *Mysis relicta*, B. *Alpheus* sp., C. *Penaeus merguiensis*, D. *Penaeus monodon*, E. *Penaeus* spp., F. *Scylla serrata*, G. *Portunus pelagicus*, H. *Episeserma* sp.

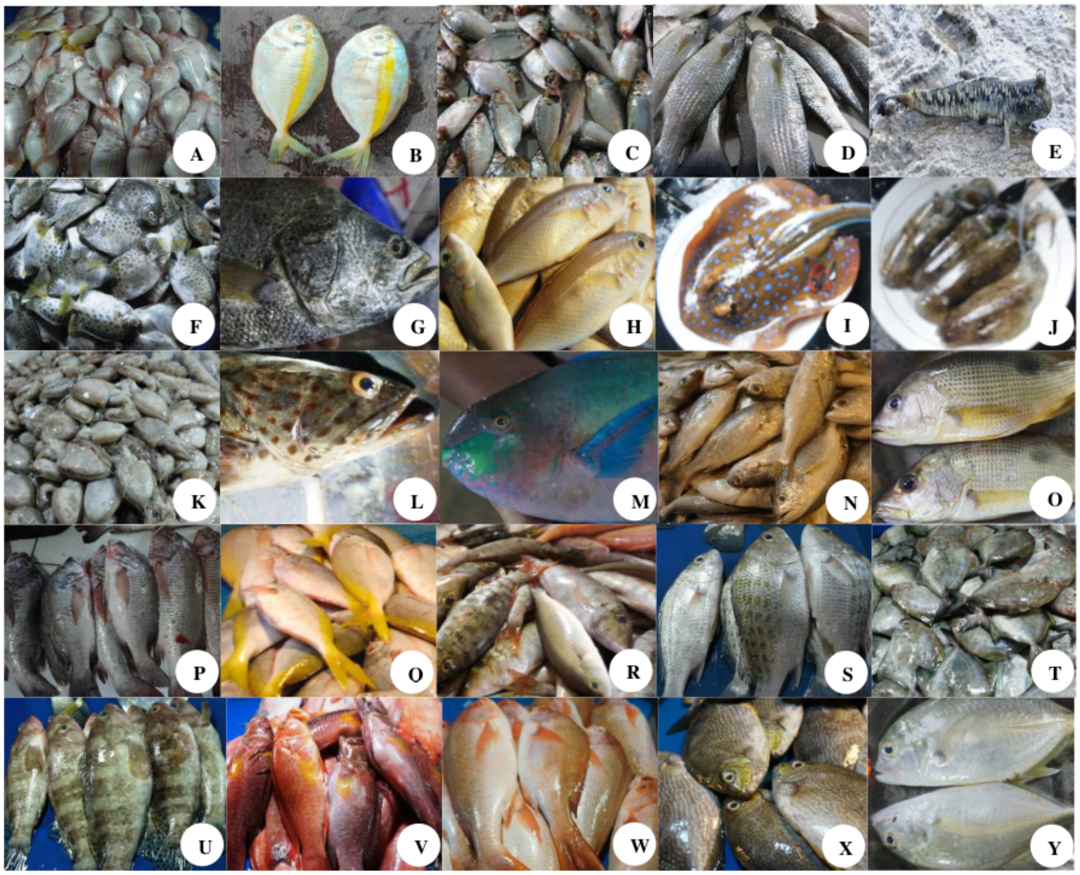

Figure 5. Species of fishes in the mangrove ecosystem of Mentawir Village, East Kalimantan, Indonesia. A. *Nemipterus* sp., B. *Selaroides leptolepis*, C. *Selaroides* sp., D. *Tade mullet*, E. *Periopthalmus sp*., F. *Scatophagidae*, G. *Micropterus salmoides*, H. *Nemipterus sp*., I. *Dasyatis sp*., J. *Cephalopoda sp*., K. *Sepiida*, L. *Epinephelus bleekeri*, M. *Labroide*, N. *Tenualosa ilisha*, O. *Lutjanus mahogoni*, P. *Lutjanus argentimaculatus*, Q. *Ocyurus chrysurus*, R. *Lutjanus griseus*, S. *Lates calcarifer*, T. *Parastromateus niger*, U. *Moluccan goatfish*, V. *Plectropomus maculatus*, W. *Plectropomus maculatus*, X. *Orange spotted spinefoot*, Y. *Caranx ignobilis*.

Figure 6. Species of molluscs fauna in the mangrove ecosystem of Mentawir Village, East Kalimantan, Indonesia. A. *Nerita lineata*, *B. Cerithidea djadjariensis*, *C. Chicoreus capucinus*, D. *Crassostrea* spp, E. *Anadara granosa*, F. *Placuna placenta*, G. *Telecopium telescopium*.

Identification of potential and types of utilization of mangrove ecosystems

The identification process was performed in order to discover the various types/forms of utilization of the mangrove ecosystems in the study location. This process was completed before the quantification or assessment of the benefits. Identification of direct use value was accomplished by asking the community to provide options related to various direct uses of the mangrove ecosystem. The types of direct use of mangrove ecosystems in various regions are usually different, so by providing options or a choice of answers, it is expected to help respondents to answer in accordance with individual knowledge related to the benefits derived from the existence of mangrove forest ecosystems in their area. The answer options or choices of the types of direct use of mangrove forests in Mentawir Village included wood resources, fisheries, tourist attractions, mangrove processed products, as well as other answer choices from respondents outside the options offered. Wood, shrimp, shellfish, mullet fish, crabs, mangrove syrup, sticky cake (*dodol*) from mangrove products, and mangrove powder were examples of direct use. However, the calculation of the direct use value of using mangroves only calculates the value of wood and fish. Indirect use value includes breakwaters, abrasion restraints, and carbon storage, as well as non-use value in the form of biodiversity. The different forms of utilization are evidence of the diversity of ecosystem benefits in each region.

Production potential of mangrove wood

The results of data collection on Plot 1 showed that there were 466 trees with ages ranged from 24 to 54 years, diameter ranged from 15 to 35 cm (average of 25 cm), and height ranged from 6 to 11 meters (average of 8.1 m). The maximum wood potential of mangroves was achieved at the age of 45 years with a total volume of 12.2 m^3 ha^{-1}, with a maximum increment of MAI and CAI respectively at 0.27 and 0.25 m^3 ha^{-1} yr^{-1}. Within the one hectare of Plot 1, there are 466 trees with a total volume of 102.1 m^3 ha^{-1} and MAI and CAI increments respectively at 2.51 and 3.45 m^3 ha^{-1} yr^{-1}. The results of analysis of wood production potential can be seen in Table 1.

The optimal mangrove increment is achieved at the age of 45 years when MAI reached the peak, and after the age of 45 years, the MAI increment has decreased from 0.27 to 0.25. This means that the timber cutting rotation for mangrove in Plot 1 is 45 years is followed by the biological cycle of the tree stand, in which the stand will be harvested when MAI is equal to CAI. The graphical relationship between MAI and CAI can be seen in Figure 7 below.

At Plot 2, the results of analysis showed that the maximum potential of mangroves was achieved at the age of 39 years with a total volume of 7.6 m^3 ha^{-1}, with a maximum increment of MAI and CAI respectively in of 0.20 and 0.21 m^3 ha^{-1} $year^{-1}$. In one hectare of Plot 2, there were 604 trees with a total volume of 62.9 m^3 ha^{-1} and the increment of MAI and CAI are respectively at 1.82 and 2.26 m^3 ha^{-1} $year^{-1}$. The results of the mangrove stand analysis in Plot 2 can be seen in Table 2.

As can be seen in Figure 8, the optimal mangrove increment is achieved at the age of 39 years when MAI reached the peak, and after this age, mangrove the MAI has decreased from 0.20 to 0.18. This means that the timber cutting rotation of mangrove at Plot 2 is 39 years.

According to Dinga (2014), Muliadi et al. (2017), Winarni et al. (2017) and Kristiningrum et al. (2019), the graphs in Figures 7 and 8 exhibit certain characteristics, as follow: CAI curve rapidly reached the peak and from there declined immediately, whereas the MAI curve climbed and declined slowly. From the graphical results in Figures 7 and 8, it was revealed that this was the beginning, MAI was lower than CAI, and CAI reached the peak preceding MAI. After reaching the peak, CAI declined and at a particular point intersected with MAI. At Plot 1, the intersection point of MAI and CAI occurred at the age of 48 years, while that of Plot 2 occurs at the age of 42 years.

After the intersection point, both MAI and CAI declined, indicating a decreasing trend in the volume increment. At Plot 1, the mean annual standing volume of increment of mangrove trees has reached the maximum at the age of 45 years, indicating that the maximum timber production potential has been attained and the tree was ready to be cut down. At plot 2, this occurs at the age of 39.

There is strong relationship between age and annual increment, either in the form of MAI and CAI. A simple linear regression test using polynomial trend shows the R^2 value is 98% for the relationship between age and MAI in Plots 1 and 2. For the relationship between age and CAI, the R^2 value is 87% and 86% for Plot 1 and Plot 2, respectively.

Mangrove in 1 hectare is respectively at 2.51 and 3.45 m^3 ha^{-1} yr^{-1}. This is in line with research conducted by Kristiningrum et al. (2019), that the highest growth increment of mangrove wood production was reached at the age of 42 years, and the highest value of MAI was 2.97 m^3 ha^{-1} yr^{-1}. This is supported by a simple linear regression test with the type of polynomial on MAI which has an R^2 of 98%. This value means that there is a close relationship between age and MAI increment of 98% and 2% influenced by other factors. Whereas the CAI has an R^2 of 87%. This value means that there is a close relationship between age and CAI increment of 87% and 13% influenced by other factors.

The results of data collection on plot two where the diameter of the log and also the height of the mangrove tree obtained indicate that the maximum potential of mangroves was achieved at the age of 39 years with a total volume of 7.6 m^3 ha^{-1}, with a maximum increment of MAI and CAI respectively in of 0.20 and 0.21 m^3 ha^{-1} $year^{-1}$. Where in 1 hectare there are 604 trees with a total volume of 62.9 m^3 ha^{-1} and the increment of MAI and CAI are respectively at 1.82 and 2.26 m^3 ha^{-1} $year^{-1}$. The results of the mangrove stand analysis in plot two can be seen in Table 2.

Table 1. Analysis of production potential of mangrove wood at Plot 1

No.	n	Age	d	h	f	TV	MAI	CAI
1	56	24	15	4.0	0.81	3.2	0.13	
2	50	27	17	4.5	0.80	4.1	0.15	0.29
3	50	30	19	5.0	0.77	5.5	0.18	0.46
4	48	33	21	5.5	0.76	6.9	0.21	0.50
5	48	36	23	6.0	0.73	8.7	0.24	0.59
6	48	39	25	6.5	0.66	10.1	0.26	0.46
7	44	42	27	7.0	0.65	11.5	0.27	0.45
8	**38**	**45**	**29**	**7.6**	**0.64**	**12.2**	**0.27**	**0.25**
9	32	48	31	8.5	0.63	12.9	0.27	0.24
10	28	51	33	9.7	0.58	13.5	0.26	0.18
11	24	54	35	10.3	0.57	13.5	0.25	0.03
Total	**466**					**102.1**	**2.51**	**3.45**

Note: n: number of trees (tree ha^{-1}), d: tree diameter (cm), h: branch tree height (m), f: tree form factor, TV: total volume (m^3 ha^{-1}), MAI: mean annual increment (m^3 ha^{-1} yr^{-1}), CAI: current annual increment (m^3 ha^{-1} yr^{-1})

Table 2. Analysis of production potential of mangrove wood at Plot 2

No.	n	Age	d	h	f	TV	MAI	CAI
1	110	18	11	2.2	0.83	1.9	0.11	
2	80	21	13	2.7	0.82	2.3	0.11	0.15
3	70	24	15	3.2	0.81	3.2	0.13	0.28
4	62	27	17	3.7	0.80	4.2	0.15	0.32
5	57	30	19	4.2	0.77	5.2	0.17	0.35
6	50	33	21	4.7	0.76	6.2	0.19	0.32
7	45	36	23	5.2	0.72	7.0	0.19	0.27
8	**40**	**39**	**25**	**5.8**	**0.67**	**7.6**	**0.20**	**0.21**
9	35	42	27	6.2	0.65	8.1	0.19	0.15
10	30	45	29	6.7	0.64	8.5	0.19	0.14
11	25	48	31	7.3	0.63	8.7	0.18	0.06
Total	**604**				**0.7**	**62.9**	**1.82**	**2.26**

Note: n: number of trees (tree ha^{-1}), d: tree diameter (cm), h: branch tree height (m), f: tee form factor, TV: total volume (m^3 ha^{-1}), MAI: mean annual increment (m^3 ha^{-1} yr^{-1}), CAI: current annual increment (m^3 ha^{-1} yr^{-1})

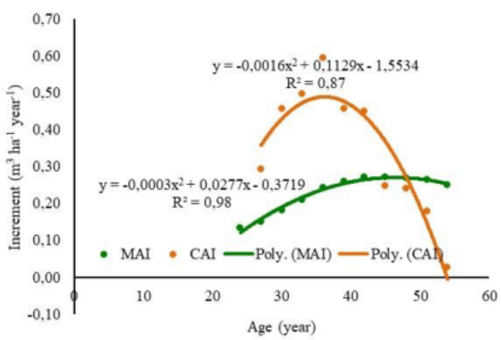

Figure 7. Standing volume increment of mangrove at Plot 1

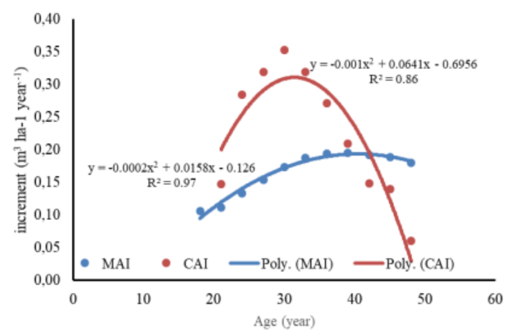

Figure 8. Standing volume increment of mangrove at Plot 2

Based on Table 2 it can be explained that in 1 hectare there are 604 mangrove trees in plot two with a diameter of mangrove at the age of 18 to 48 years of 11 to 31 cm with an average diameter of 21 cm. While the height is 2.2 to 7.3 meters with an average height of 4.7 m. With a total volume of 62.9 m^3 ha^{-1} and increment of 1.82 and 2.26 m^3 ha^{-1} yr^{-1}. The optimal mangrove increment is achieved at the age of 39 years. After the age of 39 years, mangrove increment has decreased from 0.20 to 0.18. This means that the timber cutting rotation is followed by the biological cycle of the tree stand, in which the stand will be harvested when MAI is equal to CAI. As for graphically, the relationship between MAI and CAI can be seen in Figure 8.

The intersection point of MAI and CAI occurred at the age of 42 years. After the intersection point, both MAI and CAI declined, indicating a decreasing trend in the volume increment. At the age of 42 years, the mean annual standing volume increment of mangrove tree has reached the maximum, indicating that the timber maximum production potential has been attained and the tree was ready to be cut down. Where MAI and CAI intersect at the values of 0.20 and 0.26 m^3 ha^{-1} yr^{-1}. While the total increment of MAI and CAI mangrove in 1 hectare are respectively at 1.82 and 2.26 m^3 ha^{-1} yr^{-1}. This is supported by a simple linear regression test with the type of polynomial on MAI which has an R^2 of 97%. This value means that there is a close relationship between age and MAI increment of 97% and 3% influenced by other factors. Whereas the CAI has an R^2 of 86%. This value means that there is a close relationship between age and CAI increment of 86% and 14% influenced by other factors.

Economic evaluation of mangrove ecosystems in Mentawir Village

After conducting the identification process, a valuation process or calculation of the economic value of the benefits of the mangrove ecosystem was performed to determine the value of the various benefits. Based on the results of the study, the economic valuation of the mangrove ecosystem in Mentawir Village is as follows:

Direct use value

Direct use value is the economic value obtained from the direct use of fishery resources, mangrove wood, and other products (Putranto et al. 2017). In this study, the total direct use value generated from mangrove wood for materials and fisheries was 198.375.000.000 IDR.

The par value of mangrove wood was calculated by multiplying the total volume of wood per ha by the timber selling price (i.e. 500,000 IDR.m^{-3}). In the Plot 1 and 2, the total volume of mangrove wood was 102.1 and 62.9 m^3ha^{-1}, respectively, resulted in the average value of mangrove wood of 94,875,000,000 IDR yr^{-1} with an area of 2,300 ha. The calculation of the economic value of timber products varies across regions. For example, research conducted by Putranto et al. (2017) in coastal islands of Central Sulawesi obtained an economic value of wood of 5,827,227,000 IDR yr^{-1} with an area of 107 Ha, Suzana et al. (2011) obtained an economic value of wood of 273,617,272 IDR yr^{-1}, Zen and Ulfah (2014) in the amount of 26,494,084,500 IDR yr^{-1}, Fidyansari and Hastuty (2016) in the amount of 1,325,000 IDR yr^{-1}, Widiastuti et al. (2016) in the amount of 14,219,879,920 IDR, Wahyuni et al. (2014) in the amount of 407,746,300,000 IDR.yr^{-1}, Suzana et al. (2011) in the amount of 10,888,218,123 IDR yr^{-1} ha^{-1}, Qodrina (2012) in the amount of 1,348,869,603 IDR yr^{-1} ha^{-1}, Nanlohy (2013) in the amount of 285,543,161 IDR.yr^{-1}, and Soukotta (2013) in the amount of 63.257.034 IDR yr^{-1}.

On the other hand, the par value of fishery products in the form of fish, crab, and shrimp both in plots 1 and 2 with an average selling price of fishery products was 36,000 IDR kg^{-1}, resulted in the par value average of fishery products of 103,500,000.000 IDR yr^{-1} with an area of 2,300 ha or equivalent to 90,000,000 IDR yr^{-1} ha^{-1}. The calculation of previous research conducted by Ariftia et al. (2014) showed the economic value of fishery products of 925,114 IDR yr^{-1} ha^{-1}, while Osmaleli (2013) was 32,654,428 IDR yr^{-1} ha^{-1}, Putranto et al. (2017) amounted to 141,537,809 IDR, Suzana et al. (2011) was 175,068,000 IDR.yr^{-1}, Zen and Ulfah (2014) were 26,637,368,680 IDR yr^{-1}, Fadhila et al. (2015) was 337,269,000 IDR, Prayogi et al. (2016) was 26,182 IDR billion.yr^{-1}, Fidyansari and Hastuty (2016) were 63,000,000 IDR yr^{-1}, Setyowati et al. (2016) was 1,390,787,140 IDR yr^{-1}, Widiastuti et al. (2016) was 150,148,781,610 IDR ha^{-1}, Putera and Sallata (2015) were 13,104,000,000 IDR, and Nanlohy (2013) was 16,362,912 IDR yr^{-1}. The difference can be caused by the amount of catch per year, market prices, and the condition of mangrove ecosystems in each region. This is also supported by Setiyowati et al. (2016) that the direct use value of mangroves is influenced by the price, volume and condition of each mangrove ecosystem

Indirect use value

Indirect use value at the study site was manifested as its value as a breakwater, abrasion restraints, and carbon storage. The calculation of the value of this benefit was performed using a replacement cost approach by calculating the costs required to build a breakwater and abrasion restraints, and the price of carbon market. The total indirect use value were 268,158,722,584 IDR

The replacement cost to build a breakwater and abrasion restraints referred to the Minister of Public Works Regulation Document No. 11/PRT/M/2013 concerning Guidelines for Analysis of the Price of Public Works in 2013 issued by the Public Works Research and Development Agency in 2013. Based on the analysis of the price of the work unit for a breakwater building with a length of 150 m, width 20 m, and height 5 m, the cost was 2,921,147,000 IDR or equivalent to 194,743 IDR m^{-1} (2016), which becomes 235,240 IDR m^{-1} if compounded to 2019. Assuming that for the construction of breakwater along the coastline in Mentawir Village, which is 8,083 m, covering an area of 2,300 ha with a durability of 20 years, a value of 38,028,881,407 IDR is obtained for 20 years or 1,901,444,070 IDR.yr^{-1}. The value of indirect benefits of the mangroves as an abrasion barrier is 218,549,528,110 IDR for 10 years. Our results differ with Osmaleli's (2013) research, who estimated the cost of breakwater construction was 1,010,000 IDR per year or 17,399.00 IDR.yr^{-1} ha^{-1}. Kurniawati and Pangaribowo (2017) estimated costs of 3,734,734 IDR.yr^{-1} ha^{-1}(2016) or 14,122,055 IDR yr^{-1}, Prayogi et al. (2016) 12,698,901,112 IDR ha^{-1}, and Fidyansari and Hastuty (2016) 2,784,931,510 IDR yr^{-1}. Widiastuti et al. (2016) estimated costs of 39,857,181,000 IDR ha^{-1}, Putera and Sallata (2015) 20,319,540,000 IDR, Wahyuni et al. (2014) 37,133,936,369 IDR.yr^{-1}, Nanlohy (2013) 261,968,211 IDR yr^{-1}, Soukotta (2013) 49,829,326 IDR yr^{-1}, and Zen and Ulfah (2014) 35,040,000,000 IDR yr^{-1}.

The indirect use value of mangroves as carbon sinks is 11,580,313,067 IDR, assuming a carbon price of 8.5 USD ton^{-1} covering 2,300 ha of mangroves. This is different from the study by Prayogi et al. (2016) who estimated 531,015,534 IDR for the mangrove area of 321 ha with an indirect use value of 268,084,583,762 IDR. The key factor in the calculation of this value is the extent of mangroves, the length of the coastline, and the value of foreign exchange. This is also supported by Setiyowati et al. (2016) that the indirect use value of mangroves is influenced by length of the coastline and foreign exchange.

Option value

The option value is was defined as benefits derived from biodiversity. According to Ruitenbeek (1992), biodiversity generated benefit of US $ 15 ha yr^{-1}. This was then applied to obtain a rough estimate of the value of the selected benefits at the study site. The technique for calculating biodiversity values at the study site was slightly different from other locations in general. Ruitenbeek (1992) only multiplied the value of the biodiversity benefit by the mangrove area in each area, whereas at the research location the calculation was updated by incorporating compound interest for actual values at the respective year (i.e. 2019).

Assuming the biodiversity value at the study location was 15 USD ha yr^{-1} in 1992, an exchange rate of 1 USD was 14,500 IDR, the current value was updated for 27 years (1992-2019) with a deposit interest rate of 17% $year^{-1}$, and an area of 2,300 ha mangrove. All these resulted a total biodiversity value in the mangrove ecosystems of

Mentawir Village of 34,690,085,038 IDR.yr^{-1}. This contrasts to research conducted by Putranto et al. (2017) who found a biodiversity value of 31,346,500 IDR.yr^{-1}, Suzana et al. (2011) 41,297,640 IDR.yr^{-1}, Zen and Ulfah (2014) 90,877,800 IDR.yr^{-1}, Fadhila et al. (2015) 8,885,338IDR yr^{-1}, Prayogi et al. (2016) 10,615,567,584 IDR yr^{-1}, Fidyansari and Hastuty (2016) 405,600 IDR.yr^{-1}, Setyowati et al. (2016) 911,640 IDR yr^{-1}, Widiastuti et al. (2016) 1,977,396,451 IDR yr^{-1}, Kurniawati and Pangaribowo (2017) 3,734,734 IDR ha^{-1}yr^{-1}, Wahyuni et al. (2014) 35,571,600,000 IDR, Nanlohy (2013) 1,703,065 IDR.yr^{-1}, Soukotta (2013) 1,319,787 IDR yr^{-1}, and Zen and Ulfa (2014) in the amount of 90,877,800 IDR yr^{-1}. What distinguishes this value calculation is the extent of mangroves and the foreign exchange as well as interest rate.

Existence value

The existence value of mangrove ecosystems was defined as willingness to pay (WTP) and willingness to accept (WTA) that represents someone concern to maintain the quality of the environment of the mangrove ecosystem. The approaching model of WTP of wood is assumed as the ability of the community to pay for natural and environmental services in mangrove conservation activities whose value is obtained from mangrove wood products. While the WTA model of fish catch is assumed to be the willingness of the community to receive "compensation" (compensation funds) derived from fish catches. This refers to research that has been done by Kristiningrum et al. (2019). The value of the margin (profit) from both WTPs and WTAs is made as to the balance value as set out in Tables 3 and 4.

Based on Table 3 above it can be explained that the WTPs from mangrove at Plot 1 is assumed to be the amount of community costs that must be spent to pay for natural/environmental services starting at the age of 24 to 54 years. This is to be consistent with the mangrove stand potential data (Table 1). The total WTPs to be paid from the year 24 to 54 ranged from 1.84 to 6.61 IDR million ha^{-1} with average WTP (AWTP) of 0.08 to 0.13 IDR million ha^{-1} year^{-1}. The optimal point of AWTP and MWTP is reached at the age of 45 years with the amount of costs that must be incurred at 0.13 IDR million ha^{-1} year^{-1}.

WTA is assumed as the amount of compensation funds received by the community due to natural/environmental services in the form of catches starting at the age of 24 to 54 years as per rationale above. The total WTA to be received from 24 to 54 years ranged from 4.03 to 7.36 IDR million ha $^{-1}$ with average WTA (AWTA) from 0.17 to 0.13 IDR million ha^{-1} yr^{-1}. The optimal point of AWTA and MWTA is reached at the age of 48 years with the amount of funds received amounting to 0.13 IDR million ha^{-1}yr^{-1}. The graphical explanation of the curves of WTP, WTA, and the margin balance can be seen in Figure 9.

Using the margin between WTP and WTA of 0.13 IDR million ha^{-1}yr^{-1} and assuming the total area of mangrove forests in Mentawir Area is 2,300 ha, then the total margin of WTP and WTA is 299 million IDR yr^{-1}. Using a simple linear regression to test the relationship between age and the marginal values resulted in determination coefficient (R^2) of 93% for WTP and 88% for WTA, meaning there is a close relationship between age and the marginal values.

Whereas the WTP and WTA balance margins at Plot 2 can be seen in Table 4.

The total WTPs to be paid starting from the year 18 to 48 ranged from 0.63 to 3.52 IDR million ha^{-1} with average WTP (AWTP) of 0.04 to 0.08 IDR million ha^{-1} yr^{-1}. The optimal point of AWTP and MWTP is reached at the age of 39 years with the amount of costs that must be incurred in the amount of 0.08 IDR million. ha^{-1} yr^{-1}. Whereas the total WTA to be received starting from the year 18 to 48 ranged from 1.84 to 3.93 IDR million ha^{-1} with average WTA (AWTA) of 0.08 to 0.10 IDR million ha^{-1}yr^{-1}. The optimal point of AWTA and MWTA in plot two is reached at the age of 39 years with the amount of funds received amounting to 0.08 IDR million ha^{-1} year^{-1} or equal to 184 million IDR million yr^{-1} if applied to the area of 2300 ha. The graphical explanation of the curves of WTP, WTA, and the margin balance can be seen in Figure 10.

Table 3. WTP of mangrove wood and WTA of fish catch at Plot 1

Year	TWTP (IDR million ha^{-1})	AWTP (IDR million ha^{-1}yr^{-1})	MWTP (IDR million ha^{-1}yr^{-1})	Year	TWTA (IDR million ha^{-1})	AWTA (IDR million ha^{-1}yr^{-1})	MWTA (IDR million ha^{-1}yr^{-1})
24	1.84	0.08		24	4.03	0.17	
27	2.64	0.10	0.27	27	4.10	0.15	0.03
30	3.37	0.11	0.24	30	4.25	0.14	0.05
36	4.60	0.13	0.19	36	4.73	0.13	0.10
39	5,07	0.13	0.16	39	5.07	0.13	0.11
42	5.46	0.13	0.13	42	5.46	0.13	0.13
45	5.85	0.13	0.13	45	5.85	0.13	0.13
48	6.24	0.13	0.08	48	6.24	0.13	0.16
51	6.47	0.13	0.04	51	6.71	0.13	0.22
54	6.61	0,12	0.03	54	7.36	0.14	0.31

Note: TWTP: total willingness to pay, AWTP: average willingness to pay, MWTP: marginal willingness to pay, TWTA: total willingness to accept, AWTA: average willingness to accept, MWTA: marginal willingness to accept

Table 4. WTP of mangrove wood and WTA of fish catch at Plot 2

Year	TWTP (IDR million ha^{-1})	AWTP (IDR million ha^{-1}yr^{-1})	MWTP (IDR million ha^{-1}yr^{-1})	Year	TWTA (IDR million ha^{-1})	AWTA (IDR million ha^{-1}yr^{-1})	MWTA (IDR million ha^{-1}yr^{-1})
18	0.63	0.04		18	1.84	0.10	
21	0.11	0.05	0.16	21	1.90	0.09	0.02
24	1.54	0.06	0.14	24	2.01	0.08	0.04
27	1.95	0.07	0.13	27	2.16	0.08	0.05
30	2.28	0.08	0.11	30	2.35	0.08	0.06
33	2.56	0.08	0.09	33	2.56	0.08	0.07
36	2.79	0.08	0.08	36	2.79	0.08	0.08
39	3.03	0.08	0.08	39	3.03	0.08	0.08
42	3.26	0.08	0.05	42	3.26	0.08	0.10
45	3.42	0.08	0.03	45	3.56	0.08	0.12
48	3.52	0.07	0.02	48	3.93	0.08	0.16

Note: TWTP: total willingness to pay, AWTP: average willingness to pay, MWTP: marginal willingness to pay, TWTA: total willingness to accept, AWTA: average willingness to accept, MWTA: marginal willingness to accept

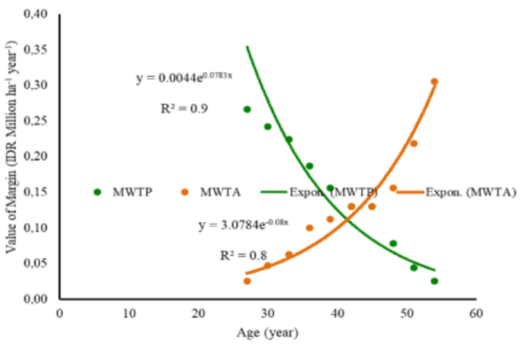

Figure 9. Balance margin between WTP of mangrove wood and WTA of fish catch at Plot 1

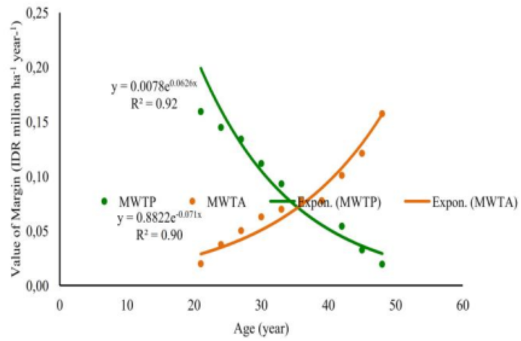

Figure 10. Margin balance between WTP of mangrove wood and WTA of fish catch at Plot 2

Table 5. Total economic value (TEV) of mangrove ecosystems in Mentawir Village

Type of value	Value (IDR)	Percentage
Direct use value	198,375,000,000	39.56
Indirect use value	268,158,722,584	53.48
Option value	34,690,085,038	6.92
Existence value	241,500,000	0.05
Total economiv value (TEV)	501,465,307,621	100

Linear regression to test the relationship between age and the marginal values resulted in determination coefficient (R^2) of 92% for WTP and 90% for WTA, meaning there is a close relationship between age and the marginal values.

So if taken the average of both Plot 1 and Plot 2, the value of the existence of 241,500,000 IDR ha $^{-1}$ yr^{-1}. A similar study was conducted by Setyowati et al. (2016) a WTP value of 5,652,958 IDR ha^{-1}yr^{-1}, Widiastuti et al. (2016) of 3,074,276,220 IDR, Kurniawati and Pangaribowo (2017) of 36,647 IDR ha^{-1}yr^{-1}. Indriyanti et al. (2015) 26,564 IDR ha^{-1}yr^{-1}, Wahyuni et al. (2014) 13,305,625,000 IDR ha^{-1}yr^{-1}, Nanlohy (2013) in the amount of 1,703,065 IDR ha^{-1}yr^{-1}, Soukotta (2013) in the amount of 2,730,000 IDR ha^{-1}yr^{-1}, whereas according to Kristiningrum et al. (2019) it ranges between 307,000,000 IDR ha^{-1}yr^{-1}.

Total economic value

Total economic value is the sum of the direct, indirect, option and existence value. The TEV of the mangrove ecosystem in Mentawir Village amounted to 501,391,168,800 IDR (Table 5) with the largest portion was contributed by indirect use value (53.47%), followed by direct use value (39.56%). The option value and existence value contributed only 6.92% and 0.05%, respectively.

The TEV above indicates that the mangrove ecosystem in the study location has a greater ecological value than its socioeconomic value. Similar results were also found in the research of Ariftia et al. (2014) and Indrayanti et al. (2015), while Hiariey (2009) and Osmaleli (2013) obtained the opposite result. There are differences in economic values that occur in similar research, partly due to changes in the exchange rate of the IDR against USD, differences in prices and characteristics, or characteristics of each mangrove forest area and the diversity of use by local communities. The value of mangrove resources illustrates its contribution to human welfare, especially in coastal communities, through economic development. This contribution should be balanced with an investment in the conservation of mangrove resources. The economic value of mangrove ecosystems can increase public investment in the form of knowledge of the intrinsic value of their natural resources. Knowledge of both values can be the basis of policymakers for managing natural resources so that their ecosystems are more protected and sustainable, and can continue to provide environmental services for the welfare of the community and the region.

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