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Article

Economic Valuation of Mangroves for Comparison with Commercial Aquaculture in South Sulawesi, Indonesia

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Abstract: Mangroves are recognized as a provider of a variety of products and essential ecosystem services that contribute significantly to the livelihood of local communities. However, over the past decades, mangroves in many tropical areas including the Takalar district, South Sulawesi have degraded and decreased mainly due to conversion to aquaculture. Currently, little is known about the economic benefits of commercialization of aquaculture as compared to those derived from mangroves in the form of products and services. Here, we estimate the Total Economic Value (TEV) of mangrove benefits in order to compare it with the benefit value of commercial aquaculture. Market prices, replacement costs, benefit transfer value and Cost-Benefit Analyses (CBA) have been used for value determination and comparison. The results show that the per year TEV of mangroves in the study area (Takalar district, South Sulawesi) was in the range of 4370 thousands USD (kUSD) to 10,597 kUSD or 4 kUSD to 8 kUSD per hectare (the highest value contribution derived from the indirect use value (94%)), whereas commercial aquaculture had a net benefit value of 228 kUSD or 3 kUSD per hectare. In addition, the comparison of Net Present Value (NPV) between the benefit value of mangroves and that of commercial aquaculture revealed that conversion of mangroves into commercial aquaculture was not economically beneficial when the analysis was expanded to cover the costs of environmental and forest rehabilitation.

Keywords: economic valuation; mangroves; commercial aquaculture; Indonesia; South Sulawesi

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1. Introduction

One of the crucial issues in development based on the use of natural resources is how to integrate economic development on the one hand with natural resources and environmental sustainability on the other in order to mitigate negative impacts and problems in the future [1]. In principle, development should take place by utilizing the natural resources optimally [2]. In many countries, development is considered inevitable as a way to improve the welfare of communities. Unfortunately, failure to take into account the costs and benefits of the use of natural resources, which leads to negligence in decision-making, is still common and currently we are facing an increasing scarcity of the resources necessary to support local livelihoods [3].

Mangroves, which are considered an important natural resource, occupy coastal and estuarine areas in many tropical places, provide goods and services for both direct use (e.g., timber, firewood, charcoal, Nypa palm leaves for crafting, wood chips, fisheries, food, medicines, material construction and tourism and recreational areas) and indirect use (e.g., coastline protection, prevention of seawater intrusion, provision of nursery and breeding grounds for fish, supply of nutrients for marine life, biodiversity maintenance and carbon sequestration) that have contributed significantly to community livelihoods [4].

Although mangroves provide a variety of products and services, they have been under great pressure due to decision making commonly based on assumptions of larger net benefits without considering the loss of wider mangrove services [5] and natural capital stocks [6]. Mangrove products and services are often undervalued [7,8] or even ignored in the economy and by industry and local inhabitants [9]. Consequently, nearly half of the total mangrove areas in the world have been lost over the past decades, with the largest areas of decline in Asia [10–12]. In Indonesia (which has the largest mangrove areas in the world), mangroves are threatened primarily by aquaculture but also by overharvesting of timber, firewood collection, charcoal production and conversion to other land uses such as agriculture, urbanization, mining and salt ponds [12–15]. Mangrove areas are characterized by some of the most rapid loss rates of coastal ecosystems in Indonesia; from 1980 to 2003, at least 1.1 million hectares of mangrove were lost, with 75% of these areas being converted to aquaculture ponds [12,16]. High economic revenues from the increase in exports and foreign trade in shrimp have become the main driving forces for the expansion of shrimp ponds by clearing mangroves [14]. In 2012, for instance, shrimp exports from Indonesia were valued at 1,304,149 thousands USD (kUSD), of which 38 percent went to the United States of America (USA), 29 percent to Japan, 9 percent to European countries and 24 percent to other countries [17]. In South Sulawesi, the value of shrimp exports in 2011 reached 42,407 kUSD [15]. Since the early 1990s, Indonesia has become one of the major shrimp producing and exporting countries in the world [18]. However, the expansion of shrimp export which mostly comes from aquaculture production has triggered a heated debate in Indonesia as well as in other exporting countries such as Thailand due to the significant consequences for coastal areas [19,20].

Evaluation of the value of mangrove products and services affected by shrimp pond expansion is therefore important as a vehicle to integrate both ecological perspectives and economic considerations [21]. Such an evaluation will support reliable instruments that can be used to shift focus towards a green economy and guide policy makers to make sustainable decisions about mangrove utilization [4,22]. In addition, it is one way to increase knowledge and awareness among stakeholders of the importance of the mangrove ecosystem for sustainable and environmentally friendly economic development [23].

Economic valuations of mangroves have been conducted in many areas of the world [9]. However, little attention has been paid in the scientific literature to an economic valuation of mangroves in areas threatened by commercial aquaculture development in Indonesia and other Asian countries and to the discussion of the economic benefits of aquaculture as compared to mangroves as a provider of a variety of products and environmental services. This paper aims to estimate the TEV of mangrove, including estimations of Direct Use Value (DUV), Indirect Use Value (IUV) and Option Value (OV), to enable a direct comparison with the benefit value of commercial aquaculture for a case study area in southern South Sulawesi, Indonesia using the CBA method. Given the threat of aquaculture expansion, information from such analyses is critical as the net benefit value generated from mangroves is currently not considered by policy makers dealing with sustainable management of mangroves.

2. Study Area

Takalar district is located in southern South Sulawesi, Indonesia (between latitude 5°12′–5°38′ and longitude 119°10′–119°39′, see Figure 1), 45 km from Makassar city (the capital of South Sulawesi). The district has a coastline of 74 km [24], occupied by mangroves, coral reefs, sea grass, sandy beaches, rocky beaches, estuaries, aquaculture ponds, rice fields and tourism and residential areas. Most areas of Takalar are plain and coastal areas (including small islands) with an altitude of 0 to 100 metres above sea level and the rest are hilly areas [25]. The district covers 566.51 km^2 and is divided into nine subdistricts (Galesong, South Galesong, North Galesong, Mangarabombang, Mappakasunggu, Pattalassang, South Polongbangkeng, North Polongbangkeng and Sanrobone). Mappakasunggu consists of a mainland part and small islands (Tanakeke, Lantangpeo, Bauluang, Satangnga and Dayang dayangan). The population is 272,316 and the population density is 481 persons per km^2. Mean temperatures vary from 23 °C to 33 °C and the monthly precipitation average over thepast eight years (2004 to 2011) has been between 174 mm and 712 mm; the greatest amount of precipitation occurred in 2008 from November to March [26].

The selected study area represents one of the hot spots of mangrove rich environments in Indonesia. However, the region is amongst the largest producers of aquaculture product in South Sulawesi [27] and mangrove forest has degraded and decreased in past decades, mainly due to the intensification of aquaculture. About 2593 hectares (77.4%) of the total mangrove forest area has been changed to aquaculture, mainly on Tanakeke Island and in Banyuanyara village. Currently, the total extent of intact mangrove forest is 1719 hectares and covers the subdistricts of Mappakasunggu, Mangarabombang, Pattallassang, Sanrobone, Galesong, South Galesong and North Galesong [15]. Mangroves in this region are dominated by saplings and seedlings and comprise 10 species (*Avicennia alba* Bl., *Bruguiera* *gymnorrhiza* (L) Lam., *Ceriops tagal* (Pers.) C.B.Rob., *Excoecaria agallocha* L., *Lumnitzera racemosa* Willd., *Nypa fruticans* Wurmb, *Rhizophora apiculata* Bl., *Rhizophora mucronata* Lam., *Rhizophora stylosa* Griff. and *Sonneratia alba* Sm.). The most dominant species has been *Rhizophora mucronata* Lam., followed by *Sonneratia alba* Sm. The Diameter at Breast High (DBH) of mangrove trees is between 6.37 cm and 23.57 cm and the diameter size classes of 10 to 15 cm are dominant, followed by 15 to 20 cm [28].

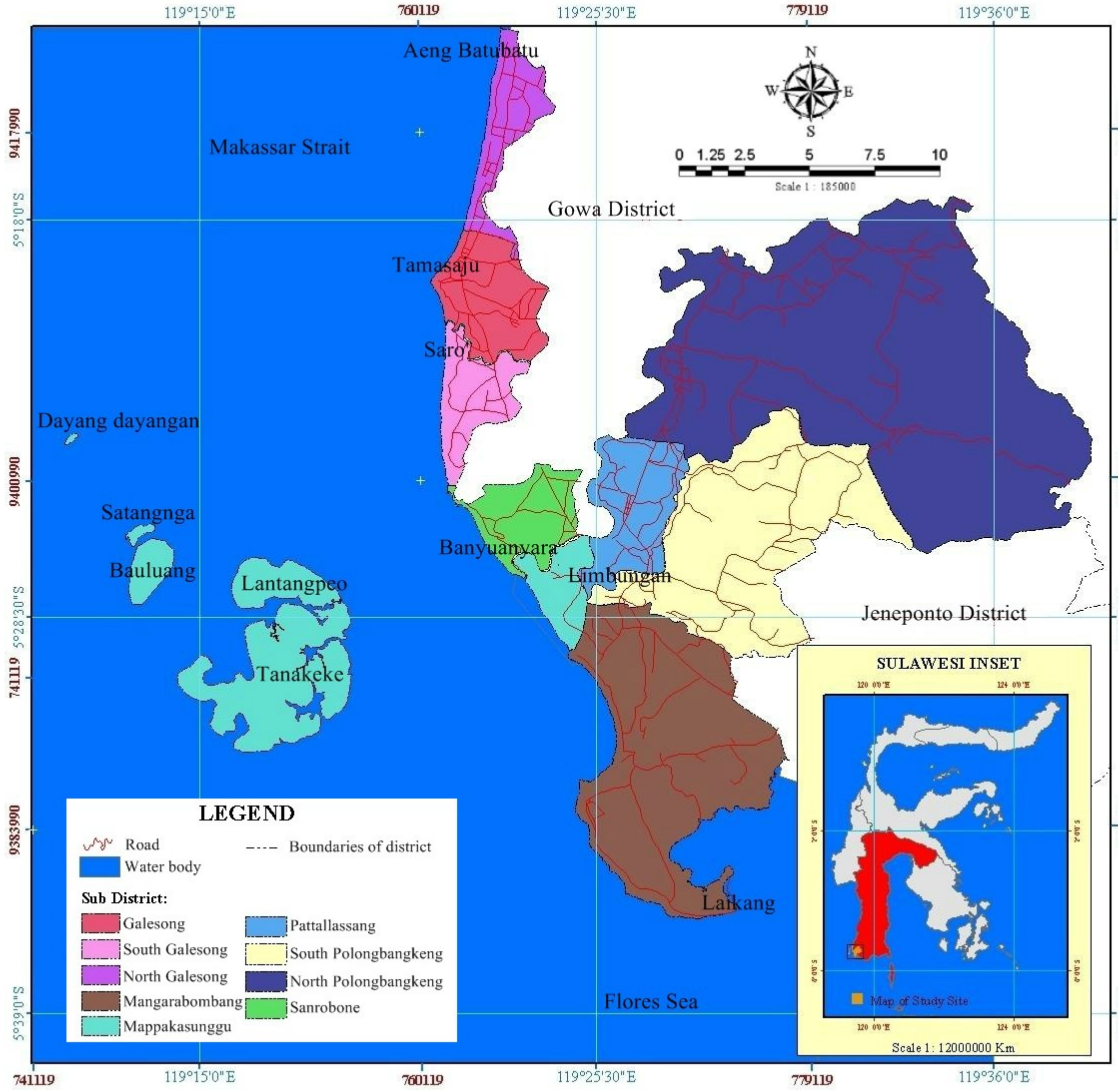

Figure 1. Map of the Takalar District Study Area, South Sulawesi, Indonesia.

3. Materials and Methods

3.1. Data Collection

Household Surveys

Data on direct use of mangrove products and aquaculture were produced from household surveys by use of questionnaires. The type of questions included in the survey related to age, number of dependents, education, livelihood and income, understanding of mangrove functions and benefits, details of the use of mangrove forests (e.g., frequency of use), the amount earned per utilization and the operation costs involved, the extent of aquaculture owned by farmers, cost of investment and production of aquaculture. Ninety-three households were selected by a Purposive Sampling method [29] and all households had a direct relation to, and dependence on, mangrove forests (fishermen, aquaculture farmers, firewood collectors, charcoal producers and Nypa palm crafters). The survey was conducted in ten areas covering the islands of Lantangpeo, Tanakeke, Bauluang and Satangnga (sub-district of Mappakasunggu), and the villages of Laikang (sub-district of Mangarabombang), Limbungan (sub-district of Pattallassang), Banyuanyara (sub-district of Sanrobone), Saro' (sub-district of South Galesong), Tamasaju (sub-district of Galesong) and Aeng Batubatu (sub-district of North Galesong) (Figure 1). The areas were selected based on the criteria that mangrove forests should be present and utilized by communities for fishery and forestry production.

3.2. Data Analysis

3.2.1. Economic Valuation of Mangrove

The TEV of mangroves was calculated from monetary values of the DUV, IUV and OV of mangroves [4,30,31], and TEV values are reported in percentage. The DUV of mangroves was derived from benefit values of fishery products (fish, crab and shrimp capture) and forestry products (firewood collection, charcoal production and Nypa palm crafting), which have been estimated using market prices [4,31] and the following formulas:

- Fish, crab and shrimp capture values (FV;CV; SV):

$$\text{FV; CV; SV} = \text{Production (kg/year)} \times \text{Price (USD/kg)} - \text{Production cost (USD)} \quad (1)$$

- Firewood value (FwV):

$$\begin{gathered}\text{FwV} = \text{Wood collection (bundle/year)} \times \text{Price (USD/bundle)} - \text{Production cost} \\ \text{(USD) (1 bundle = 100 stems with a length of 1 m and a diameter of 4 to 8 cm)}\end{gathered} \quad (2)$$

- Charcoal value (CcV):

$$\begin{gathered}\text{CcV} = \text{Production (sack/year)} \times \text{Price (USD/sack)} - \text{Production cost (USD)} \\ \text{(1 sack = 25kg)}\end{gathered} \quad (3)$$

- Nypa palm crafting value (NpcV):

$$\text{NpcV} = \text{Production (piece/year)} \times \text{Price (USD/piece)} - \text{Production cost (USD)} \quad (4)$$

The IUV of mangroves was derived from benefit values of mangrove services such as coastline protection, seawater intrusion prevention, provision of nursery grounds and carbon sequestration. These benefit values were estimated using replacement costs and benefit transfer methods [4,31]. The coastline protection service was estimated by the cost of breakwater construction over a 10-year project lifespan; the seawater intrusion prevention service was assessed by the cost of the water supply needs of people if the availability of fresh water was reduced due to mangrove loss; the provision of nursery grounds service was estimated by foregone benefit from fishery according to the KKP-Indonesia (Ministry of Marine and Fisheries of Indonesia) [32], who reported an average loss volume of fish catch in South

Sulawesi of 1211 tons per year during the period 2003 to 2011. The loss of 612 ha of mangrove in the same period is from Malik et al. [15]. Finally, carbon sequestration was estimated by using transferring rates of carbon storage of mangrove (100 to 200 tons C/ha) from Ong [33]. The price of carbon credits (USD 5.5/tCO_2) was based on Diaz *et al.* [34]. Calculation of IUV is conducted using the following formulas:

- Coastline prevention value (CPV)

$$\text{CPV} = \text{coastal length (m)} \times \text{cost of breakwater construction (USD)} \quad (5)$$

Coastal length = 74,000 m; the cost of breakwater construction has been reported to range between 158 USD/m^3 [35] and 875 USD/m^3 [36].

- Seawater intrusion prevention value (SwIPV)

$$\text{SwIPV} = \text{household population x number of water supply (gallon/day)} \times \text{Price (USD/gallon)} \times 365 \text{ days} \quad (6)$$

- Provision of nursery grounds value (PNGV)

$$\text{PNGV} = \text{loss volume of fish catch (kg/year) x fish price (USD/kg)/total loss of mangrove area during the period 2003–2011 (612 ha)} \quad (7)$$

- Carbon sequestration value (CSV)

$$\text{CSV} = \text{carbon sequestration rate (100 - 200 tonC/ha) x total area of mangrove (1719 ha)} \times \text{priceof carbon market(USD 5.5/ton}CO_2) \quad (8)$$

The OV of mangroves was calculated using the benefit transfer value method [4,23,31]. The benefit values of medicinal material from mangrove ecosystems was estimated by transferring the available valuefrom Sribianti [37], who studied East Luwu district, Indonesia. The annual benefit was 157 USD per hectare [37].

3.2.2. Commercial Aquaculture

The economic value of aquaculture (AV) was calculated using the following formulas:

$$\text{Total area of aquaculture (ha)} = \text{number of farmers (23 farmers)} \times \text{area of aquculture per farmer (3 ha)} \quad (9)$$

$$\text{Investment cost} = \text{cost construction (USD/ha)} + \text{farming equipment (USD/unit)} \times \text{total area of aquaculture (ha)} \quad (10)$$

$$\text{Production cost} = \text{fixed cost (e.g. equipment depreciation) (USD/unit)} + \text{variable cost (fry, feed, fertilizer, fuel, etc) (USD/unit)} \times \text{total area of aquaculture (ha)} \quad (11)$$

$$\text{Benefit of AV} = \text{production (kg/ha/year)} \times \text{price (USD/kg)} \times \text{total area of aquaculture (ha)} \quad (12)$$

$$\text{Net Benefit/year of AV} = \text{benefit of AV (USD/year)} - \text{(investment cost + production cost) (USD/year)} \quad (13)$$

$$\text{Net benefit/ha/year of AV} = \text{net benefit of AV (USD/year)/total area of aquaculture (ha)} \quad (14)$$

3.2.3. Cost-Benefit Analysis (CBA)

CBA was conducted to compare economic value of mangroves with commercial aquaculture, to assess whether converting mangrove forest into commercial aquaculture is economically feasible. CBA was used to determining the NPV of internal costs and benefits of commercial aquaculture. The project life span of aquaculture was found to be five years on average in the study area [15]. Several studies (e.g., [4,36,38,39]) have observed that shrimp production decreases successively after the fifth year due to the lower survival rate of shrimp. Hence, the production of shrimp over a 10-year project period also decreases by 5% to 20% and investment and production costs increase to sustain shrimp production [39]. However, aquaculture involves external costs including environmental cost (water pollution cost) related to the high salinity content of the water released from the ponds, agrochemical runoff and forest rehabilitation cost for land degradation [36]. Thus, CBA was required to also including the NPV of external cost. The value of environmental cost was adopted from Lan [40], who reported that the production of 360,000 tons of shrimps generates an environmental cost of 280 million USD (1 kg shrimp produced = USD 1.28), whereas the forest rehabilitation cost was estimated from seed provision, planting and maintenance costs [39]. The forest rehabilitation cost was estimated from year 6 to year 10.

Furthermore, CBA is required to determine the NPV of mangroves from fishery and forestry, medicines and mangrove services over a 10-year project period. This is done by using the cost and benefit values of each products and services based on an average age of the present mangrove (17 years) [28] and duration of exploitation of mangrove by local communities. Whereas, the exploitation of mangroves for fishery and forestry products has been ongoing during past several decades, the most intensive exploitation occured over the past 20 years [15]. A discount rate of 10% was used in the CBA reflecting the predominant cost of the loan interest rate at financial institutions when the survey was conducted [39,41]. The formula for calculating the NPV is as follows [31]:

$$\text{NPV} = \sum_{i=1}^{n} \frac{Bit - Cit}{(1+r)^t} \tag{15}$$

$$\text{NPV} = \sum_{i=1}^{n} \frac{(Bit + EBit) - (Cit - ECit)}{(1+r)^t} \tag{16}$$

where:

NPV = Net Present Value;

B = annual gross benefit; EB = annual extended benefit;

C = annual gross cost; EC = annual extended cost;

r = discount rate;

i = each benefit or cost;

t = period of time;

Criteria: NPV > 0: financially feasible; NPV = 0: impasse; and NPV < 0: not financially feasible.

$$\text{Environmental cost} = \text{shrimp production (kg/ha/year)} \times \text{USD } 1.28 \times \text{total area of shrimp ponds (ha)} \tag{17}$$

$$\text{Forest rehabilitation cost} = \text{seed provision cost (USD/ha)} + \text{planting cost (USD/ha)} + \text{maintenance cost (USD/ha)} \times \text{total area of aquaculture (ha)} \tag{18}$$

4. Results and Discussion

4.1. DUV of Mangroves

In past decades, people who lived around mangroves in this area were highly dependent on mangroves for various fishery and forestry products for domestic and commercial purposes. In fisheries, mangrove forests have benefits for the capture of fish, crab and shrimp as well as aquaculture, whereas in forestry, benefits related to the collection of firewood, charcoal production and Nypa palm leaf crafting are generated.

The results of the household survey showed that 43 households have been directly using mangroves for fish capture, six for crab capture, and six for shrimp capture. They are using traditional fishing gear such as fishing rods, fishing nets, fish/crab traps and scoop. Annually, fish capture is conducted during eight months (February to September), when sea conditions are good, whereas the remaining four months (October to January; characterized by high waves and strong winds) are used to rest, repair boats and fishing gear or engage in alternative work [15]. Eight households have been using mangrove for harvest firewood, three for charcoal production and four for Nypa palm leaf crafting. The production averages of fish, crab and shrimp capture per household per year are 2450 kg, 338 kg, and 213 kg, respectively. The production of firewood, charcoal and handcrafts such as roofs, walls, floor mats, baskets and especially hats from Nypa palm leaves per household per year amounted to 60 bundles, 720 sacks and 6750 pieces, respectively. The total of fish, crab and shrimp production was 105,350 kg/year, 2028 kg/year and 1278 kg/year, respectively. Harvested mangrove forests for firewood reached 480 bundles per year, charcoal production was 2160 sacks per year and handcrafting produced 27,000 pieces per year.

The highest benefit of DUV was obtained from fish production, earning 53 kUSD per year, followed by charcoal production for 9 kUSD per year. Thus, the total benefit of the DUV of mangrove ecosystem is 82 kUSD per year (Table 1).

Table 1. The Direct Use Value (DUV) of mangrove in the Takalar district, South Sulawesi, Indonesia.

No.	Products	Household users (n = 70)	Net use value (USD/year)	Net use value/household (USD/year)	Net use value (USD/ha/year)
			Fishery products		
1	Fish capture	43	52,511	1,221	31
2	Crab capture	6	6,531	1,088	4
3	Shrimp capture	6	2,822	470	2
	Sub Total of DUV		61,863		36
			Foresty products		
1	Firewood	8	3,379	422	2
2	Charcoal	3	8,809	2,936	5
3	Nypa palm crafting	4	7,804	1,951	5
	Sub Total DUV		19,992		12
	Total of DUV		81,855		48

Total area of mangrove = 1719 ha.

A large number and variety of fish species and other marine species use the mangroves for nursery, spawning and feeding grounds [42]. The main fish, shrimp and crab species available for fishery in the mangrove area include small pelagic fish, snapper (*lates calcarifer* Bloch), milkfish (*Chanos chanos* Forsskål), whiteleg shrimp (*Penaeus vannamei* Boone) and mud crab (*Scylla serrata* Forsskål). Furthermore, the harvest of mangroves for home consumption and firewood and charcoal for commercial use are mostly derived from *Rhizophora* sp., whereas leaves of *Nypa fruticans* Wurmb are used for handcrafts such as hats, floor mats, baskets, roofs and walls.

Even though fish capture is the dominant source of revenue for the local population and the highest generator of net benefit per year (53 kUSD), the highest net benefit value per household per year (3 kUSD) is derived from charcoal production. Over the last decades, clearing mangroves to expand shrimp ponds has been wide spread in this area, causing mangrove areas to decrease and degrade rapidly, which in turn has led to a decrease in fish production and fishermen's income [15].

4.2. IUV of Mangroves

Besides providing a variety of products, mangrove forest supports ecological services by protecting the coastline from exposure to waves, preventing seawater intrusion and providing nursery grounds and carbon sequestration [43]. Mazda *et al.* [44] stated that the stand of *Kandelia candel* (L.) Druce (six years old) can reduce waves with an offshore height of 1 m to 0.05 m when they reach the shore. Hajramurni [45] and Halim [46] revealed that abrasion and seawater intrusion occurred in several places in the region where mangroves are absent. Abrasion was found along the coast in six sub-districts of Takalar district (Mappakasunggu, Mangarabombang, Sanrobone, South Galesong, Galesong and North Galesong), reaching 20 to 100 metres per year over the past five years. Moreover, seawater intrusion into inland areas has made growth conditions difficult for local crops such as banana. Furthermore, Pirzan *et al.* [47] and Gunarto [48] found that 17 commercial fish species inhabit and use mangroves as nursery grounds in Lamuru Estuary, Bone district, South Sulawesi while 27 commercial fish species do so in the Tongke-tongke mangrove forest area and Sinjai district. In Selangor, Malaysia, Sasekumar *et al.* [49] noted that many species of fish (119) and prawn (9) inhabit and use mangroves as nursery and feeding grounds. In addition, Ong [33] reported that mangroves could store 100 to 200 ton C/ha above ground, whereas below ground carbon can reach 700 ton C/1 m soil thickness/ha (with an estimated carbon sink rate of 1.5 ton C/ha/year).

In this case study area, the net benefit values of these mangrove services have been estimated using the replacement cost and benefit transfer methods. Annual values of prevention of coastline erosion and seawater intrusion provided by mangroves were estimated to be in the range of 1192 kUSD to 6475 kUSD or 694 USD/ha to 3767 USD/ha and 476 kUSD or 277 USD/ha, respectively. Provision of nursery ground service was estimated to be 1403 kUSD or 2292 USD/ha. Furthermore, carbon sequestration services were estimated to be in the range of 945 kUSD to 1891 kUSD or 550 USD/ha to 1100 USD/ha. Thus, annually, the aggregate benefit of IUV mangroves was in the range of 4017 kUSD to 10,245 kUSD or 3813 USD/ha to 7436 USD/ha (Table 2).

Some studies have reported benefit values of such mangrove services, and Sathirathai and Barbier [36] estimated the cost of constructing breakwaters to prevent coastal erosion in Southern Thailand to be 3679 USD/ha. Samonte-Tan *et al.* [23] estimated the benefit value of preventing coastline erosion and supplying nursery grounds from mangroves in the Bohol Marine Triangle, Philippines to be 672 USD/ha/year and 243 USD/ha/year, respectively. Harahab [39] calculated the annual benefit value of preventing seawater intrusion in Probolinggo district, East Java to be USD 7 kUSD/ha/year. In addition, Salem and Mercer [50] stated the range of economic value of mangroves for coastal protection and carbon sequestration services is 10.45 to 8044 USD/ha/year and 39.89 to 4265 USD/ha/year, respectively.

Table 2. The Inderect Use Value (IUV) of mangrove in the Takalar district, South Sulawesi, Indonesia.

No.	Services	Use value (USD/year)	Use value (USD/ha/year)
1	Coastline protection	1,192,475–6,475,000	694–3,767
2	Seawater intrusion prevention	476,114	277
3	Provision of nursery grounds	1,402,775	2,292
4	Carbon sequestration	945,450–1,890,895	550–1,100
	Total of IUV	4,016,814–10,244,784	3,813–7,436

Total area of mangrove = 1719 ha.

4.3. OV of Mangroves

The option value (OV) of mangroves include the future potential use as a pharmaceutical resource [51]. Most mangrove plants have medicinal importance, such as *Avecennia* sp., *Bruguiera* sp., *Ceriops* sp., *Excoecaria* sp., *Rhizophora* sp., *Sonneratia* sp. and *Xylocarpus* sp. [52,53]. Frost [54] reported that communities living in mangrove areas in Indian Sundarban have used *Rhizophora* sp., *Excoecaria* sp. and *Bruguiera* sp. to treat angina, leprosy, and diarrhea and blood pressure, respectively. Jusoff and Taha [51] reported that the tree bark of *Rhizophora* sp. is commonly used to treat fractures, cure diarrhea and stop hemorrhages. In addition, Prakash and Sivakumar [52] stated that dried plant samples of *Excoecaria agallocha* L. prevent pathogenic bacteria. Mangroves are furthermore a rich source of steroids, triterpenes, saponins, flavonoids, alkaloids and tannins [53].

By transferring benefit values of medicine material of mangroves in East Luwu district Indonesia [37], the estimation of the annual benefit value of medicinal material in this area was 270 kUSD (mangrove extent of 1719 ha) or 157 USD per hectare (Table 3). However, over the past decades, mangroves in the study area have degraded, leading to depletion of their composition and diversity [28]. Nonetheless, the economic value of medicinal material in this area is quite high and many species commonly used for medicine are available, such as *Avicennia* sp., *Bruguiera* sp., *Ceriops* sp., *Excoecaria* sp., *Sonneratia* sp., and especially *Rhizophora* sp. [28].

Table 3. The Option Value (OV) of mangrove in the Takalar district, South Sulawesi, Indonesia.

No	Option value	Total use value (USD/year)	Total use value (USD/ha/year)
1	Medicines	269,883	157

4.4. TEV and Npv of Mangroves

On the basis of the sum values of the DUV, IUV and OV, the annual benefit of the TEV of mangroves varies between 4370 kUSD and 10,597 kUSD or 4 kUSD/ha and 8 kUSD/ha (Table 4). In addition, the NPVs per hectare for all three values (DUV, IUV and OV) of mangroves benefits (over a 10-year time period with a discount rate of 10%) were 271 USD (DUV), ranging between 13 kUSD and 34 kUSD (IUV), and 893 USD (OV), respectively (Table 5).

The largest benefit value of mangroves (94%) and the highest NPV were derived from the IUV, including the value of coastline protection, seawater intrusion prevention, nursery ground provision and carbon sequestration. The value of coastline protection services dominated the TEV of mangroves in the current study. This finding was similar to observations from Thailand as reported by Barbier *et al.* [8].

These results suggests the ecological functioning of mangroves has an important role in supporting local people's livelihoods [7]. Currently, there is a lack of awareness in local communities concerning the value of such benefits. People are driven by urgent needs and quickand real benefits that can be easily obtained by exploiting mangroves; they may tend to disregard the sustainability and the greater benefit value provided by this resource. In addition, the lower values of the DUV and OV as compared to the IUV suggest that the mangroves have been degraded and have decreased, thereby impacting fishery and forestry production.

Table 4. The Total Economic Value (TEV) of mangrove in the Takalar district, South Sulawesi, Indonesia.

No.	Economic use value	Use value (USD/year)	Use value (USD/ha/year)	%
1	DUV	81,885	48	2
2	IUV	4,106,814–10,244,784	3,813–7,436	94
3	OV	269,883	157	4
	TEV	4,368,582–10,596,552	4,018–7,641	100

Total area of mangrove = 1719 ha.

Table 5. The Net Present Value (NPV) of mangrove in the Takalar district, South Sulawesi, Indonesia.

NPV	DUV	IUV	OV
NPV (USD)	465,567	22,846,488–58,269,399	1,535,017
NPV (USD/ha)	271	13,291–33,897	893

Total area of mangrove = 1719 ha.

4.5. Benefit Value of Commercial Aquaculture and Comparison to Economic Value of Mangroves

Interviews of 23 aquaculture farmers revealed that aquaculture ponds in the study area have been constructed (to an average extent of 3 hectares) by clearing mangrove forests. The types of aquaculture ponds found were monoculture of shrimp (three ponds), monoculture of milkfish (three ponds), polyculture of shrimp and milkfish (nine ponds) and polyculture of milkfish and seaweed, mainly from *Gracilaria* Greville (eight ponds). The total investment cost, including construction costs and equipment, for all pond areas were 57 kUSD (average cost per pond is about 2488 USD). Meanwhile, the total production cost, including fixed costs (e.g., equipment depreciation costs and taxes) and variable costs (e.g., costs of labour, seed, feed, fertilizer, fuel) for all pond areas was about 43 kUSD (average per pond 1860 USD). Using two annual harvests, shrimp production generated on average 422 kg/ha/year, milkfish production was 6700 kg/ha/year, and seaweed production was 2862 kg/ha/year. The market prices of shrimp, milkfish and seaweed (*Gracilaria* Greville) were 5.79 USD/kg, 1.58 USD/kg and 0.42 USD/kg, respectively. Thus, annually the net benefit amounts to 228 kUSD or 3301 USD/ha and the NPV of the revenue of aquaculture ponds per hectare during the 10-year project period (with a discount rate of 10%) was estimated to be 1227 USD (Table 6).

This suggests that aquaculture is financially feasible and when compared to the NPV of the DUV and the OV of mangroves, the revenue is 4.5 and 1.4 times higher, respectively. However, when the comparison includes the NPV of the IUV of mangroves, the economic benefit value of mangroves providing environmental services (e.g., providing nursery grounds, protecting coastlines, preventing seawater intrusion, and carbon sequestration) were far higher (varies between 10.8 and 27.6 times) as also reported by Rönnbäck [7]. When the estimation of the NPV of aquaculture is extended to include external costs (costs of environmental and forest rehabilitation or social costs related to water pollution and loss of mangroves), the revenue of commercial aquaculture becomes negative (USD −663/ha) or is no longer economically beneficial (Table 6 and Figure 2).

In Indonesia, generally the expected levels of shrimp production are met during the first five years, after which production starts to decline and many shrimp farmers suffer from heavy economic losses, often leading to bankruptcy [55]. Consequently, many shrimp farms are abandoned as owners try to find new locations for farming [38]; a general pattern also observed in other Asian countries as reported by Bann [4] and Sathirathai and Barbier [36]. Abandoned shrimp ponds are exposed to abrasion and their transformation has limited value for other productive use such as agriculture, due to being very acidic and poor soil quality [36].

In summary, degraded and decreased areas of mangroves, water pollution caused by waste ponds and the loss of nursery, feeding and spawning grounds of marine organisms have become visible evidence of the environmental impacts of aquaculture development. If local environmental conditions are recoverable, the associated costs are very high and, therefore, the economic benefit value of commercial aquaculture in the long term becomes questionable, as also discussed by [56].

Table 6. Benefit value of commercial aquaculture in the Takalar district, South Sulawesi, Indonesia.

No	Description	Unit	Value
1	Investment	USD	57,216
2	Production cost	USD/year	42,800
3	Production		
	Shrimp	Kg/ha/year	422
	Milkfish	Kg/ha/year	6,700
	Seaweed (*Gracilaria* Greville)	Kg/ha/year	2,862
4	Market price		
	Shrimp	USD/Kg	5.79

Table 6. *Cont.*

No	Description	Unit	Value
4	Milkfish	USD/Kg	1.58
	Seaweed (*Gracilaria* Greville)	USD/Kg	0.42
5	Benefit of AV	USD/year	327,796
	Net benefit of AV	USD/year	227,780
	Net benefit/ha/year of AV	USD/ha/year	3,301
6	NPV without external cost:		
	NPV	USD	84,659
	NPV	USD/ha	1,227
7	NPV with external cost:		
	NPV	USD	−45,752
	NPV	USD/ha	−663

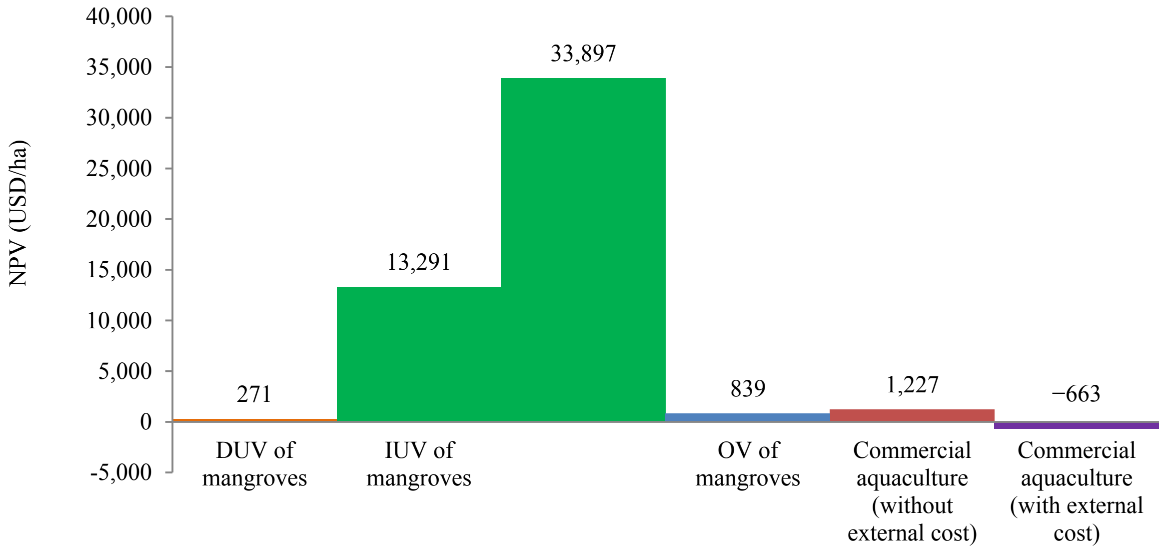

Figure 2. Comparison of the Net Present Value (NPV) of mangrove *versus* commercial aquaculture in the Takalar district, South Sulwesi, Indonesia.

5. Conclusions

This study has demonstrated that the economic benefit value of mangrove exceeds the economic benefit value of commercial aquaculture in the Takalar district, South Sulawesi, Indonesia. The highest contribution of the TEV (Total Economic Value) of mangroves was found to be derived from the IUV (Indirect Use Value) of mangroves (the benefit value of protecting the coastline, preventing seawater intrusion, acting as a nursery ground and for carbon sequestration). The conversion of mangroves into commercial aquaculture was found to have a higher beneficial value than the DUV (Direct Use Value; the benefit value of fisheries and forestry products) and OV (Option Value; benefit value of medicine) of mangroves and at a first glance seems to be financially viable. However, when the IUV of mangroves was included in the comparison, the value of mangroves was considerably higher. In addition, when the analysis of NPV (Net Present Value) was extended to include also the costs of environmental and forest rehabilitation, the revenue of aquaculture became negative and thereby no longer economically beneficial.

The comparison of mangrove and commercial aquaculture economic benefit values was essential in policy making targeting sustainable management of mangroves. The approach, as presented in this study, can be used to put monetary values on mangrove forest and aquaculture, including also the environmental costs related to aquaculture development; thereby, providing a balanced economic valuation of conversion of mangrove forest into aquaculture.

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Author Contributions

Abdul Malik led the design of the study, conducted the field work and data analysis used for the economic valuation and wrote the first draft of the paper, with subsequent improvements by the co-authors.

Conflicts of Interest

The authors declare no conflict of interest.

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