The externalities value of mangrove forest conversion into fishponds in the coastal area of wulan delta in demak regency

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Abstract. The high dynamic development in Wulan Delta coincides with the mangrove forest conversion into fishponds. The purpose of this research was to determine the externalities value of mangrove forest conversion into fishponds in Wulan Delta in Demak Regency. This research used a quantitative descriptive method. The data were collected through surveys using questionnaires and an interpretation of fishpond and mangrove forest use through Sentinel 2A on 2016 and 2018. The targets in this research were residents of Menco Hamlet and fishpond owners in Wulan Delta. The data were processed by calculating the economic value of the direct and indirect uses of mangrove forests as negative externalities, and fishpond production as positive externalities. The analysis was carried out in a descriptive-quantitative way by comparing the negative externalities value and the positive externalities value of mangrove forests conversion into fishponds. The results of this research show that the conversion of mangrove forests into fishponds indicates negative externalities. The negative externalities are indicated by fishpond productivity which is not able to surpass the mangrove forest use, even in terms of direct value only.

1. Introduction
Coastal areas are dynamic because they are transitional areas between land and sea [1]. Their positions in transitional areas make them regions with abundant natural resource potentials as well as big threats [2]. The abundant potentials of natural resources and the big threats originate from both the land and the sea. The big threats to coastal areas cause them sensitive to change. The dynamic nature of coastal areas is evident in their dynamic coastlines [3]. The coastlines may experience accretion or abrasion. A coastline is accreted due to a sedimentation process. An example of a coastal formation dominated by a sedimentation process is a delta [4]. A delta is a deposition formation in the coastal area located at the mouth of a river. A delta can be formed because the material transported by the river flow is deposited due to the weakening of the river energy and calm ocean waves [22]. Material deposits that accumulate for a long time can lead to accretion to the shoreline in such that a new land will be formed. One of the deltas with high dynamics is Wulan Delta.

Wulan Delta is a delta formed in the upper reaches of the Wulan River located in Wedung District, Demak Regency. The developments occurring in Delta Wulan coincides with the conversion of mangrove forests into fishponds. According to Fathurohmah and Marjuki [5], during the 1994-2010 period mangroves in the central part of Delta Wulan or in more inland areas were converted into fishponds. Furthermore, Marfai et al. [6] added that the mangrove area in Delta Wulan which was reduced due to conversion and ocean waves was 92.81 Ha. Conversion of mangrove forests into fishponds will result in externalities value, both positive and negative. The need to assess externalities due to the conversion of mangrove forests into fishponds is to compare the values of negative and positive externalities of a business [7] and facilitate the decision making [8]. A positive externality value that is higher than the negative externality value indicates that the profit gained is greater than the costs of environmental services impacts that should be paid [9].

2. Methods
The data in this study was collected through structured interviews and on-screen digitization. The structured interviews were conducted with residents in Menco Hamlet, Berahan Wetan Village, Wedung District, Demak Regency. The interviews were conducted with the residents of Menco Hamlet because the utilization of both mangroves and fishponds was controlled by them. The structured interviews were conducted by asking the benefits and direct and indirect benefits felt by the people from the existence of mangrove forests, the productivity of fishponds managed by the people, and the costs incurred for managing the fishponds. The on-screen digitization was conducted to determine the areas of mangrove forests and fishponds in Wulan Delta. The on-screen digitation used Sentinel 2 Imagery with the recordings of July 2016 and 2018. The imageries was used because of its 10-meter spatial resolution and its availability can be downloaded for free of charge (open data) via the USGS earth explorer page [23]. The choice of year the 2016 was due to the limitation of Sentinel 2 Imagery in recording the research location, while year 2018 was the latest recording that could be obtained in the same month.

The determination of the number of samples in the structured interviews was done with the Slovin method with an error level of 0.1. Based on calculations, from 1798 households in Menco Hamlet, a sample of 90 households was obtained with the proportionate sampling method. The proportionate sampling was done by dividing the sample population into sub-populations. Proportionate sampling was used to identify the heterogeneity of a population [10]. A population with many sub-populations would need many samples because they are more heterogeneous. The population in this sample was the households in Menco Hamlet, while the sub-populations are the households in some sub-hamlets in Menco Hamlet. In more detail, the distribution of samples determined using proportionate sampling can be found in Table 1.

Table 1. Distribution of samples determined with the proportionate sampling methods.

| Sub-hamlet | Households population | Samples |
|------------|-----------------------|---------|
| 5          | 279                   | 29      |
| 6          | 128                   | 13      |
| 7          | 95                    | 10      |
| 8          | 214                   | 22      |
| 9          | 160                   | 160     |

The results of the structured interviews of the direct and indirect benefits of mangrove forests were processed by conducting economic valuation with various approaches [11]. The resulting economic value was included in the negative externalities value. This was done because when there is a conversion of mangrove forests into fishponds, the direct and indirect benefits of mangrove forests will decrease. As for the results of the structured interviews of fishpond productivity and costs were included in the positive externalities value, because when there is a conversion of mangrove forests into fishponds the value will increase. An externalities value shows whether the consequences of the conversion of mangrove forests into fishponds are positive or negative. The variables and data in this study can be seen in Table 2.

Table 2. Research variables and data.

| Variable                  | Data                                      | Source of Data                         |
|---------------------------|-------------------------------------------|----------------------------------------|
| Mangrove and fishponds area | Mangrove and fishponds area of 2016 and 2018 | Primary (on-screen digitation)         |
| Positive externalities value | Fishpond production and productivity | Primary (structured interview)         |
| Negative externalities value | 1. Direct use of mangrove 2. Indirect use of mangrove | Primary (structured interview)         |

3. Results and Discussion

3.1. Mangrove forests into fishponds conversion

During the 2016 to 2018 period there was a conversion of mangrove forest into fishponds in Wulan Delta with an area of 65.09 ha. In percentage, the area of conversion is around 0.041% of the total delta area or 0.078% of the total mangrove forest in Wulan Delta in 2018. The conversion coincides with the accretion of Wulan Delta area from 1563.79 ha in 2016 to 1569.37 ha in 2018 with an addition of 5.59 ha. The conversion of mangrove forest into fishponds includes a smaller area compared to the extension of fishpond area for from 2016 to 2018. This was because the conversion into fishponds does not only
occur in mangrove forests, but also in vacant land and small rivers. The changes that occurred at Wulan Delta during the 2016 to 2018 period can be seen in detail in Table 3.

Table 3. The Changes in land use in Wulan Delta during the 2016 to 2018 period.

| Landuse        | 2016    | 2018    | Changes    |
|----------------|---------|---------|------------|
| Mangrove area (ha) | 894.73  | 829.64  | -65.09     |
| Pond area (ha)     | 517.92  | 583.16  | 65.23      |
| Vacant land (ha)   | 65.63   | 71.27   | 5.65       |
| Rivers (ha)        | 85.51   | 85.30   | -0.21      |
| Total (ha)         | 1563.79 | 1569.37 | 5.59       |

The distribution of the mangrove forests into fishponds conversion area in Wulan Delta can be seen in Figure 1b. It can be seen from this figure that the conversion happens more in the old Wulan River (north river) and the areas close to the mainland. This could be because the locations of fishponds that are closer to the mainland can save transportation costs and be easier to access. The widest mangrove fores-to-fishpond conversion area can be seen in Figure 1a. It includes an area of 2.07 ha located at the southern end of Wulan Delta in the upstream of a small river which is a branch of the new Wulan River (south river). The conversion in this area can be due to the accumulation of sediment which can facilitate the construction of embankment fishponds. In addition to facilitating the construction of fishpond embankments, a sedimentation accumulation can also provide nutrient supply for animals living in the fishponds [12].

Figure 1c shows the conversion occurring near a small river which is a branching from the old Wulan River and located close to the sea which is blocked by spit. The conversions that occur in this area is also supported by the conditions that occur in the area, namely the sedimentation supply that can be used to build fishpond embankments and be protected from direct ocean waves which can threaten
the sustainability of the fishponds [13]. The conversion in this area includes an area of 0.63 ha. The conversions that occur in Delta Wulan also tend to cluster into small areas. This type of conversion can be because individual fishpond owners make expansions to the existing fishponds in these areas. The conversion of this type can be seen in Figure 1d. The conversion seen in Figure 1e shows the conversion of mangroves caused by fishponds merging. This is indicated by the differences in the fishpond patterns in 2016 and 2018. In 2016, the fishponds in the area were separated from each other and consisted of approximately 3 fishponds, while in 2018 the pattern of the fishponds did not leave a visible trace and turned into a different pattern which includes a larger area. The extent of conversion of mangrove forests into fishponds in Wulan Delta during the 2016 to 2019 period was dominated by conversions with small areas of less than 0.20 ha per unit which constitute 48.6% of the total conversion area. The conversion area is dominated by small areas because there had been many fishponds in Wulan Delta and thus conversions with large areas are difficult to do. The frequency distribution of mangrove forest-to-fishpond conversion areas in Wulan Delta during the 2016 to 2018 period can be seen in Figure 2.

Figure 2. The frequency distribution of mangrove forest into fishpond conversion areas in Wulan Delta during the 2016 to 2018 period.

3.2. The Direct and Indirect Uses of Mangrove Forest

Mangrove forests have benefits both directly and indirectly to daily life. These benefits can be reduced or even lost when mangrove forests are converted. The direct and indirect benefits of mangrove forests can vary by region. This is because the direct benefits obtained and the indirect benefits felt by the people vary by region too.

3.2.1. Direct Uses

Based on the interviews with the residents of Menco Hamlet, the direct benefits obtained from the existence of mangrove forests in Wulan Delta are in the forms of wild-caught fish, shrimp, and crabs. The type of fish the local people obtain as the direct benefit of mangrove forests is Kempar Fish. This particular type of fish is usually caught by people when harvesting fishponds for those who have fishponds or caught in the river around the fishpond for those who do not. The average catch per hectare is around 2 kg per day. This type of fish is usually sold by people to be used as duck feed. The average price of Kempar Fish is IDR 150,000 per big bucket equivalent to 100 kg or IDR 1,500 per kg. Another direct benefit of mangrove forests is wild-caught shrimp. The shrimps can be caught daily by people in fishponds or rivers around the fishponds. The average catch of shrimp a day is 1.9 kg per hectare with a value of IDR 13,000 per kg. A direct benefit in the form of wild-caught crabs is also felt by the community. The type of crab caught by the population is Mangrove Crab. The crabs are usually caught by people in their habitats, namely around mangrove fishponds or rivers [14]. The average catch per day is 3.2 kg per hectare. These mangrove crabs are usually sold for IDR 110,000 per kg. The direct use value obtained per year per hectare in Wulan Delta can be seen in Table 4.

Table 4. The Direct use of mangrove forests.
3.2.2. Indirect use
The indirect benefits felt by Menco Hamlet people from the existence of mangrove forests in Wulan Delta include their function as breakwaters and natural food for fishpond farmers. According to UNEP [11] the indirect use of mangrove forests as perceived as breakwater is converted to use value through a shadow project. The shadow project used is the breakwater construction project located in Batang Regency which uses geotubes with 15-year building durability [15]. The project costs IDR 9,200,000,000. The details of calculations regarding the project can be found in Table 5. Another indirect benefit felt by the population from the existence of mangrove forests is natural food. Based on the interviews with local people it was revealed that each fishpond requires approximately 1 kg of feed per hectare per day at IDR 350,000 per 30 kg or IDR 11,666/kg. Therefore the indirect use value of animal feed obtained from Wulan Delta is IDR 4,258,090 per hectare per year.

Table 5. Geotube breakwater shadow project calculation

| Construction Length (m) | Construction Width (m) | Construction Height (m) | Construction Volume (m³) | Cost (IDR) |
|-------------------------|------------------------|-------------------------|--------------------------|------------|
| Geotube Construction project | 1,700                  | 4                       | 1.5                      | 9,200,000,000 |
| Breakwater Cost/m³ (IDR) |                        |                         | 10,200                   | 901,961    |

3.3. Pond Productivity and Costs
The fishponds cultivated in Wulan Delta are silvofishery ones. Silvofishery is fishpond farming that integrates fishpond business with the benefits obtained from mangrove ecosystems [16]. The types of aquaculture cultivated in Delta Wulan fishponds include Milkfish, Crab, Giant Tiger Prawn, and Vannamei Shrimp. All types of aquaculture are put together in the same fishpond, except for crabs that are given a fence with a net.

Table 6. Fishpond Productivity in Wulan Delta

| Types of Aquacultures | Productivity/ Harvest (kg/ha) | Selling Price/kg (IDR) | Income/Ha/ Harvest (IDR) | Harvest time (Days) | Productivity/ Year (kg/ha) | Income/Ha/ Year (IDR) |
|-----------------------|-------------------------------|------------------------|--------------------------|---------------------|---------------------------|-----------------------|
| Milkfish              | 277.65                        | 25,000                 | 6,941,250                | 120                 | 844.52                    | 21,112,969             |
| Crabs                 | 4.30                          | 130,000                | 559,000                  | 14                  | 112.11                    | 14,573,929             |
| Giant tiger prawn     | 28.71                         | 95,000                 | 2,727,450                | 90                  | 116.44                    | 11,061,325             |
| Vannamei shrimp       | 15.63                         | 55,000                 | 859,650                  | 60                  | 95.08                     | 5,229,538              |
| Total Income of fishponds/Ha/Year (IDR) |                     |                         |                          |                     |                           | 51,977,760             |

3.3.1. Pond productivity
Each type of aquaculture has a different level of productivity. This is due to the time of harvesting and the number of seedlings needed. The type of aquaculture that has the highest productivity is Milkfish with productivity of 844.52 kg/ha/year. Milkfish is harvested every 4 months. This high productivity is because milkfish is the main commodity of the fishpond farmers in Menco Hamlet. Milkfish is used as the main commodity because its production is relatively more stable relative to other aquacultures. Milkfish productivity is relatively stable due to its ability to adapt to less favorable environments, such as pesticide-contaminated environments [17] and tolerate a wide range salinities of water [18].

The productivity of crab cultivation in Wulan Delta fishponds is 258 kg/ha/year. On average, aquaculture crabs are harvested in 2 weeks. The acquired aquaculture crabs in a single harvest is around 4.3 kg per hectare of fishponds. Aquaculture crabs are usually separated with net dividers both from other aquaculture and other cultivated crabs of different ages. The price of aquaculture crabs is valued at IDR 130,000 per kilogram. There are 2 types of shrimp cultivated in fishponds on Wulan Delta, namely Udang Windu (Giant Tiger Prawn) and Vannamei Shrimp. Giant tiger prawn has a higher selling price than Vannamei Shrimp. The selling price of giant tiger prawn is IDR 95,000 per kg, while
Vanamei Shrimp is IDR 55,000 per kg. The harvesting times of Vanamei Shrimp and Giant Tiger Prawn are different. Vanamei shrimp take up to 2 months to harvest, while Windu Shrimp takes 3 months. The results of the fishpond productivity calculation can be seen in Table 6.

### 3.3.2. Fishpond Costs

Fishpond farming costs can be grouped into the initial costs of starting fishpond farming business and the operational costs. The initial cost of fishpond business is incurred only once, i.e. when building the fishpond. The costs for building a fishpond in Wulan Delta include the costs of purchasing equipment and paying labor. The costs incurred for purchasing equipment is IDR 2,000,000 which is used to buy water pumps and carpentry tools such as hammers, hoes, and sickles. The equipment can be broken, but based on the results of interviews they can be used for more than 3 years. The cost used to pay labor to build a fishpond is IDR 10,800,000 per hectare. These costs can be broken down into daily costs of IDR 50,000/day. Each farm takes 3 months to complete by using 3 workers on a 6 working day/week basis. Operational costs are the regular costs incurred for running a fishpond farming business. The operational costs consist of transportation cost, seedling purchasing cost, labor cost, sluice replacement cost, and net purchasing cost. These operational costs have different periodic time frames. The operational costs incurred for running fishpond farming can be seen in Table 7.

### Table 7. Fishpond operational costs in Wulan Delta

| Types of Operational Costs | Duration (days) | Cost (IDR) | Operational Costs/Year (IDR) |
|----------------------------|-----------------|------------|-----------------------------|
| Transportation/person      | 1               | 10,500     | 3,832,500                   |
| Milkfish                   | 120             | 130,000    | 243,333                     |
| Crab                       | 14              | 183,333    | 4,779,762                   |
| Giant tiger prawn          | 90              | 320,000    | 1,297,778                   |
| Vannamei shrimp            | 60              | 133,333    | 811,111                     |
| Labor/ha                   | 1               | 50,000     | 18,250,000                  |
| Sluice replacement/ha      | 365             | 2,750,000  | 2,750,000                   |
| Purchasing nets/ha         | 30              | 350,000    | 4,258,333                   |

### 3.4. Externalities Value

Externalities value consists of positive externalities and negative externalities values. A positive externality occurs when the impact caused by a business is positive, a negative externality occurs when the impact caused by a business is negative [9]. The positive externalities in the case of mangrove forest-to-fishpond conversion occur from the increase in the size of a fishpond area, whereas the negative externalities from the conversion of mangrove forests to fishponds occur from the reduction in the mangrove forests area. An increase in pond area is considered a positive externality because, with the conversion of mangrove forests into fishponds, the production and income from ponds can increase. Conversely, when there is a conversion of mangrove forests into fishponds, the reduced mangrove area is considered to have a negative impact because there is a loss or reduction in the mangrove use-value. The externality value of mangrove forest conversion into fishponds was calculated by subtracting the fishpond costs from the fishpond income, then the direct use value and the indirect use value of mangrove forests is subtracted from the calculation result. The result of all of these deductions show the externalities value obtained from the conversion of mangrove forests into fishponds in Wulan Delta from 2016 to 2018. The results of the externalities value calculation can be seen in Table 8. Based on the calculation results, it was found that the conversion of mangrove forests into fishponds caused a loss of IDR 134,374,886,856.

The loss of direct benefits from catching crabs due to conversion is quite substantial because wild crabs are quite easy to catch but can be sold at a relatively expensive price. Relative to the total fishpond income obtained, the loss of direct benefits from catching crabs is much higher. The externality value of the conversion of mangrove forests into fishponds in Wulan Delta during the 2016 to 2018 period indicates a negative externality. This negative externality occurs because the value of the positive impacts of mangrove forest-to-fishpond conversion is lower than the negative impacts it causes. Negative externalities can also occur from other efforts carried out by humans, such as corn farming [19] and rice-wheat farming [20]. The negative externalities value resulting from mangrove
forest-to-fishpond conversion need to be considered so that losses do not continue to occur. Policies from the local government are required to reduce the rate of mangrove forests into fishpond conversion. Among the policies that can be implemented is to set regulation on the minimum percentage of mangrove forest cover in the fishponds, as what is done by Perum Perhutani in Karawang Regency [21].

Table 8. The calculation results of the externalities value of mangrove forest-to-fishpond conversion in Wulan Delta during 2016-2018 period

| Fishpond income | Positive externalities | Negative externalities |
|-----------------|------------------------|-------------------------|
| Milkfish        | 21,112,969             | -10,800,000             |
| Crab            | 14,573,929             | -184,726,500            |
| Giant tiger prawn | 11,061,325             | -7,131,984              |
| Vannamei shrimp | 5,229,538              | -2,750,000              |
| Purchasing equipment | 5,229,538 | -5,258,333              |
| Labor for building fishpond | -1,095,000 | 4,258,333               |
| Transportation Purchasing seedlings | -7,131,984 | 9,252,750              |
| Labor Sluice replacement Purchasing net | -18,250,000 | -2,750,000              |
| Wild-caught fish Wild-caught shrimp Wild-caught crab | -1,095,000 | -2,750,000 |
| Breakwater Natural feed | -2,375,624,110 | -1,095,000 |

| Year/ha (IDR) | 2 Years/ha (IDR) | 2 Years (IDR) |
|---------------|------------------|---------------|
| Fishpond costs | Milkfish         | Crab          |
| 2,000,000     | 42,225,938       | 2,748,300,142 |
| 2,000,000     | 29,147,857       | 1,897,105,539 |
| 2,000,000     | 22,122,650       | 1,439,865,773 |
| 2,000,000     | 10,459,075       | 680,735,089   |
| 2,000,000     | -10,800,000      | -702,924,394  |
| 2,000,000     | -14,263,968      | -928,378,819  |
| 2,000,000     | -36,500,000      | -2,375,624,110|
| 2,000,000     | -5,500,000       | -357,970,756  |
| 2,000,000     | -8,516,667       | -554,312,292  |
| 2,000,000     | -2,190,000       | -142,537,447  |
| 2,000,000     | -18,505,500      | -1,204,441,424|
| 2,000,000     | -256,960,000     | -16,724,393,733|
| 2,000,000     | -554,280,617,3  |

Externalities Value: -134,374,886,856

4. Conclusions
The conversion of mangrove forests into fishponds at Wulan Delta during the 2016 to 2018 period occurred with an area of 65.09 ha. Most conversion areas are located near the old Wulan River. The conversion that occurred at Wulan Delta during this period was dominated by conversions with small areas of smaller than 0.2 ha per unit. The conversion of mangrove forests into fishponds has negative impacts as indicated by the occurrence of negative externalities. The value of negative externalities indicates the need for attention from the local government towards the conversion of mangrove forests into fishponds. One policy that can be made is to set a minimum percentage of mangrove trees in the fishponds managed by the residents.

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