The elasticity of mangrove ecosystem services in the Jor Bay, Indonesia

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Abstract. The mangrove ecosystem in Jor Bay is described as a socio-ecological system that has a multi-puidrose function and is related to ecosystem services. The concept of ecosystem services is based on the relationship between ecosystem quality and human well-being. But this relationship is complicated and we have a poor understanding of how the quality of mangrove ecosystems can affect human well-being, and how human well-being changes in response to increase or decline in ecosystem change. Therefore, an elasticity analysis is conducted to determine that linkage mechanism and simplify the complexities and context dependency of the ecosystem quality and human well-being relationship. The study was conducted in April-May 2018 in Jor Bay, East Lombok Regency, West Nusa Tenggara. The approach that was used in this research is an Elasticity Model. The results obtained are ecosystem services that are most widely used in Jor Bay, especially in non-direct extraction use. The general condition of ecosystem services in Teluk Jor is still in a suidrlus condition (using a capacity matrix, demand matrix and supply matrix). After mapping out the elasticity, it was found that the mangrove ecosystem in Jor Bay has a high positive elasticity.

Keyword: complexities, elasticity model, mangrove ecosystem services

1. Introduction

Jor Bay is located in Jerowaru Sub-district, North Lombok Regency, Nusa Tenggara Barat, Indonesia. This bay administratively is in between two villages namely Jerowaru and Paremas. It covers an area about 962.27 km square and possesses some small islands, of which, two of them are inhabited. There are three natural ecosystems in this bay such as coral reefs, seagrass, and mangroves. These ecosystems are managed by local wisdom named awig-awig. A responsible institution in maintaining these resources is called LPATJ (Lembaga Pemangku Awig-awig Teluk Jor).

Mangrove ecosystems in the bay are vast, covering about 73.5 ha and distributed in coastline areas starting from the edge of Paremas village to Jerowaru village. This ecosystem plays an important role in providing ecosystem services. An ecosystem service is a benefit that is derived for the human being from the ecosystem [1]. Millenium Ecological Assessment (MEA) [2] divides the ecosystem services into four forms, such as regulating, supporting, provisioning, and cultural services. A healthy ecosystem is characterized by its ability to support human interest sustainably [1]. Most of the local communities who are living in and around Jor Bay are fishermen. They rely on marine resources,
especially mangrove ecosystems and their nursery function as their main livelihood and income sources.

A concept of the elasticity mangrove ecosystem services refers to a positive relationship between the ecosystem quality and human welfare [3]. However, this relationship is complicated and often is not directly connected. Eventually, community welfare is more or less related to the quality and quantity of the ecosystem. The connectivity between ecological and social dimensions is ascertained by measuring the elasticity of the ecosystem services. The elasticity of ecosystem services is defined as a human well-being changes that resulted in the ecosystem stock changes [4].

Impacts of mangrove ecosystem quality changes on community welfare are to be able to direct on “elasticity” concept that reflects how to respond to a change of a certain variable to other variables. The elasticity of ecosystem services is established by social, ecological, historical and contextual factors [5]. Therefore, to understand the elasticity of mangrove ecosystem services, there needs interdisciplinary means that integrate the existing literature strengths regarding production, trade-offs, values of ecosystem services, and literature relating to community welfare and its relationship to the natural resources. The aim of this research was to measure the social-ecological linkage systems of mangroves in Jor Bay, North Lombok Regency through an elasticity approach of mangrove ecosystem services. By using the elasticity approach of mangrove ecosystems, it is expected to be able to set a proper management for mangrove ecosystems in the bay.

2. Methods

2.1. The scope of this research
Geographically, this research encompasses mangrove ecosystems in Jor Bay, East Lombok Regency which consisted of two villages Jerowaru and Paremas. The study area in this research was bordered by a designated area of the LPATJ as an awig-awig territorial that covered these two villages.

Ecologically, this bay has three coastal ecosystems namely mangrove, seagrass, and coral reefs. However, this research only would be focussed on a linkage of mangrove ecosystem towards fishermen welfare in the bay. The studied mangrove ecosystems are located in LPATJ territorial which started from the first vegetation and leading to the seashore until the last vegetation. Fieldwork of this research was carried out in Jor Bay, North Lombok Regency, Nusa Tenggara Barat, Indonesia. The research location included two villages, Jerowaru and Paremas. Of these villages, there are seven sub-villages that are directly adjoint with the bay namely four sub-villages in Jerowaru (Paton Bako, Telong Elong, Jor, and Tutuk) and three sub-villages in Paremas (Permas 1, Permas 2, and Keranji). Data sampling was taken during April to May 2018 as described in the map in figure 1 below.
2.2. Data Analysis

The elasticity of mangrove services was analyzed by calculating the magnitude of mangrove changes (positive and negative) on local community welfare. A flowchart of the ecosystem services elasticity (ES elasticity) and its relation with socio-ecological systems referred to the model of ES Elasticity [4] that is depicted in figure 2. A detailed explanation of each element is listed in table 1.

![Flowchart](image)

**Figure 2.** Flowchart of mangrove ecosystem services elasticity and its relation to socio-ecological systems.
Each component of the elastic chart above is described in detail in the following table 1.

| Element/multiplier | Explanation |
|--------------------|-------------|
| **Impact**         | Factor that affects mangrove ecosystem stock internally and externally |
| a. Mangrove Ecosystem Stocks | Condition, volume, diversity of mangrove ecosystem, natural capital including the supporting services |
| b. Goods           | Something physical or services that is used or valued by people |
| i. Valorization    | Process that determines a price to the community |
| c. Value           | Aggregated benefit from producing products, remains, and distribution |
| ii. Access         | Process that defines who is able to access goods and benefits |
| d. Share           | The receiving values of each person/group |
| iii. Needs, gaps, alternatives | Contextually determine what needs and aspirations can be supplied by the ecosystem |
| e. Well-being Contribution | An increase of welfare that is received by a person or group as a result of distributing their needs |

In the flowchart above and its described components, in general, the elasticity formula of ecosystem services (ES elasticity) is able to be defined as follows.

$$\text{ES elasticity (E_{c,a}) = E_{b,a} \times E_{c,b} \times E_{d,c} \times E_{e,d}}$$ (1)

Where:
- $E_{b,a} = \frac{\Delta b}{\Delta a}$
- $E_{b,a} =$ elasticity of component b towards a
- $\Delta b =$ component change of b
- $\Delta a =$ component change of a

In the context of this research, elasticity would be measured in each ecosystem services such as supplying service, regulating services, and cultural services. Description of each mentioned ecosystem is presented in the following formula.

$$\text{Total ES elasticity (ET) = Ep + Er +Ec}$$ (2)

Where:
- ET = Elasticity of total Ecosystem Services
- Ep = Elasticity of Provisioning Service
- Er = Elasticity of Regulating Service
- Ec = Elasticity of Cultural Service
The elasticity of the mangrove ecosystem is distinguished into two forms, positive and negative. The positive elasticity means that people’s welfare will increase when there is an increase in the quality and quantity of the ecosystem. Whilst the negative elasticity signifies that people’s welfare will decline when there is an escalation in the quantity and quality of the ecosystem. Positive elasticity is classified into two levels, high and low. A high elasticity indicates that people’s welfare will increase significantly when there is less increase in the quantity and quality of the ecosystem, and the negative elasticity points out the reverse.

An established framework in this research used a “cascade model” that was adopted from [4] aiming to clarify steps that generate ecosystem values conceptually. Values of the ecosystem were gathered from interviewing respondents, up to 70 people as users of the ecosystem services. Estimation of elasticity used a scale of 1 – 5, where value <3 means that the elasticity is low and ≥3 means the elasticity is high. The final result of this analysis would be a flowchart map with a “cascade model”.

3. Results and Discussion

Mangrove ecosystem services are well known for having positive contributions to local communities. However, a mechanism on how this ecosystem is able to increase the prosperity of the local people, and reversely, how the welfare capable to influence the ecosystem change is rare to be understood in a whole [6]. A lesser understanding of this relationship indicates the impacts, especially on communities with low welfare and are highly dependent on these ecosystems for food, amenities, and livelihoods [7,8].

A concept of elasticity has begun from economics that is used to calculate elasticity of price, income, and cross price. Elasticity is a percentage change measured in a certain variable that is resulted in one percent of change in other variables in a catteries paribus condition [9]. This concept was later adapted to be applied for ecosystem services.

In a glance, how the flowing of benefits from resource stocks lead to human prosperity is able to be explained through diagrams of resource stocks, goods/services, values, shares, and fishermen welfare. Each mentioned element is linked and has its own elasticity value. The elasticity of mangrove services is adjusted to analyze the three types of the ecosystem services such as supplying, regulating, and culture.

3.1. The elasticity of provisioning services

Provisioning services of mangrove ecosystems are utilized by local fishermen and communities around the Jor Bay for supplying shrimp, fish, mud crabs, and shells. Destructive uses of mangrove resources in this bay have almost never been found. This is due to the awig-awig regulation, where one of prohibition in this regulation is mangrove cutting. Fishing activities, such as collecting small shrimps (well known as rebon) and fish are taken in the surrounding mangrove ecosystem by using a scope net or a sare (local name). Collecting the crabs in the night is well known as “mobok”. Gleaning shells usually occurs in the afternoon during the low tide. The elasticity of provisioning services for mangrove ecosystem in the bay is able to be figured out diagrammatically in figure 3.
Fishermen who utilize the sare as their main fishing gear are mostly found in the Tutuk Sub-village with about 30 fishermen of the total 110 sare fishermen in this bay. The target species from this fishing gear are small shrimps and the bycatch are small fishes, respectively. This fishing gear is operated by 3-4 fishermen. The average catch of the small shrimp is in range of 5-10 kg per trip and by-catch is in range of 2-4 kg. The elasticity of the mangrove ecosystem towards the small shrimp and fish is categorized as a high elasticity. This is because the mangrove ecosystem stock is correlated positively with the small shrimps and fish amounts. A rise in the mangrove ecosystem stock is able to increase the total catch of the small shrimps and fish. Values of these commodities are divided into two aspects namely earnings and nutrition. Profit is a total revenue (in Indonesian Rupiah (Idr)) that is received by fisherman as income, while the nutrition is defined as a number of fishes (in Indonesian Rupiah (Idr)) which is used for their diet. The elasticity of these commodities towards income is classified as high elasticity due to an increase in fishing catch for the small shrimps and small fish automatically is going to escalate the fishermen incomes. However, the nutrition value has a low elasticity which is resulted by numerous factors including a low fish consumption that is under average level. This condition prompts most of the fish catch to be dropped to the fish collectors directly. The total of these two mentioned commodities is as much as Idr 1,701,150,000.00 /year. A detailed description of this value is listed in table 2.
Table 2. Total value of mangrove ecosystem as supplying services for small shrimps and fish commodities.

| Description                      | Unit      | Value      |
|----------------------------------|-----------|------------|
| Income in each trip (3 fishermen)| Rupiah    | 257,750    |
| Income for each person           | Rupiah    | 85,917     |
| Number of fishermen              | People    | 110        |
| Fishing days in a year           | days/year | 180        |
| Total value                      | Rupiah/year | 5,103,450,000 |

The share of the resources is related to the access and anyone who can utilize the values of the resources. There are four actors who get involved in organizing the small shrimps and fish commodities in this bay such as, fisherman in the bay, fisherman outside the bay, fish collectors (middleman), and shrimp paste processors. These actors possess a low elasticity except fisherman. This is due to the number of fishermen who go fishing as the commodity is fluctuating according to the seasons and catch. Fish collectors and shrimp paste processors have never been changed even when the catch was increasing. Contributing welfare, in this case, can be like incomes, where both fishermen and fish collectors have a low elasticity. It happens because they have alternative jobs as either fishing other resources or being farmers.

Trapping mud crab activities are mainly taken by the fishermen from Tutuk sub-village while other fishermen from outside of this bay also come in to trap the mud crabs. The value of this commodity only come up from income. Due to a higher price of this commodity that drives the local fishermen more interested to sell all their catch than to consume them. The total value of this commodity is predicted as much as Idr 2,227,500,000.00 / per year that is presented in table 3.

Table 3. Total values of supplying services for the mud crab commodity.

| Description                        | Unit         | Value       |
|------------------------------------|--------------|-------------|
| Average income                     | Rupiah/person/day | 137,500    |
| Number of pemobok                  | Person       | 90          |
| Day fishing in a year              | Day/year     | 180         |
| Total Value                        | Rupiah/year  | 2,227,500,000 |

The elasticities of mangrove ecosystem stocks against mud crab commodity and the mud crab commodity towards income are categorized as a high elasticity. But a low elasticity comes about a relationship between the value and the share. This occurs due to the skills required and special equipment needed to trap mud crabs. That is why only certain fishermen are able to do this activity. The contribution of welfare in trapping mud crab activities has a low elasticity in fishermen and fish collectors. A factor, namely an alternative job, influences the magnitude of elasticity which allows the fishermen to change their profession to others during offseason.

Gleaning shells is highly found to be taken up by women, especially during low tide and during dark moon. This activity is conducted in mangrove ecosystems and its surrounding areas. Similar to the small shrimp and fish commodity, the elasticity value of income is high and nutrition is low. This indicates that the local fishermen consume the sell as needed and the rest is sold to the fish collectors. The welfare elasticity of both fishermen and fish collectors in terms of shell commodity are low. One of infecting factors is the shell gleaning activities (otherwise known as madak) is only used as a sideline. The generated total value of this commodity exceeded IDR 3,681,814,500.00/year and its detail description are listed in table 4.
Table 4. The total value of providing services for shell commodity.

| Description                  | Unit                  | Value          |
|------------------------------|-----------------------|----------------|
| Average Income               | Rupiah/fisherman/day  | 60,125         |
| Number of pemadak fisherman  | Person                | 729            |
| Day fishing in a year         | Day/year              | 84             |
| Total value                  | Rupiah/year           | 3,681,814,000  |

3.2. Regulating services

The regulating services of mangrove ecosystems experienced by local fishermen and coastal communities, surrounding Jor Bay, consist of the barriers for seawater currents and high waves, absorbing carbons, producing oxygen, and preventing seawater intrusion. These four services were derived from the literature study and then verified using field interviews with the communities around the bay. The flow of the elasticity in this point is able to be illustrated in figure 4.

Figure 4. Elasticity flow of the regulating services in the mangrove ecosystem at Jor Bay.

High elasticity ( ); Low elasticity ( ); Prosperous family 1 and 2 (BKKBN Criteria) ( ); Prosperous family 3 and 3 (BKKBN Criteria) ( ).

The mangrove services for barriers of seawater currents and high waves are estimated through a replacement cost by establishing coastal wave breaks. This ecosystem can also restrain coastal abrasion through breaking the kinetic energy of seawater waves and diminish high tide extent in the coastline, as has been proven by a research of Suryana [10] in the north coast of Java Island in which coastal abrasion occurs relatively rarely in mangrove areas that are 100 meters wide. By this width, the high tide range will decrease by more than 60%. The costs of establishing and maintaining coastal wave break facilities in North Lombok Regency for one km is estimated at approximately Idr 9,000,000,000.00. This cost already includes expenses for the maintaining the facilities during 30 years of economic age. The total value of the mangrove ecosystem that functionates as coastal break, is as much as IDR 6,757,725,000.00 / year as described in table 5.
Table 5. The benefit of mangrove ecosystem that is functioning as coastal waves and currents break.

| Description                              | Unit   | Value             |
|------------------------------------------|--------|-------------------|
| Cost of establishing concrete buildings  | Idr/km | 9,000,000,000    |
| Coastline length                         | km     | 23.9              |
| Total Cost                               | Idr    | 215,100,000,000  |
| Economic Age                             | Year   | 30                |
| Decent profit                            | Idr/year | 12,368,250,000   |
| Total value of benefit                   | Idr    | 202,731,750,000  |
| Net value of benefit                     | Idr/year | 6,757,725,000    |

The second function of mangrove services is as a carbon storage. Mangrove forests are a type of coastal forest that possesses a function as carbon storage through photosynthesis, which is also known as sequestration. Contents of carbon storage in some trees of mangrove species are presumed to have a positive correlation with its tree size and increased in line with their age mounting. In terms of photosynthesis, mangrove tree absorbs CO₂ and H₂O by the support of the sun. These two elements are converted to become glucose, which is a source of energy for the plant, and generates H₂O and oxygen. The last two elements are important for other organisms in sustaining their life (respiration). By understanding this background, we have to be aware that forests are crucial needs for humans in absorbing the excess carbon in the atmosphere. Total generated carbon stock of mangroves in the Jor Bay is approximately 128 tons C/year. The carbon price in the European market in 2018 is nearly €15,00/tonC in the European Union Emission Trading Scheme (the euro exchange rate is Idr 16,183.00). Hence, total revenue for carbon stock benefits is about Idr 32,259,362.00/year and detail of this value is listed in table 6.

Table 6. The benefit of mangrove ecosystems as carbon storage.

| Description          | Unit                | Value     |
|----------------------|---------------------|-----------|
| Accumulating Rate    | tonC/Ha/year        | 1.74      |
| Mangrove Area        | Ha                  | 73.51     |
| Total Carbon         | TonC/year           | 128       |
| Carbon Price         | Idr/tonC            | 252,195   |
| Total Benefit        | Idr/year            | 32,259,362|

Furthermore, mangrove ecosystems producing oxygen is counted by using the potency of oxygen resulted in the ecosystem. The oxygen price, therefore, is assumed equal to the oxygen uses in the medical activities in Nusa Tenggara Barat Provinces which is approximately Idr 581,000/m³. An optimal production of oxygen in mangrove ecosystems is at 5 years of age. Potential oxygen in the research location was recorded at nearly 3.65 m³/ha/year and a mangrove area of 73.51 ha will yield the total of oxygen is approximately 268.28 m³/year. Accordingly, the total benefit value of mangroves as producing oxygen is about Idr 155,870,000.00 per year that has been detailed in table 7.
Table 7. Benefit value of mangrove ecosystem as producing oxygen.

| Description                | Unit          | Value  |
|----------------------------|---------------|--------|
| Potential Oxygen           | m³/ha/year    | 3.65   |
| Mangrove Area              | Ha            | 73.51  |
| Total Produced Oxygen      | m³/year       | 268.28 |
| Oxygen Price               | Idr/m³        | 581,000|
| Total Benefit              | Idr/year      | 155,870,812 |

Mangrove benefits in term of regulating services are to protect seawater intrusion. After planting and prohibiting mangrove cuts, the coastal communities will obtain benefits like an increasing abundance of fresh water in wells near to the seashore and an increase of rice field production in coastal areas around the Jor Bay, especially in Jor village. Mangrove ecosystem stocks have a high elasticity on protecting seawater intrusion. The higher the values of mangrove ecosystem stocks, the more benefits that will be generated for protecting seawater intrusion. The elasticity of this function is high which is composed of providing freshwater and increasing rice field production. The total value of this function is predicted to be as much as Idr 6,045,225,000.00 (table 8). This benefit is able to be received by the people who live in the surrounding bay that exhibit a relationship of elasticity between the value and the share is categorized as low. Lastly, share elasticity on the people’s welfare is classified as low. This condition is due to most of the people who live in the bay have other alternatives in gaining freshwater even though they are relatively far.

Table 8. Benefit value of mangrove ecosystem as protector of seawater intrusion.

| Description                        | Unit                      | Value                |
|------------------------------------|---------------------------|----------------------|
| Values of Providing freshwater     |                           |                      |
| Number of Household                | Household                 | 1,493                |
| Freshwater needs of each household | m³/household/year         | 1,095                |
| Total water needs                  | m³/year                   | 1,634,835            |
| Freshwater price                   | Idr/m³                    | 3,000                |
| Benefit value                      | Idr                       | 4,904,505,000        |
| Values of increasing rice field production |                   |                      |
| Rate of rice production            | ton/ha/year               | 1.5                  |
| Price of dried rice grain          | Idr/kg                    | 4,000                |
| Field rice area                    | Ha                        | 190.12               |
| Volume rate of rice production     | Ton/year                  | 258.18               |
| Benefit value                      | Idr                       | 1,140,720,000        |

3.3. Cultural services

The receiving cultural services by local people and fishermen in the Jor Bay become a shelter. Fishermen who capture fish around the mangrove areas utilize the mangrove trees as their shelter during waiting phases for their fishing gear that have been set. These fishermen prefer to stay a while in these ecosystems with reasonable motivation in saving fuel costs. Mangrove ecosystems towards shelter service has a high elasticity. The wider the mangrove ecosystems, the larger the shelter to be formed as well. However, this service has a low elasticity towards the fuel substitution cost, and the share. This condition is built by fishermen accessing mangroves for their shelters, have never been changed even though the substituting fuel cost is changing. The share of elasticity on the local people’s share is low. It is highly influenced by some alternative works except being fisherman. Overall elasticity of mangrove towards fishermen’s welfare is low as illustrated in figure 5.

The benefit value of cultural services as a shelter for fishermen was approached by calculating the fuel substituting cost and amenity values. The local fisherman can skimp fuel cost of an average of 1 liter/day. The total benefit of mangrove ecosystem as substituting cost of fuel is able to be
approximated to IDR 776,800,000.00 / year (table 8) and the receiving amenities value to IDR 972,000,000.00 / year (table 9).

### Table 9. Benefit value of mangrove ecosystem as a shelter for fishermen.

| Description                              | Unit   | Value       |
|------------------------------------------|--------|-------------|
| Fuel Needs                               | Liter  | 1           |
| Price of fuels                           | Idr/Liter | 8,000      |
| Day fishing                              | Day    | 300         |
| Number of fishermen                      | Person | 324         |
| Benefits in exchanging the fuels         | Idr/year | 777,600,000 |
| Other needs (coffee and cigarettes)      | Idr/day | 10,000      |
| Day fishing                              | Day    | 300         |
| Number of fishermen                      | Person | 324         |
| Benefits of amenities                    | Idr/year | 972,000,000 |
| Total Benefits                           | Idr/year | 1,749,000,000 |

**Figure 5.** Elasticity flow of cultural services in mangrove ecosystem in the Jor Bay. High elasticity ( ); Low elasticity ( ); Prosperous family 1 and 2 (BKKBN Criteria) ( ); Prosperous family 3 and 3 (BKKBN Criteria) ( ).

In terms of a conceptual framework of Millenium Ecosystem Assessment [2], humans are a part of an ecosystem that interacts dynamically. Human activities will result in changing the ecosystem which is contained therein biodiversity and then is going to influence human life itself, especially welfare aspects [11]. Not only do human activities affect ecosystem changes, but social, economic, and cultural factors play an important role also which are happened in the local, regional and global scales [12]. The communities’ life is indirectly influenced by various conditions such as demography, economy, social, technology, culture, and religion. These conditions will evoke a direct influence on people, for instance, land use, fertilizer use, harvest, and others. Furthermore, the direct effects are going to predispose communities’ life and ecosystem services [13].

The elasticity of ecosystem services depends on a linkage between the ecosystem condition and communities’ welfares. This linkage is applied in calculating the elasticity. The elasticity holds necessarily implications in the resource management and poverty alleviation [4]. The elasticity of
ecosystem services has been also exercised to understand human vulnerability on ecosystem change and critical factors for adaptation. It also relates to social, ecological, and historical aspects of natural resources. Hence, in understanding the elasticity process of ecosystem services requires interdisciplinary perspectives that integrate the existing literature, production, trade-off, and valuation of ecosystem services and their relationship to the welfare of communities.

In general, a linkage between ecosystem stocks and the availability of goods or services has a high elasticity. A process between these components is affected by the different biophysical processes that are happening in the mangrove ecosystems. However, after entering mechanism factors of market, access, and alternativeness, it will result in the decrease of elasticity. This signifies that elasticity of the resources becomes lower in a flow where there is a human factor.

The policy implications of studying the elasticity of ecosystem services rely on certain circumstances, especially if the elasticity either high or low (or even negative) and whether the ecosystem quality declines or increases [14]. A vulnerability can occur in ecosystems with high elasticity that leads to a decrease in the quality of the ecosystem or comes from multiplier change processes and decreasing elasticity. A benefit will be gained from higher elasticity conditions when an increase of ecosystem quality is still possible or where an intervention is able to escalate multiplier changes towards welfare [4].

4. Conclusion

Mangrove ecosystems in the Jor Bay are able to contribute in providing benefits for local people in three forms of services namely supplying, regulating, and cultural services. The supplying services consist of providing small shrimps and fish, mud crabs, and shells. Furthermore, the regulating services become a shelter for fishermen. Overall, this research infers that the regulating service possess a high elasticity, while the two other services are categorized in low elasticity.

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