

# Social-Ecological System in Seagrass Ecosystem Management at Kotania Bay Waters, Western Seram, Indonesia

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**Abstract.** The concept of the Social-Ecological System (SES) of the coastal region, can be found in the seagrass ecosystem in the Kotania Bay Waters. Seagrass ecosystem as one of the productive ecosystem is part of an ecological system that can influence and influenced social system, in this case by people living around the seagrass ecosystem. This aim to estimating the socio-ecological vulnerability system of the seagrass ecosystem in the Kotania Bay Waters, the Linkage Matrix is used (de Chazal et al., 2008). This linkage matrix was created to determine the perception and understanding of the community on the ecosystem services provided by the seagrass ecosystem through the appraisal of various stakeholders. The results show that social values are rooted in the public perception of ecosystem goods and services, which are rarely considered. The ecological and economic value of natural resources is increasingly being used to determine the priority areas in the planning and management of coastal areas. The social value that exists in natural resources is highly recognized in conservation.

## 1. Introduction

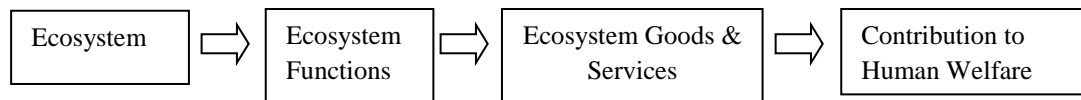
The study of seagrass ecosystem management can be said very little. In the national and international constellation, management of mangrove and coral reef ecosystems dominate the coastal and marine ecosystem management. Internationally, at least there is now MFF (Mangrove for the Future) and CTI (Coral Triangle Initiative) which became an icon of coastal and marine ecosystem management. As part of the vegetation, the primary function of seagrass is to absorb carbon to play a role in the carbon balancing process in the biosphere [1].

The function of ecosystem management is not only physical dimension to maintain the sustainability of coastal and marine resource system, but also has a social aspect. Because the existing social system in the coastal and marine areas (example coastal communities that have interacted dynamically with coastal and marine resources) is one of the elements to be considered in the management of coastal and marine ecosystems, including the management of seagrass ecosystems. Integration of ecosystem-based management by considering the dynamics of social systems in it, known as the Social-Ecological System Approach [2].

The concept of a model combining human systems and natural systems is also revealed by [3]. Communities rely heavily on natural systems, resulting in a continuous flow of ecosystem goods and services. The same as between the seagrass ecosystem and the people living nearby. The concept of ecosystem services has been proposed as a meaningful framework for natural resource management [4]. In management, to understand the importance of ecosystems in the economy and decision-making policy is to establish the relationship between what ecosystems (goods and services) provide and how individuals value them. Figure 1 shows this relationship with a simple model: the ecosystem and its



functions and processes provide output in the form of goods and services, resulting in benefits to the population which can then be measured as an increase in human welfare.



**Figure 1.** The relationship between ecosystem and human welfare [5].

The existence of the seagrass ecosystem in the waters of Kotania bay is currently decreasing extent [6]. With the reduced scope of the seagrass ecosystem, the services provided automatically also reduced. Whereas according to some research results on the seagrass ecosystem in the waters of Kotania bay, there are various services provided by the ecosystem (Table 1).

**Table 1.** Goods and services provided by the seagrass ecosystem in the Kotania Bay waters

Seagrass Ecosystem Services	Seagrass Ecosystem Goods
As a place of seaweed cultivation	35 species of seaweed, <i>Gracilaria</i> sp. and <i>Hypnea</i> sp. (more difficult to find).
As the habitat of some organisms	Nine species of sea cucumbers, only two species are economically important ( <i>Holothuria scabra</i> and <i>Stichopus variegatus</i> ). Whereas in 1984 there are four species of economically important. Six species of economically important mollusks ( <i>Anadara antiquate</i> , <i>Fragum fragum</i> , <i>Pinna</i> sp., <i>Modiolus modiolus</i> , <i>Strombus</i> sp., and <i>Tridacna</i> sp.). Abundance is diminishing. 99 species of fish, its existence is decreasing. Dugong ( <i>Dugong dugong</i> ) and penyu hijau ( <i>Chelonia mydas</i> ), the population continues to decline.

Source: [7]

Based on the above description, the sustainability status of seagrass ecosystem in Kotania bay waters is understood as a matter worthy to be studied in the framework of development and conservation of seagrass ecosystem. The management of seagrass ecosystems related to the status of seagrass ecosystems and coastal communities, whose lives depend on seagrass ecosystems and their interrelations, needs to be further investigated using the Social-Ecological System approach. So the research is aimed to estimate the socio-ecological vulnerability system of seagrass ecosystem in Kotania Bay waters, where the management of seagrass ecosystem with Matrix Method of Linkage based on ecosystem services will again influence the existence of seagrass ecosystem and also its community system.

## 2. Methodology

This study was conducted from May to July 2011, at Kotania Bay Waters, Western Seram, Maluku Province. Sampling sites were determined through PRA activity using community mapping approach that relates to resource uses on seagrass ecosystem by coastal communities. Participatory rural approach (PRA) is an approach has been written as “how to” guide stakeholders to employing participatory decision-making techniques for resource management in coastal zone [8]. Survey ecology and common method were used to collect data.

To know the perception and understanding of community on seagrass ecosystem, using the approach of Linkage Matrix [9]. The Linkage Matrix is an assessment method of SES vulnerability that is implicitly related to the evaluation of various stakeholders in the resolution of vulnerability estimates in the same or different places. Three steps must be taken namely:

1. Various ecosystem services are identified and assessed by different stakeholders.
2. A series of matrices are used to quantify sequentially related to social and ecology information. The matrices organize and integrate information from the initial change of the ecosystem to the determination of changes in ecosystem services.
3. The ecosystem traits underlying the delivery of ecosystem services are identified, followed by quantification and measurement of some intangible ecosystem services including the classification of the existence of ecosystem services.

To estimate the socio-ecological vulnerability system of the seagrass ecosystem, used five matrixes (ecosystem services matrix, descriptors matrix, ecosystem properties matrix, land-use attributes matrix and Utilization Attributes matrix) are transparent and flexible to classify and link social and ecological information so that they can be integrated. By combining the results of ecological surveys, land use and social surveys, matrix is filled with scores or values that describe the relationship between rows and columns. Scores or assessments show how stakeholder groups assess each ecosystem service and assessment form categorized in 3 simple values according to the Likert scale: (-) = negative, (0) = unimportant and (+) = positive. Information is based on interviews with individuals.

Explanation of scores used are as follows:

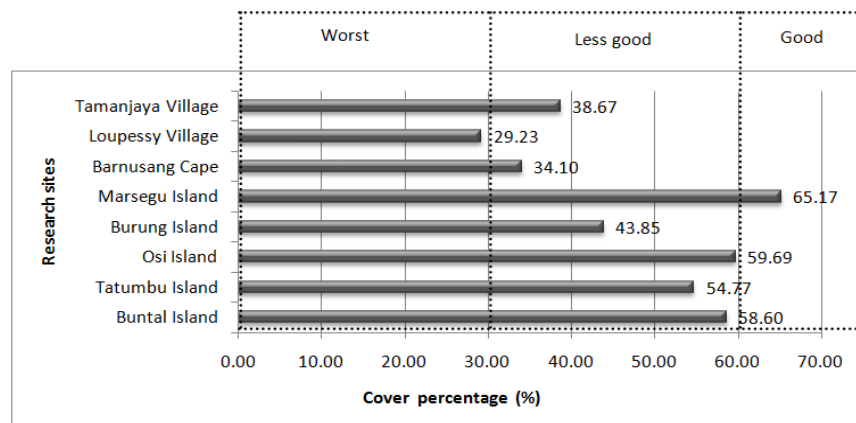
- A positive value (+) means stakeholders directly do the activity (gain/ benefit), others do activities that benefit stakeholders, or stakeholders have a positive assessment of ecosystem services.
- Zero (0) means that the stakeholder does not perform the activity and the activity does not have an impact on the assessed ecosystem services or the services of the ecosystem are considered unimportant.
- A negative value (-) means an activity or representation of a region is seen to have a negative effect on ecosystem services.

### 3. Results and Discussion

#### 3.1. Ecological system

The extent of seagrass beds in the waters of the Kotania bay is 823,615 ha, with the presence of 7 species of seagrass namely *Enhalus acoroides*, *Thalassia hemprichii*, and *Halophila ovalis* from Hydrocharitacea, and four species of *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodule pinifolia*, and *Syringodium isoetifolium* from Cymodoceaceae [10]. In Indonesia found as many as 13 species of seagrass. The spread of seagrass species at the study sites varied. Five species can be found starting from Buntal Island, Tatumbu Island, Osi Island, Burung Island, Marsegu Island to Barnusang cape. Six species are found only in Loupessy village, while seven species of seagrasses are found in Tamanjaya village.

Average cover percentage of seagrass in Kotania Bay waters can be seen in Figure 2, generally of 50.59%, with a range of 29.23% (in Loupessy village) up to 65.17% (on Marsegu Island). The percentage distribution of high seagrass cover is likely to be in open water area of Marsegu Island rather than the area that is in the bay waters that jutted into/mainland. Based on the above-mentioned seagrass status, the seagrass status conditions in the Kotania Bay Waters are in less good or less healthy condition. The conditions of seagrass beds on Marsegu Island are still in good or healthy condition, and seagrasses in Loupessy village are in worst shape.



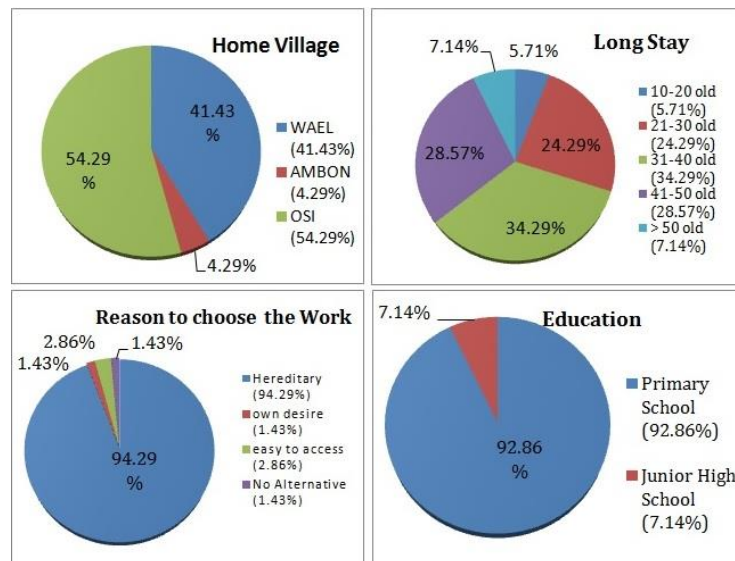
**Figure 2.** Average Cover Percentage of Seagrass Based on Research Sites and Status according to State Minister of Environment in Decision no. 200 in 2004

### 3.2. Social system

Coastal communities located in the three research sites (Osi Island village, Buntal island and Wael village) are from Buton/Southeast Sulawesi who has lived there for many years, and the majority are Muslim. They have mixed livelihoods according to season conditions for a year. The reasons for the selection of these three locations because the coastal communities have a major work that takes place on the seagrass ecosystem. The 70 respondents were selected in Wael village (27 people), Osi Island village (41 people) and Buntal Island (2 persons). Utilization of damaging coastal resources is still often done by people who are in the Kotania bay, to meet the needs of his life such as fishing activities using explosives (bombs) and ornamental fishing with potassium and coral collection activities for sale as building material (PRA results). Coral sales conducted by the community at a price of IDR 150 thousand /m<sup>3</sup>.

The livelihoods of coastal communities (fishermen) in the Kotania Bay are distinguished using fishing gear used to utilize marine organism in the seagrass ecosystem, such as gill nets, set net, trap, handline fishing and "bameti". Based on the result of research, the dominant livelihood is handline fishing (47,24%) followed by bameti (27,15%), gill net (13,47%), set net and trap (12.14%). The catch on the seagrass ecosystem in the form of economically important fish. Various utilization activities are undertaken by fishermen located in coastal areas of the Kotania Bay, to meet their living needs. On the seagrass ecosystem operates several fishing gears that are used by local fishermen to catch the organism to fulfill their life needs, such as gillnet, set net, trap, handline fishing and "bameti". These utilization activities are activities undertaken by the community, which utilizes the services that providers of the seagrass ecosystem, evident by the average revenue per year from fishing operations (gillnet, set net and trap) received by the community of IDR. 30-44 million.

Communities inhabiting the coastal of Kotania Bay mostly have livelihoods as fishermen because they have been hereditary (94.29%), not for their desires, easy to access or no alternative (Figure 3). Fishermen who move on this seagrass ecosystem mostly come from Osi Island village (54.29%), followed by Wael Village (41.43%) and Ambon Island (4.29%). They have settled for (31-40) years at the study site (34.29%). Fishermen education on the coastal of Kotania Bay is mostly only at Primary School (92.86%).



**Figure 3.** Characteristics of fisherman at research sites

### 3.3. Linkage Matrix

Social-Ecological System concept located in the coastal area can be found in the seagrass ecosystem in the waters of Kotania Bay. Seagrass ecosystem as one of the productive ecosystem is part of an ecological system that can influence and changed social system, in this case by the people living around the seagrass ecosystem. Seagrass ecosystems that have a role as a fish habitat are one of the main places for fishermen to take and exploit fish resources. Thus it forms a social system of society in the shape of fishing communities that depend on the existence of the ecosystem of seagrass (ecological system). On the other hand, the excessive exploitation done by the society, for the higher economic needs, makes the seagrass ecosystem disrupted. Utilization that is not balanced with conservation activities causes worsening of existing seagrass ecosystem. Social and ecological systems are two systems that have connectivity in the form of a relationship of interdependence. Changes in the social system will result in changes in ecological systems as well as changes in the ecological system will change the existing social system. In other words, the seagrass ecosystem is very vulnerable due to the behavior of the surrounding community. Human behavior more often increases the vulnerability of ecosystems rather than increasing resilience. Every action and human intervention has the potential to reduce ecological toughness because the goal of the human activity is generally to control or alter the processes occurring within an ecosystem [11].

The concept of vulnerability has a clear history of biophysical and social sciences. More recently, biophysical and social orientations have been simultaneously used in testing the vulnerability of the environment and human or socio-ecological systems [9]. In that aspect, the relationship between the property of ecosystem and increased human well-being forms a framework known as ecosystem services. The ecological and economic value of natural resources is increasingly being used to determine the priority areas in planning and managing coastal areas. Social value is rooted in the public perception of ecosystem goods and services, which are rarely considered. These values include the social value existing in natural resources, highly recognized in conservation that offers a comprehensive understanding of a process toward change in the socio-ecological system [12]. Based on human perception, natural ecosystems provide not only life support services but also other services that actively support human life, such as recreation and aesthetics [13]. The community is a part directly related to environmental problems because people live for long periods and who feel the first time the impact. Public perception is the key to managing environmental challenges.

The ecosystem services matrix is a matrix containing stakeholder identification and assessment of seagrass ecosystem services in Kotania Bay waters (Table 2). The existence of seagrass ecosystem services at the research sites, enjoyed by various layers of society or stakeholders, among others, managers of natural tourism parks, government, fishers, seaweed farmers and academician/researchers.

Perceptions of different stakeholders on the existence or function of the seagrass ecosystem (seagrass ecosystem services) vary. Seagrass ecosystem services in Kotania Bay areas production/provider services (habitat of sea organism), administrative/regulation services (carbon storage, current absorber) and cultural services (Tourism, research sites). The seagrass ecosystem services cannot be doubted as revealed by [14].

**Table 2.** Ecosystem services matrix

Seagrass ecosystem services matrix		Ecosystem services matrix				
		Habitat of sea organism	Current absorber	Tourism	Research sites	Carbon storage
Stakeholder	Managers of marine nature parks	0	0	+	0	0
	Government	0	0	+	0	0
	Fisherman	-	0	0	0	0
	Seaweed farmers	-	0	-	0	-
	Academician / Researcher	0	0	0	+	0

The presence of seaweed cultivators has an adverse impact on seagrass ecosystem services (habitat of sea organism, tourism and carbon storage). Similarly, the presence of fishermen to sea organism habitat services. This is supported by the results of research conducted in the Kotania bay that the bay is rich in sea organisms such as seaweed, sea cucumbers, mollusks, fish, and dugong. But now the existence of this sea organism is increasingly reduced and become scarce [15]. Managers of marine nature parks and Government are related or have a positive impact on tourism services. Similarly, the presence of academician/researcher on seagrass ecosystem services as a research site. According to [9], ecosystem services have a real relationship with the physical elements of the ecosystem, such as the number of service providers (food/organism) or regulatory services (control of erosion/current absorber).

In the descriptor matrix (Table 3), stakeholders utilizing seagrass ecosystems in the Kotania Bay describe the observable characteristics of the seagrass ecosystem itself. The observable characteristics associated with seagrass ecosystem services are the percentage of seagrass cover, seagrass species density, fish abundance, association organism, seagrass biomass, and beauty. Features described by stakeholders as a whole have a positive impact on seagrass ecosystem services, unless the characteristics of beauty are neutral to the service of the current absorber and the carbon storage. Similarly, the same value to tourism services

**Table 3.** Descriptor matrix

Descriptor matrix		Descriptor Stakeholder					
		% of Seagrass cover	Seagrass species density	Fish abundance	Association organism	Seagrass biomass	Beauty
Ecosystem services	Habitat of sea organism	+	+	+	+	+	+
	Current absorber	+	+	+	+	+	0
	Tourism	+	0	+	+	+	+
	Research sites	+	+	+	+	+	+
	Carbon storage	+	+	+	+	+	0

The ecosystem property intended for the following matrix is the typical or functional component of the seagrass ecosystem (Table 4). This matrix links the biophysical description to the specific features of the seagrass ecosystem as a service provider. Overall, ecosystem property and descriptor stakeholder have an active relation to each other, except for beauty aspect and fishery production have a negative relationship.



**Table 4.** Ecosystem Property Matrix

Ecosystem Property Matrix		Ecosystem Property		
		Important value index	Water quality	Fishery production
Descriptor Stakeholder	% of seagrass cover	+	+	+
	Seagrass species density	+	+	0
	Fish abundance	+	+	+
	Association organism	+	+	+
	Seagrass biomass	+	+	0
	Beauty	0	+	-

The matrix of Utilization Attributes correlates between descriptor utilization with the utilization quality. The use attribute is a description of the seagrass ecosystem management practices on the characteristics that characterize the ecosystem (Table 5). In the matrix shows that the activity of seagrass ecosystem utilization in the form of conservation is very closely related to attribute of seagrass cover, association organism, and beauty. This assessment is in contrast to fisheries activities on the seagrass ecosystem.

**Table 5.** Matrix of Utilization Attributes

Matrix of Utilization Attributes		Utilization Attributes		
		Seagrass cover	Association organism	Beauty.
Descriptor utilization	Conservation	+	+	+
	Fisheries	-	-	-

The matrix that links the functional trait with the ecosystem property is called the functional character matrix (Table 6). The relationship described in this matrix is a direct correlation between the ecosystem ownership and the benefits received by society. The functional trait characteristics of the seagrass ecosystem can be interpreted as a function or benefit that can be accepted and done by the community from the seagrass ecosystem property. Elements of major value indexes, water quality, and fishery production are either active or in other words closely related to people's income and carbon existence.

**Table 6.** Matrix functional trait

Matrix functional trait		Functional trait	
		Community Revenue	Carbon Existence
Ecosystem Property	Important value index	+	+
	Water quality	+	+
	Fishery production	+	+

The linkage matrix used in assessing the vulnerability of SES to this seagrass ecosystem, making general seagrass ecosystem services, is slightly easy to quantify and be measured. The integration of social values into ecosystem services taking into account the ecological and economic aspects of natural resource assessment will result in a fair and efficient policy that can enhance the resilience of the socio-ecological system [12, 16].

#### 4. Conclusion

1. The socio-ecological system of the seagrass ecosystem in the Kotania Bay waters is evidenced by the significant dependence of coastal communities/fishermen on the seagrass ecosystem.
2. Social values are rooted in the public perception of ecosystem goods and services, which are rarely considered. The social value that exists in natural resources is highly recognized in conservation.
3. The ecological and economic value of natural resources is increasingly being used to determine the priority areas in the planning and management of coastal zones.

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