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Formulation of Mangrove ecosystem management model based on eco-minawisata in the Coastal Sinjai, South Sulawesi

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Abstract

The rising price of crab in the world has fueled conversion of mangrove ecosystems into ponds, including in South Sulawesi. The conversion of mangrove allegedly contributed to environmental degradation in South Sulawesi Coastal Area. On the other hand, conservation efforts that have been made have not received a positive response from the public. Thus, it needed to formulate the proper management model. Analysis techniques used in this study is scoring and AHP (Analytical Hierarchy Process). The result are: (1) development and land use in areas suitable for fish and crabs in the mangrove conservation area; (2) development of fisheries areas based around the mangrove conservation area; (3) development of strategic infrastructure in a potential area for aquaculture, fisheries and marine tourism; (4) development and management of coastal areas and sea-based maritime tourism in mangrove conservation area; (5) development and management of coastal and marine areas based on mangrove conservation.

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Keywords: Conservation; mangrove ecosystems; management model.

1. Introduction

Sinjai coastal area has mangrove area around 786 ha which is play an important role in the dynamics of coastal and marine ecosystems, particularly in the development of aquaculture and supporting the potential of aquatic biota. Not only have biophysical and biological function, mangrove forests in the coastal Sinjai also has a function to

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enhance productivity, economy of coastal communities, the potential of fisheries, coastal protection, and added value to the surrounding community. Physically, this ecosystem serves to maintain the stability of the coast from the effects of erosion, waves and abrasion, protective mainland (filter) of tsunamis, hurricanes, sea water intrusion, and the threat of various pollutants and pathogens.

Ecologically, mangrove ecosystem serves as a buffer of ecological balance between life on the land and the sea. Mangrove become an energy source for many species of marine biota such as fish, shrimp, clams, crabs and various types of other biota, spawning ground, enlargement (nursery grounds), foraging (feeding ground) and shelter. Economically, mangrove ecosystem serves as a supplier of products that bring economic benefits to humans, such as providers of recreational facilities, education, aquaculture (marine culture) and livestock (honeybees), and provider of products for the purposes of fuel (charcoal), paper (pulp), construction, household appliances, textiles, leather, food, drinks and medicines (anti-tumor, anti-inflammantory) (Bengen, 2001; Alongi, 1998; Salm and Clark, 2000).

Mangrove ecosystem has long been used by the community and can support the improvement of public welfare in the coastal areas, because this area produces a wide range of export commodities with high value such as shrimp, crabs and fish. The high price of crab in the world market has triggered conversion of mangrove ecosystems into fishpond in various areas, including in the province of South Sulawesi. On the other hand, the conversion of mangrove land suspected to contribute to the environmental degradation of coastal in the province of South Sulawesi, such as the intensification of coastal erosion, tidal flooding, decline in water quality and loss of spawning a variety of marine life, including fish and crustaceans. The phenomenon responded by the South Sulawesi provincial government to support the development of mud crab farming in ponds, with the area of development reached around 35,000 ha, cover the ponds in Wajo, Sinjai, and Luwu District.

However, rehabilitation and conservation efforts that have been made have not received a positive response from the public because there is no direct contribution to the improvement of people's income. Then it raises a conflict of interest between communities and local governments with the Regional Regulation No. 8 of 1999 on the prohibition of logging in mangrove areas of society, so that needs to be reviewed appropriate management model that government policy can be maintained but the wishes of the people fulfilled too.

On the other hand, the utilization of mangrove areas in a planned is also expected to increase the added value for the people who live around the mangrove area, including fish farmers and fishermen. While intercropping cultivation of mangrove crab (silvofisheries) can increase the production of crab as well as to suppress the encroachment of mangrove forests. To reduce fishing pressure on mud crab, it necessary to develop the cultivation effort to prevent a decline in production due to reduced resources. Based on this, the formulation required management model that can unify the perception among the public desire with the local government policies, thus ensuring the sustainability of mangrove ecosystems is maintained, but still provide added value to the surrounding community by utilizing a variety of alternative businesses that are economically viable and sustainable development.

2. Methods

2.1. Data Collection Technique

The data was collected through a primary and secondary data survey. The data collected is observational data of economic, social, cultural, legal, and public perception. Primary data is collected through observation and interviews. Interviews with local communities involved in the conservation and management of mangrove forests is done with PCRA method (Participatory Coastal Resource Assessment), local governments, relevant institute, ACI and Baku Lestari group, and community associated with the sites. Secondary data collected through searches the literature contained in the related government and private institutions.

2.2. Analysis Technique

The analysis technique used in this research is scoring method, which is based on the condition of ecological, economic, and social. The values of the scoring range from 1 to 3, the value of 1 (one) is given on the low or bad condition, the value of two (2) is given on the average condition, and the value of 3 (three) is given on the high or good condition. While the formulation of models and management strategies are done by using AHP (Analytical Hierarchy Process). This analysis is based on weighted criteria, wherein the weight value of each criteria and sub-

criteria is the input value based on the results of interviews with the competent authorities in determining the policies and the management of coastal resources in the mangrove conservation area.

3. Result and Discussions

This research was conducted in the coastal areas of mangrove ecosystems in the Sinjai District, South Sulawesi. The location study is presented in Figure 1.

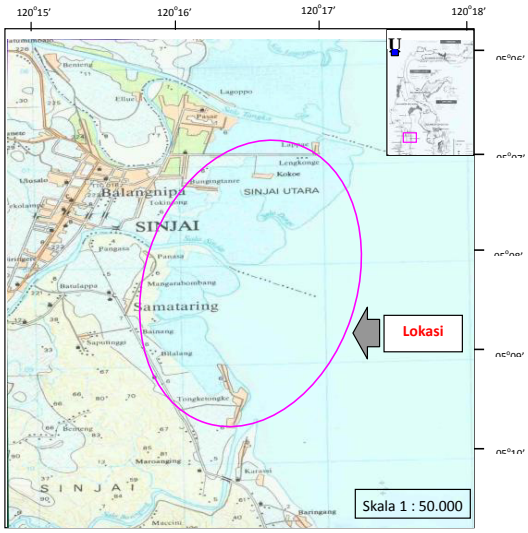

Fig. 1. Map Location of Mangrove Research Areas in the Sinjai District, South Sulawesi

3.1. Coastal Area Capability Analysis

The quantification of the water volume which is available in coastal areas for the development of aquaculture is determined from the observation characteristics of Sinjai coastal waters (Table 1).

Table 1. Characteristics of Sinjai Coastal Water

Parameter	Value
The long of the coastline (m)	17.000
The average grade of the beach (°)	8,17
Angle beach (Tg. Θ)	0,145
Distance from the shoreline (tide) to the location of the seawater (water intake) for the fishing ponds (m)	791,88
Tidal range (m)	1,26
The volume of water available at the beach (Vo) (m^3)	33,718,802.17
Tidal frequency (times hr^{-1})	2
The average speed of the tide (m sec^{-1})	0,312
The volume of sea water that goes to the beach when the tide (Vt) (m^3 hr^{-1})	67,437,604.330
The average discharge of river water (m^3 hr^{-1})	211,655.372
The average of total water volume available at the beach for the fishing ponds per day (m^3 hr^{-1})	67,649,259.702

Source: The results of the analysis, 2015

3.2. Coastal Area Management Model based on Sustainable Environment Capacity

The development of aquaculture in Sinjai is done based on the principles of sustainability, by considering such aspects of the ecological, economic and social. The basis for determining the allocation of land use aquaculture optimally based on: (1) land suitability; and (2) the carrying capacity of the environment, as scientific information in formulating management policy, regulation, and licensing that can be justified. The study provides a number of data

and information that can be used as a reference in the use of Sinjai coastal areas for sustainable aquaculture based on land suitability and capacity of the environment are presented in Table 1.

1) Physical Carrying Capacity

The results of water volume calculating which is available at the beach (Vt) in the Sinjai District for the development of aquaculture is 68.934.266,17 m^3, with the speed of the tide in the spring tide is 0,32 m sec^{-1}. Based on the volume, it can drain 6.893,43 ha pond area, but not all of these lands should be developed for aquaculture, because eligibility is determined by several criteria of land suitability cultivation, that is: (1) the slope; (2) the distance from the coast; (3) the distance from the river; (4) the type of soil; (5) the height (elevation) of land; (6) drainage; (7) salinity and (8) geology. Based on those criteria, land classified as appropriate and very appropriate for the aquaculture area is 1324,76 ha.

2) Production Carrying Capacity

The production capability limiting factor of shrimp aquaculture is the ability of the water to assimilate organic waste from the shrimp aquaculture activities. The availability of dissolved oxygen for the respiration process of shrimp, fish, and other aquatic organisms is a major determinant of the production capability whether it is able to produce in a sustainable shrimp production amounted to 829,79 tons per cropping season (MT). So that, the water capability to assimilate organic waste amounted to 504.377,08 kg. Based on the pilot aquaculture area of 10.000 m^2 with a stocking density 30 individuals m^{-2} or 300,000 tails ha^{-1}, with a maintenance period of 120 days MT^{-1} is required feed up to 6.557,5 kg with 57% survival rate. Stocking practices can be done twice a year with the first growing season (MT I) in February-May and the second growing season (MT II) in August-November.

Table 2. Bio-ecological and Coastal Environment Condition for the Sustainable Aquaculture Pond Development

Parameter	Value	Description
Mangrove land area (ha)	346,05	Citra at 2013
Land area suitable for mangrove conservation (ha)	326,36	Results of the analysis of land suitability for conservation
Land area suitable for aquaculture (ha)	1.324,76	The image analysis results, in 2013
Existing added cultivated land area (ha)	1.033	Data at 2014
Extensive land cover pond (ha)	1.077,39	Citra at 2013
Optimal land area used for the pond amounted to 1.217 ha	35	Intensive
	440	Semi-intensive
	742	Traditional
Type of tidal (Formzahl-F)	0,71	Mix dominant semidiurnal tide
Stables tides (cm)	126	• *Spring tide*
	74	• *Neap tide*
Tidal current velocity (m sec^{-1})	0,32	• *Spring tide*
	0,20	• *Neap tide*
The total volume of water available in beach (m^3 hr^{-1})	68.934.266,17	2 tidal cycles per day
Water long live at the beach (hours)	2,00114	1 tidal cycle times
Oxygen capacity available on the beach (kg)	100.875,42	-
The carrying capacity of environment decompose an organic waste collected (kg)	515.570,87	TSS waste carrying capacity
The amount of organic waste disposal of residual feed (kg ha^{-1})	2.100	Intensive
	1.145	Semi-intensive
	350	Traditional
Wide sustainable farms that are allowed by the carrying capacity of waste feed (ha)	245,5	Intensive
	449,9	Semi-intensive
	1.473,1	Traditional
Optimizing the utilization of the land by priority, that is: Ecology> Economy> Social. The comparison between pond and mangrove (1.208 ha : 471 ha)	525,85	Shrimp traditional
	350,08	Semi-Intensive
	117,00	Intensive
	155,15	Polyculture (milkfish + RL)
	99,85	Silvofishery
	471,78	Mangrove conservation
Optimizing the utilization of the land by priority, that is: Social> Economy> Ecology. The comparison between pond and mangrove (1.168 ha: 451 ha)	426,00	Shrimp traditional
	370,05	Semi-Intensive
	117,00	Intensive
	255,00	Polyculture (milkfish + RL)
	0,00	Silvofishery
	451,78	Mangrove conservation

Parameter	Value	Description
Optimizing the utilization of the land by priority, that is: Economy> Social> Ecology. The comparison between pond and mangrove (992 ha: 371,93 ha)	426,00	Shrimp traditional
	449,93	Semi-Intensive
	117,00	Intensive
	255,15	Polyculture (milkfish + RL)
	0,00	Silvofishery
	371,93	Mangrove conservation

Source: The results of the analysis, 2015

3) Social Economy Carrying Capacity

The determination of the land area of aquaculture in the Sinjai coastal areas has considered land use status of aquaculture today. The development of aquaculture is expected to avoid the appearance of interest conflict of land use in coastal areas, such as the presence of aquaculture without inhibiting or reducing the production of paddy. That management is expected to create jobs, improve the value-added products and the income of the communities around Sinjai coastal area. Cost production of shrimp and milkfish aquaculture in the study area amounted to Rp 2.841.881,8 ha^{-1} th^{-1} with a total production value around Rp 9.652.277,4 ha^{-1} th-1, then earned a profit around Rp 5,788,836.3 ha^{-1} yr^{-1}, with the value of the RC ratio around 3,65.

4) Ecological Carrying Capacity

The shrimp aquaculture which is doing intensively are activities that could potentially impact the environment due to the load of organic waste as a result of nutrient enrichment, eutrophication, hypoxia, and sedimentation, so the development of shrimp pond aquaculture must be appropriate with the carrying capacity or capability of the environment. The environmental impact caused by the shrimp aquaculture activities must be within the limits of the environment capability, the amount of organic waste from aquaculture activities based on the carrying capacity and environmental assimilation should not exceed 515.570,87 kg.

The calculation results of the amount of waste that is discharged into coastal waters amounted to 2.100 kg TSS $ha^{-1}MT^{-1}$ for intensive farms, then about 1.145,9 kg TSS ha^{-1} MT^{-1} for semi-intensive pond, and 350 kg TSS ha^{-1} for traditional farms. Intensive land area for aquaculture that is able to be supported by the environmental carrying capacity amounted to 245,5 ha, for semi-intensive aquaculture is able to support 449,93 ha, and for traditional aquaculture is able to support of 1.473,06 ha.

3.3. Alternative Management of Sinjai Coastal Area

There are several alternatives can be developed for the management of sustainable aquaculture in the Sinjai coastal area is:

1) Silvofishey System

An optimal aquaculture land use should consider ecological, economic, and social aspect, with the allocation of traditional plus aquaculture amounted to 525,85 ha; semi-intensive cultivation amounted to 350.08 ha; intensive cultivation amounted to 117; polyculture of milkfish and seaweed covering 155 ha; and aquaculture of silvofishery and sea faming amounted to 99,85 ha.

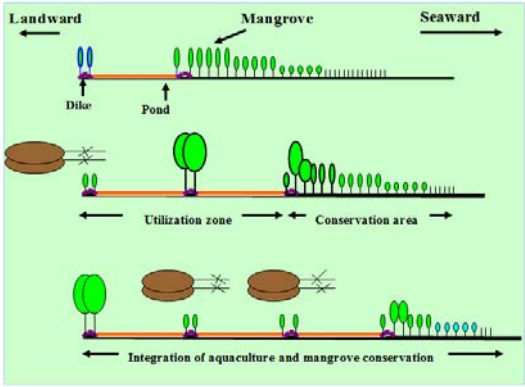

Fig. 2. Integration Utilization of Mangrove Ecosystems and Pond Aquaculture with Silvofishey System

2) Creating Regional Economic Development Plan based on Aquaculture (REDPA)

REDPA of Sinjai coastal area as a hint to develop the aquaculture is bio-techno-socio-economically viable and helps minimize the conflicts of interest. As the direction of driving the utilization of sustainable Sinjai coastal areas, REDPA should be addressed as a comprehensive component in the integrated coastal planning as outlined in the form of local regulations. The division of the coastal areas and the designation is presented in Table 3.

Table 3. Appropriation Referral of Sinjai Coastal Area

Zone	Land Characteristic	Appropriation Referral
A	**Fishpond** This land elevation / height between 0-2 meters from the MSL, with a land area around 417 ha. Argillaceous sand soil texture basis. Filling water into the pond 100% done with gravity system. The land directly bounded to mangrove forests.	Can be developed for traditional plus aquaculture with the rationalization of farms with an area stretch of mangrove areas. Crab can be developed with the confinement system.
B,C,D	**Fishpond** This land elevation 2-9 meters of MSL amounted to 891 ha. Filling water into the pond is done by pumping. Argillaceous sand soil texture basis. This land bounded by rice fields and settlements.	Can be developed for the intensive and semi-intensive cultivation, then polyculture cultivation of milkfish and seaweed.
E	**Mangrove** The land directly bounded to aquaculture ponds, some have been converted into ponds. Land area of about 99 ha.	Can be developed for the cultivation of fish, seaweed, and mud crab with Silvofishery system.
F	**Mangrove** Mangrove conservation land, this land is already partially converted into ponds. The extensive mangrove presents approximately 310 ha. Efforts to do farm land expansion became a major obstacle for mangrove conservation.	This area is designated as a mangrove conservation area and supported by mangrove reforestation activities. Rationalization between the extensive of mangrove conservation area and pond became priority.
G	**Coastal waters** This area is close to mangrove forests, has shallow waters, and it is still influenced by the tides.	This area is suitable to be developed for the sero waring catchment area and step charts
H	**Port** Fairly calm waters of the influence of waves and used for harbor between the islands.	This area is designated as a port between the islands.
I	**Fish Landing Base** This area is fairly sheltered from wave influenced and used as fish landing port.	The area is designated as fish landing area
J	**Residential areas**	Settlement development region. It necessary to arrange the residential land.
K	**Paddy field**	The area is suitable for the development of paddy field.

Source: The results of the analysis, 2015

3.4. Management Priority Strategy of Eco-Mina-Tourism

Prioritization of mangrove conservation area management is an extremely important point, particularly in relation to land use activities / areas accordingly based on ecological, economic, and social culture. The analysis used in this research is AHP (Analytical Hierarchy Process). This analysis is based on weighted criteria, wherein the weight value of each criteria and sub-criteria is the input value based on the results of interviews with the competent authorities in determining the policies and management of living resources in coastal mangrove conservation area. Based on the results of land suitability analysis, found that the region of mangrove conservation area is very appropriate and supportive to the development of an integrated maritime mina-tourism. Mangrove conservation areas are physically very fit for the development of marine aquaculture, marine conservation, the port, and the fishing industry.

Based on the results of interviews with stakeholders in the mangrove coastal area, with AHP analysis obtained top priority in the management of marine mina-tourism based, that is: (a) the management of coastal and marine biological resources in order to improve the welfare of coastal communities through fisheries and tourism with a weight of 0,4428; (b) joint management in order to improve the quality of human resources through community empowerment and provision of strategic infrastructure with a weight of 0,3218; and (3) joint management within the framework of the conservation and protection of marine resources and fisheries (SDKP) with a weight of 0,2355 (Table 4).

Table 4. Priority Management based on Eco-Mina-Tourism

Management Referral Based on Eco-Mina-Tourism	Weight	Priority
The management of coastal and marine biological resources in order to improve the welfare of coastal communities through fisheries and tourism	0,4428	1
The management of coastal biological resources in order to improve the quality of human resources through community empowerment and provision of strategic infrastructure	0,3218	2
The management of biological resources in the context of coastal conservation and protection of marine resources and fisheries	0,2355	3

Source: The results of the analysis, 2015

Based on the analysis of AHP, priority programs of marine biological resources can be compiled based on mina-tourism, in accordance with the order is: (1) the development and utilization of land use in areas which is suitable for fish and crabs in the mangrove conservation area; (2) the development of fisheries areas around the mangrove conservation area; (3) the development of strategic infrastructure in a potential area for aquaculture, fisheries, and marine tourism; (4) the development and management of coastal areas and sea based on marine tourism in mangrove conservation area; (5) the development and management of coastal and marine areas based on mangrove conservation (Table 5).

Table 5. Priority Program of Mangrove Conservation Area Management based on Marine-Mina-Tourism (2, 4, dan 5 beda di kesimpulan dan tabel)

Management Program of Marine Biological Resources	Weight	Priority
The development and utilization of land use in areas which is suitable for fish and crabs in the mangrove conservation area	0,3178	1
The development and management of coastal areas and sea based on marine tourism in mangrove conservation area	0,2970	2
The development and management of coastal and marine areas based on mangrove conservation	0,1690	4
The development of fisheries areas around the mangrove conservation area	0,1280	5
The development of strategic infrastructure in a potential area for aquaculture, fisheries, and marine tourism	0,1763	3

Source: The results of the analysis, 2015

4. Conclusions

The study provides a number of data and information that can be used as a reference in Sinjai Coastal area utilization for a sustainable aquaculture. Based on the carrying capacity of the physical, production, social, economic, and ecological, the strategy in the management of Sinjai coastal resources based on mina-tourism accordance with the order is: (1) the development and utilization of land use in areas which is suitable for fish and

crabs aquaculture is in the mangrove conservation area; (2) the development of fisheries areas based around the mangrove conservation area; (3) the development of strategic infrastructure is in the potential area for aquaculture, fisheries, and marine tourism; (4) the development and management of coastal and marine areas based on maritime tourism is in mangrove conservation area; (5) the development and management of coastal and marine areas based on mangrove conservation.

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