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Land Use Optimization for Mariculture, Marine Fishery and Tourism in Spermonde Archipelago, South Sulawesi Province

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Abstract: Lack of land use optimization in Spermonde Archipelago has effect on low employment and regionally generated revenue. The study aims to analyze optimization by determining optimal area for mariculture, sea fishing and marine fishery tourism. Types of data consist of total production/season, tourist visitation/day, man-day count, area size for activity, production price level/kg, retribution fee/person in floating net cage activity, seaweed cultivation, coral reef fisheries, marine tourism and beach tourism. Analysis method applies Linear Goal Programming (LGP). The program aims to allocate land use in Spermonde Archipelago optimally and continuously. The findings found that land use optimization for marine fishery tourism management in every land use reaches 36.23 ha for floating net cages, 67.79 ha for seaweed cultivation, 520.45 ha for marine tourism, 26.94 ha for beach tourism and 288.59 ha for coral reef fisheries. Through the optimized area size, the management needs involvement of private sector, society and the government to increase the production and to absorb labor through an integrated area management.

Key words: Optimization, floating net cage, seaweed, sea fishing and marine fishery tourism, LGP

INTRODUCTION

Pangkajene Regency and Islands have 17,000 km marine areas and 3 islands sub-districts, consisting of Liukang Tupabbiring sub-district, Kalmas Liukang sub-district and Liukang Tangaya sub-district. Liukang Tupabbiring sub-district has 40 islands and the 10 islands are uninhabited. This sub-district is the region with numerous islands where the distance between island and coastal area is close enough by regency that belongs to Spermonde group of islands. Liukang Tupabbiring sub-district has 30,988 people.

Those small islands have ecosystem diversity such as coral reef ecosystem, mangrove ecosystem and seaweed ecosystem.

Kasnir *et al*. (2009a) report that potential resource in Spermonde Archipelago, especially coral reef ecosystem is extending around 207.72 ha in research site. The most numerous coral reef species found therein is *Acropora* sp. in depth of 1-10 m; percentage of coral reef in general is good but in some locations, the coral is found damaged or badly damaged where the coverage ranges from 22-70%. The use of resources shall be increased through marine fishery tourism development, even it still finds some obstacles such as lack of freshwater and lack of means and infrastructure.

Further, Kasnir *et al*. (2009b) finds suitable area and environmental capacity for marine fishery tourism. The area is divided into zone allocation for fishing; floating net cages which can carry 200 units floating net cages at size of 3×3×3 m/unit seaweed cultivation where the carrying capacity is 285 units (long line method at size of 40×60 m); marine tourism with visitor carrying capacity and snorkeling category for 41,578 visitors/day; beach tourism with visitor carrying capacity for 11,756 visitors/day and coral fisheries with suitability by 2.89 km^2 and maximum sustainable yield by 89.00 ton. To support economic development, small islands development shall be built on objective condition of every small island. Small islands capacity to make natural resources available shall be taken into consideration regarding its natural resource exploitation rate and space use in the island. Thus, management is a requirement in the hope of integrity and accountability in resource utilization. Optimum utilization is arranged based on compatibility result and carrying capacity through coordination, collaboration and consultation to make an integrated plan. The management shall involve various dimensions, for example ecological, economic, socio-cultural and institutional dimensions; the dimensions are integrated into utilization optimization. Therefore, the study aims at determining land use optimization for mariculture they are floating net cages, seaweed cultivation in addition to capture fisheries and marine tourism.

MATERIALS AND METHODS

Research site and time: This study is carried out in Spermonde Archipelago, Liukang Tupabbiring sub-district, Pangkajene Regency, South Sulawesi Province Islands. The islands consist of Sapuli Island, Satando Island, Saugi and Cambang-Cambang Island Salemo Island, Sakoala Island, Sabangko Island, Sagara Island, Gusung Torajae and Sabutung Island. The study is carried out from March to July, 2013.

Types and sources of data: Types of data consist of total production/season, tourist visitation/day, man-day count, area size for activity, production price level/kg, retribution fee/person in floating net cages activity, seaweed cultivation, coral reef fisheries, marine tourism and beach tourism.

Types and amount of samples: Sampling is determined on purposive sampling method to each of floating net cage cultivation, seaweed cultivation, coral reef fishing, marine tourism and beach tourism. Respondents are taken from all kinds of activity, i.e., 120 respondents. Other respondents are taken from limited company/non-governmental organization, Department of Marine and Fisheries, Regional Development Planning Agency, Department of Environmental Affairs, Department of Tourism, Department of Zoning and Planning there are 30 respondents from these organizations.

Data analysis: Data analysis on land use optimization is given to Spermonde Archipelago coastal areas, i.e., seaweed cultivation, floating net cage, cultivation, marine and beach tourism and also optimal and sustainable fishing. The analysis applies Linear Goal Programming (LGP). The program aims to allocate optimum and sustainable land use in Spermonde Archipelago by considering some aspects, for example ecological aspect, economic aspect and socio-cultural aspect. The land will be used for seaweed cultivation, floating net cage cultivation, marine and beach tourism and fishing.

RESULTS AND DISCUSSION

Based on the interview, observation in the field and data taken from the related institution it is found description about land use activity in Spermonde Archipelago coastal areas as presented in Table 1.

According to the strategic plan document on coastal management from Regional Development Planning Agency and Department of Marine and Fisheries, Pangkep Regency as embodied in the marine and fisheries strategic plan of Pangkep Regency and according to allocation, utilization and carrying capacity analysis, optimum utilization target will be achieved either in land use, production rate for various fisheries and tourism activities or employment rate in the research site. The data is presented in Table 2.

Calculation on man-day/ha/year is based on the interview and the data from related institution, i.e., 0.5 man-day×30 days×1.5 month/MT×5 MT×10 person/ha = 1125 man-day/ha/year. For floating net cage, 1 man-day×30 days×12 month×1 MT×04 person/ha = 1440 man-day/ha/year. Calculation for marine tourism found 0.75 man-day×8 days×12×1 person/ha = 72 man-day/ha/year and calculation for beach tourism found 0.75 man day×30×8×12×2 person/ha = 0.144 man-day/ha/year. The ecological potential for visitor and area, diving tourism gets 20 visitors/ha, snorkeling gets 40 visitors/ha and beach tourism gets 200 visitors/ha. Calculation on coral reef fishery found 1.25 man day× 30 days×12×1 person/ha = 450 man-day/ha/year.

Table 1: Condition of current land use per hectare in Spermonde Archipelago coastal areas

Utilization	The land area that is used today (ha)	Production/visits	Labor (day/ha/year)	Production value (IDR/ha/year)
Seaweed cultivation	2.00	3 tonnes/ha/year	169	24.000.000
Raising KJA	1.20	0:15 tonnes/ha/year	675	18.000.000
Marine tourism	3.71	10 org/ha/year	48	500.000
Beach tourism	1.46	60 org/ha/year	96	360.000
Reef fisheries	6018.00	0.18 tonnes/ha/year	315	13.300.000

Table 2: Target per hectare to be gained in coastal utilization in Spermonde Archipelago

Type allotment	Maximum land quota (ha)	Labor (Day/ha/year)	Production	Price (Rp.)	Value of production (Million Rp.)/ha)
Seaweed cultivation	67.79	1125	6 ton/ha/year	8000/kg	48.00
Raising KJA	36.23	1440	0.72 ton/ha/year	120.000/kg	86.40
Marine tourism	520.45	72	114 org/ha/year	5.000/org	0.57
Beach tourism	26.94	144	400 org/ha/year	3000/org	1.20
Reef fisheries	288.59	450	0.2 ton/ha/year	35.000/kg	7.00

Data analysis, 2013

Table 3: Overall target to be achieved in coastal utilization, Spermonde Archipelago

Optimization	Development land use (ha)	Target employment absorption (day/year)	Target production/ visit (years)	Target value of production (Juta IDR /year)
Seaweed cultivation	67.79	87.952	469 ton/year	3.752.00
Raising KJA	36.23	50.558	25.28 ton/year	3.033.60
Marine tourism	520.45	37.419	74.839 org/year	77.96
Beach tourism	26.94	4.232	11.756 org/year	17.63
Reef fisheries	288.59	130.365	57.94 ton/year	2.027.90

Table 4: Decision-making variable of multiple objective program for land use optimization in eco-marine fishery tourism management

	Land area governance Ekominawista				
Processing data	Seaweed cultivation	Raising KJA	Marine tourism	Beach tourism	Reef fisheries
Decision variables decision	X_1	X_2	X_3	X_4	X_5

The table presents optimum utilization of various types of allocation. For seaweed cultivation activity it is expected that every household can handle 5 units (0.5 ha) in which the length per unit is 40×60 m. The labor involved per unit is around 4-5 people and this cultivation can produce 6 ton/year.

The target of regionally generated revenue will be gained by optimistic scenario at average of 9.98% per year while if it uses pessimistic scenario, the average increase will be 5.64% per year. In addition to the regionally generated revenue, employment target has to be improved by making job vacancy available and maximum where the job vacancy has to be equal with the job seeker counts. Current unemployment rate reaches 3.44% per year.

Based on the findings and Management Strategic Plan on coastal and sea areas of Pangkep Regency, land development and utilization is set in Spermonde Archipelago coastal areas as presented in Table 3.

Considering all targets set for every activity, carrying capacity of every allocation is also determined based on conservation area capacity, it covers the core zone that becomes supporting zone for every developing activity. Carrying capacity of the conservation zone, based on the findings can be predicted, for example if the size area is 23.81 km^2 it is assumed that for every 1 km^2 healthy seaweed can produce 12-50 ton coral reef fish per year. Based on the CPUE which is analyzed by types of fishing gear and fish (fishing power index of the gill net is 0.0716 and fishhook has 1), the equation will be $y = 2113.9\text{-}12.551X$ and $R^2 = 0.8856$, thus, maximum sustainable yield is 71.206 ton and Fopt is 89 units.

Therefore, problems to be answered by this study is what is the length area (in hectare) to be utilized for eco-marine fishery tourism including size areas for seaweed cultivation, floating net cage cultivation, marine tourism, beach tourism and coral reef fishery. The activity management shall work optimally and continuously.

Problem solving is formulated and analyzed by multiple objective programs in purpose to optimize land use by determining decision-making variable as presented in Table 4. The decision-making variable is used for land use optimization in Spermonde Archipelago coastal areas.

The targets set and listed in Table 3 do not have priority grading, then decision-making variables for the data processing consist of:

X_1 = Land size area for seaweed cultivation
X_2 = Land size area for floating net cage cultivation
X_3 = Land size area for beach tourism
X_4 = Land size area for marine tourism
X_5 = Size area for coral reef fishing

To describe the exceeded deviation variable it is symbolized as (d^+) and (d^-) is the symbol for the unrealized variable.

The objective of land optimization through eco-marine fishery tourism management in Spermonde Archipelago coastal areas by considering ecological, economic, socio-cultural, regulation, institutional and infrastructure aspect is to improve any allocation activities to achieve production and employment raise in conformity with carrying capacity of the environment.

Formulation of objective functions: Objective functions to be achieved in the analysis is to minimize the deviation (d) of every target. Therefore, the objective functions are follows:

$$\begin{aligned}\text{Min. } Z = {} & d_1^- + d_1^+ + d_2^- + d_2^+ + d_3^- + d_3^+ + d_4^- + d_4^+ + d_5^- + \\ & d_5^+ + d_6^- + d_6^+ + d_7^- + d_7^+ + d_8^- + d_8^+ + d_9^- + d_9^+ + \\ & d_{10}^- + d_{10}^+ + d_{11}^- + d_{11}^+ + d_{12}^- + d_{13}^- + d_{14}^- + d_{15}^- + \\ & d_{16}^- + d_{17}^- + d_{18}^- + d_{19}^- + d_{20}^- + d_{21}^- + d_{22}^+ + d_{23}^+ + \\ & d_{24}^+ + d_{25}^+ + d_{26}^+ + d_{27}^- + d_{28}^- + d_{29}^- + d_{30}^- + d_{31}^-\end{aligned}$$

Formulation of goal constraint functions: Goal constraint functions of every target are follows:

- Maximizing the employment rate to allocate labor from various activity allocations in Spermonde coastal areas, the labor data for every activity allocation is needed:
    - Number of seaweed cultivator employed in seaweed cultivation is 87.952 man-day/year
    - Number of employment in floating net cage cultivation is 50.558 man-day/year
    - Number of employment in marine tourism is 37.419 man-day/year
    - Number of employment in beach tourism is 4.232 man-day/year
    - Number of employment in capture fisheries is 130.365 man-day/year

Similarities of goal constraint faced by every activity are follows:

- Maximizing the production targets for every business allocation development
    - Seaweed cultivation is 469.08 ton/year
    - Floating net cage cultivation is 25.28 ton/year
    - Marine tourism is 74.836 visitors/year
    - Beach tourism is 11.756 visitors/year
    - Capture fishery is 57.94 ton/year

Equation of the goal constraint for every activity is:

- Maximizing the regionally generated revenue

If the goverment sets the target for the regionally generated revenue at 9.98%, value of production for every development shall be increased up to Rp. 3,752,000,000/year in seaweed cultivation, Rp. 3,033,600,000/year in the floating net cage cultivation, Rp. 77,960,000/year in marine tourism, Rp. 17,630,000 in the beach tourism and Rp. 2,027,900,000/year in the coral reef fishery. At the target of value of production by Rp. 8,909,090,000/year if retribution for the regionally generated revenue of 2.5% multiplied by value of production, the target of the regionally generated revenue is Rp. 222,727,250 in the research site. According to the interview representing current condition on business activity for example land size area, production, tourist arrival, retribution and price per unit, value of production in every business activity can be found. They are Rp. 24,000,000/year in seaweed cultivation, Rp. 18,000,000/year in the floating net cage cultivation, Rp. 500,000/year in marine tourism, Rp. 360,000/year in beach tourism and Rp. 13,300,000 in the coral reef fisheries. Current total value of production for all business activities reaches Rp. 55,710,000. If retribution tax is 2.5%, amount of the regionally generated revenue in the research site is Rp. 1,392,750. Therefore, equation of the goal constraint is:

$$2.5\%\times(24{,}000{,}000X_1+18{,}000{,}000X_2+500{,}000X_3+360{,}000X_4+13{,}300{,}000X_5)+d_{11}^{-}-d_{11}^{+}\geq 222{,}727{,}250$$

- Maximizing employment in every developing business activity (man-day/ha/year) equation of the goal constraint is:

$$X_1+d_{12}^{-}\geq 125$$
$$X_2+d_{13}^{-}\geq 1440$$
$$X_3+d_{14}^{-}\geq 72$$
$$X_4+d_{15}^{-}\geq 144$$
$$X_5+d_{16}^{-}\geq 450$$

- Minimizing the land use in every activity equation of the goal constraint is:

$$X_1+d_{17}^{-}\geq 2$$
$$X_2+d_{18}^{-}\geq 1.2$$
$$X_3+d_{19}^{-}\geq 3.71$$
$$X_4+d_{20}^{-}\geq 1.46$$
$$X_5+d_{21}^{-}\geq 6018$$

- Maximum land use optimization for the developing activity equation of the goal constraint is:

$$X_1+d_{22}^{+}\leq 78.18$$
$$X_2+d_{23}^{+}\leq 35.11$$
$$X_3+d_{24}^{+}\leq 519.72$$
$$X_4+d_{25}^{+}\leq 29.39$$
$$X_5+d_{26}^{+}\leq 289.70$$

- Value of production (Rp.) in every activity:

$$X_1+d_{27}^{-}\geq 24.000.000$$
$$X_2+d_{28}^{-}\geq 18.000.000$$
$$X_3+d_{29}^{-}\geq 500.000$$
$$X_4+d_{30}^{-}\geq 360.000$$
$$X_5+d_{31}^{-}\geq 13.300.000$$

The analysis of optimization shows that most of the goal constraint functions for every target is achieved. It is proved by the value of every deviation variable (d^+ or d^-) in general is zero meaning that the goal constraint function variable has achieved the target set before.

Considering the goal constraint function in maximizing employment rate, the number of labor for eco-marine fishery tourism management of every activity, the target has not been achieved. Seaweed cultivation has deviation value (d_{aa}^-) of 81.346 man-day and the target is 87.952 man-day/year; floating net cage has deviation value (d_{ba}^-) of 49.118 man-day and the target is 50.558 man-day/year; marine tourism has deviation (d_{ca}^-) of 30.715 man-day and the target is 37.419 man-day/year; beach tourism has deviation value (d_{da}^-) of 2299.607422 man-day and the target is 4.232 man-day/year; coral reed fishery has deviation value (d_{ea}^-) of 129.916 man-day and the target is 130.365 man-day/year.

Being observed from the goal constraint function in maximizing the production target, it represents that value of production in eco-marine fishery tourism, every utilization activity has not achieved the target, except the coral reef fishery. Seaweed cultivation has deviation value (d_{fa}^-) of 234.54 ton and the target of production is 469.08 ton/year; floating net cage has deviation value (d_{ga}^-) of 18.96 ton and the target is 25.28 ton/year; marine tourism has deviation value (d_{ha}^-) of 55.554 visitors and the target is 74.836 visitors/year; beach tourism has deviation value (d_{ia}^-) of 9.181 visitors and the target is 11.756 visitors/year; coral reef fishery has deviation value (d_{jb}^+) of 13.69 ton and this value has exceeded the target (57.94 ton/year).

Regionally generated value has not achieved the target. It is seen by deviation value (d_{ka}^-) Rp. 63,018,396, whereas the target set in the research site is Rp. 222,727,250.

To optimize utilization allocation for eco-marine fishery tourism management in the research site, land use allocation for seaweed cultivation shall be 78.18 ha, 35.11 ha for the floating net cage, 519.71 ha for marine tourism, 29.39 ha for beach tourism and 289.7 ha for coral reef fisheries.

CONCLUSION

In purpose to make allocation for various utilizations optimal, land use allocation for seaweed cultivation shall be 78.18 ha, floating net cage cultivation has to be 35.11 ha, 519.71 ha for marine tourism, 29.39 ha for beach tourism and 289.7 ha for fisheries. With the optimized area, the management needs involvement of private sector, society and the government to increase the production and to absorb labor through an integrated area management both for fishing activity and marine tourism.

SUGGESTION

To achieve the maximum employment, land uses for every activity shall be increased for example: 78.18 ha for seaweed cultivation, 35.11 ha for floating net cage cultivation, 519.71 ha for marine tourism and 29.39 ha for beach tourism. On the other side, coral reef fishery allocation will be better if it is decreased into 289.7 ha.

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