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Suitability Analysis for Shrimp-pond Culture Using GIS:

Case Study of Maros Region, South Sulawesi

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ABSTRACT

A research was done to develop suitability criteria for shrimp-pond culture. The research was conducted in Maros, South Sulawesi, Indonesia. The objective is to compare the validity of the criteria overlay method. Two overlay methods were tested: the method of" limiting factors" ("matching") and the method of "scoring". A Field campaign was done during August 2004.

The overlay parameters by "matching" give a more reliable result compared with "scoring" method. The parameters used for shrimp-pond suitability analysis using GIS have a relatively uniform weight as limiting factors.

Key words: shrimp-pond culture, GIS, scoring, matching

Background

Indonesia is the largest archipelago country in the world, with more than 17,500 islands. The length of country's coastline is estimated to be more than 81,000 km. The sea surface coverage (7,9 million km^2 or about 81%) is about four times than the land surface coverage (about 1,9 million km^2). This condition force Indonesia to manage its coastal and marine area seriously in order to increase the development in a sustainable way. Suitability analysis is the best way to manage natural resources, not only in land area but also in marine environment. Marine culture suitability analysis is now developed by Indonesia government in order to select the best location for certain commodity. The suitability analysis for shrimp-ponds culture, man-made coral reef, cage, sea grass and pearl culture have been studied by Center for Marine Resources Surveys, National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL), Indonesia, since 2004.

In such analysis, it is necessary to make an information integration related to the area. In this research, development of a suitability criteria prototype is done, especially by using geographic information system (GIS) analysis. A case study was done in one of coastal aquaculture area in Indonesia, Maros District, South Sulawesi.

Shrimp, a marine commodity having the highest need of environmental condition for their live compared to the other marine commodity was taken as case study. Shrimp-ponds culture was booming in Indonesia since 1997 due to increasing demand of shrimp from overseas, especially Japan. It gives an impact to the enormous conversion of mangrove to shrimp ponds.

Basically, a suitability analysis for marine culture is done by selection the best location which is suitable for certain commodity, based on bio-physical criteria. In a suitability analysis using GIS, suitability degree of a commodity to its environment could be resulted from comparison between the actual bio-physical conditions with the suitability criteria. Such comparison could be done by processes of matching, scoring, or application of a weighted index. The processes of matching, scoring or application of weighted index, in general is done by overlying of the attribute data added.

2 Methodology

2.1 Study Site

This research is done in Maros, South Sulawesi, Indonesia. The research area is located at latitude of 4°45' - 5° S and longitude of 109° 21' - 119° 42' 30'' E. Total area of Maros is around 1.613.11 km^2.

2.2 Suitability Parameters

Parameters used for suitability analysis in this research come from primary data (field survey), Landsat image interpretation, and secondary data (existing map). Field campaign was done on August 2004 during 8 days. At the field campaign, some soil samples was collected, the existing shrimp-pond was ground-checked. The secondary data used, which consist of topographical map, geological map, soil map and agro-ecological zone map, were collected from database of Center for Marine Surveys, BAKOSURTANAL. Landsat imagery was interpreted in terms of landform and landuse.

2.3 Overlay Method

Suitability degree of bio-physical parameter could be defined in several classes: S1 class (very suitable), S2 class (suitable), S3 (marginally suitable) and N (not suitable) (FAO, 1986 *in* Widiatmaka & Hardjowigeno, 2007). Quantified as numerical notation in percentage (for example percentage of production), S1 class is the class having the value between 80 – 100, S2 class is a class between 60 – 80, S3 class is a class between 40 – 60 and N class is a class below 40. Comparing between bio-physical characteristic and suitability criteria, the weight of the parameter should be fixed. Using overlay method, zonation of suitability can then be determined.

In scoring method, the first step of suitability analysis is giving the weight to each of bio-physical parameter by comparation with suitability criteria. If a bio-physical parameter is going to S1 class, it should have a value of 100. The S2 class has a value of 80, S3 class has a value of 60 and N class has a value of 40. This step is illustrated in Fig. 1.

The step after, all of the bio-physical factors having a value is summed or overlie. Average value could be calculated as:

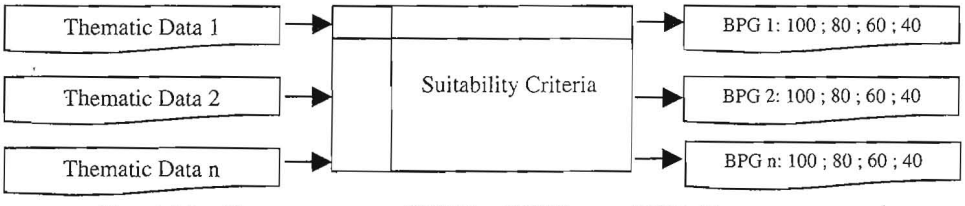
$$\text{Scoring average} = (HBF1 + HBF2 + \ldots + HBFn)/n$$

$$\text{Weighted Index} = a*HBF1 + b*HBF2 + \ldots + m*HBFn$$

with HBF1, HBF2,...,HBFn are bio-physical grade (value); a,b,...,m are indexes in which the value depend on its contribution of biophysical parameter to suitability.

According to the value resulted from such equation, the suitability for shrimp-ponds culture could be defined as:

- Highly suitable, if score average or weighted index have a value >= 80
- Suitable, if score average or weighted index have a value between 60 – 79
- Marginally suitable, if score average or weighted index have a value between 40 – 59
- Unsuitable, if score average or weighted indexes have a value < 40.



average ("matching") **= (HBF1 + HBF2+ ... +HBFn)/n**

Weighted Index ("scoring") **= a*HBF1+ b*HBF2+ ... +m*HBFn**

HBF1, HBF2,...,HBFn : Bio-Physical Grade, a,b,...,m is an index, which value depend on its contribution to the suitability

Figure 1. Parameters Overlay

In overlay analysis using matching method, all bio-physical parameters are considered as have the same weight or have equal contribution in determining suitability class.

3 Result and Discussion

3.1 Suitability Criteria Development

In this research, a literature study has been done to develop criteria for shrimp-pond evaluation (Boyd, 1990; Pramomo, 1988; Ahmad & Mangampa, 2000). The parameter should be parameters which allow to be assessed by using GIS. This study result on the criteria, mentioned in Table 1. The parameters could be grouped into 4 groups of parameters. They are (i) Locational Parameters Group, (ii) Topographical Parameters Group, (iii) Substratum Parameters Group, and (iv) Landuse/Land cover Parameters Group.

Table 1. Suitability Criteria for Shrimp-pond Culture

Parameters	Suitability				Score*)
	S1	S2	S3	N	
Locational Parameters					
Distance from coastline (km)	0 - 5	5 – 6	6 - 7	> 7	20
Distance from Ordo-0 rivers (m)	0 – 500	500 – 800	800 – 1100	> 1100	
Topographical Parameters					
Slope	0-2%	2-3%	3-8%	> 8%	20
Height above sea level (m)	0 - 10	10 - 20	20 - 30	> 30	20
Substratum Parameters					
Lithology	Qac	Temt	Tme	Tmet, Tmcv	10
Soil Great-group	Entisol, Inceptisol	Entisol, Inceptisol	Ultisol	Oxisol, Organosol	10
Landuse/landcover Parameters					
Land Unit	F7, F11, M4, M10, M14	F5, F12, F13	-	D1, D3, D15, S1, S2	10
Landuse	ponds, rice field, swamp, forest	-	-	setlement, sand	10
Total Score					100

*) in case scoring method is used

3.2 Suitability Criteria for shrimp-pond culture based on Locational Parameters

Locational parameters used include the parameter of "distance from coastline" and "distance from ordo-0 river". Shrimp-pond culture is a type of land utilization which is influenced by sea water supply. Field survey indicates that in study area, in existing topographical situation, the existing shrimp-ponds could atteint 7 km distance from coast-line. Related with social economic survey in term of production of ponds, the criteria has fixed as: 0 – 5 km, 5 – 6 km, and 6 – 7 km, each for suitability of S1, S2 and S3. In other, shrimp-pond could be found at distance more than 7 km, if the location is affected by tidal range by river. For that reason, it has been decided to include the criteria of "distance from ordo-0 river". Again, related to socio-economic survey, the criteria are fixed at: 0 – 500 m, 500 – 800 m, and 800 – 1100 m as S1, S2 and S3 grade of suitability.

Combination of these two locational parameters should consider the location of the intersection between these two parameters. In the intersection, the logic of "water flow" is used: in each intersection, the strongest influence, either from the river or from the sea are decisive for suitability class. It should be noted also, that for the reason of overlay facility, this two parameters is unified as 1 shapefile.

3.2.1 Suitability classification by topographical parameters

Topographical parameters used in this research are class of slope and class of height above sea level (a.s.l.). Class of slope is derived from contour map. Suitability according to class of slope is defined as: S1 (0 – 2 %), S2 (2 – 3%) and N (> 3 %). Parameter of height a.s.l. for this research is defined as: S1 (0 – 10 m), S2 (10 – 20 m), S3 (20 – 30 m) and N (> 30 m). Such values are obtained by considering the result of field checking.

3.2.2 Suitability Classification by Substratum Parameters

Substratum parameters used are soil and geology. Geological parameter was obtained from Sukamto (1982). For soil parameter, suitability classification could not be done in detail by using soil map, for the reason of soil map availability. Soil map available is Agro-ecological zone Map (SRI, 2002). In this map (scale 1 : 250.000), the soil unit is too rough to be considered. However, the assignment of suitability according to soil unit was done with respect to agro-ecological zone legend. Such legend include regime of soil moisture, physiography, soil drainage and development of zonation system.

In other, the suitability assignment for soil unit is also done with respect to the result of laboratory soil analysis, as well as field survey, which has been done for each soil unit map. From field survey, it is known that the soil and geological substratum in coast region do not contain pyrite, and soil texture is relatively fine. This fact indicates that in the coast of this region, soil factor does not a limiting factor for shrimp-pond development. For upland soil several soil map units are assign as N because the soil map include Oxisol and Ultisol, which soil structure, soil texture and its high contain of Al exchangeable is not favorable for shrimp-pond culture.

3.2.3 Suitability Classification by Land covers Parameters

Landform parameter is obtained from Landsat imagery interpretation according to landform classification of Dessaunettes (1981, *in* Widiatmaka & Hardjowigeno, 2001). Landforms which are considered as suitable for shrimp-pond culture are group of marine and fluvial landforms. For that reason, such landforms are assigned as class S1 to S3. Structural and Denudasional landform are assigned as unsuitable for shrimp-pond culture.

Parameter of landuse is also obtained from Landsat interpretation. Landuse existing in research area consist of settlement, agricultural land, forest, sand and ponds. The existing pond is assigned as S1. Agricultural land and forest because of its possibility to be converted to ponds (this fact is generally found in location), are also assigned as S3.

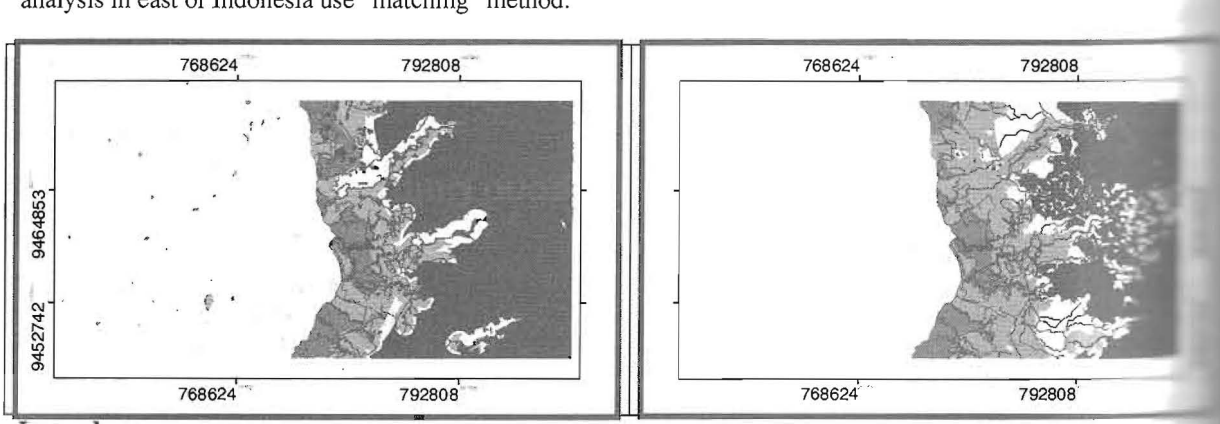
3.2.4 Overlay of Suitability Parameters

From each parameter which has been assigned their suitability class, overlay are then done. Fig. 2 present the result of parameter overlay by "matching" method and "scoring" method.

These two overlay method result in regional class of suitability for shrimp-pond culture which could be considered "good". They result of regional structure of suitability "radier" to coast-line, describing that locational aspect distance from the sea determine the result of suitability for shrimp-pond culture. Inside this radier structure, appear the suitable location going more far to upland, describing locational effect of sea water intake by river.

Comparing the quality of these two overlay method, it could be mentioned some disadvantage in scoring method. With this method, it appears some class "suitable" in the region which topographically located in upland. These do not coincide with field data. Contrarily, land use "settlement", with class "unsuitable" does not appear in this method. These facts appear because slope parameter could not be eliminated by weight factor used in scoring method.

These facts indicate that result of suitability assignment is rigorously depending on expertise judgment. which is often subjective. For this reason, for instance, analysis of suitability used by BAKOSURTANAL for marine culture analysis in east of Indonesia use "matching" method.



Legend:

Figure 2. Overlay "matching" (left) and Overlay "scoring" (right)

Conclusions

In this research, the locational suitability for shrimp-pond culture has been evaluated. The criteria have been developed based on literature study. The parameter used are obtained from field survey, secondary data including existing map, and image interpretation, and consider uniquely the parameter which could be assessed by using GIS. The parameter used could be grouped into 4 groups of parameters, they are locational, topographical, substratum and landuse/landcover groups of parameters.

Parameter overlay is evaluated by "*matching*" and "*scoring*" method. Overlay parameter by "matching" method is judged more reasonable to be used with respect to the result of suitability to shrimp-pond culture. Scoring method is very depending on expertise judgment, especially in assigning the weight of parameters.

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