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Evaluation of Land Suitability for Brackishwatershrimp Farming using GIS in Mahakam Delta, Indonesia

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Abstract
This paper briefly described land evaluation of shrimp farming development in Mahakam Delta, discusses its ecological and socio-economic impacts and recommends measures to achieve long term sustainability using Geographic Information System (GIS). The objectives of this research were to know land evaluation based on suitability for brackish water aquaculture and optimal utilazation level. This reserarch was conducted at Mahakam Delta Sub Distric Kutai Kartanegara; East Kalimantan. Surveys have been done collected primary data, while secondary data was obtained from related institution and needed maps for GIS analysis, with overlying map and primary data in each station observation with considering and assessment scale value of determining land suitability for brackish water pond using AHP method.The result of GIS analysis had been obtained the land suitability at Mahakam Delta, area of highly suitable for shrimp pond was 1,185 ha (3.02%), suitable was 32,137 ha (81.93%), and not suitable was 5,905 ha (15.05 %) of 39,226 ha total land area that was studied. It can be concluded the sites with generality were suitable based on potential for pond construction, water availability, and water quality but not suitable for soil quality and infrastructure facilities.
Keywords: GIS, Land suitability, Shrimp pond, Analytic Hierarchy Process (AHP), Land use evaluation

1. Introduction

Land evaluation is formally defined as 'the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation' (FAO, 1976). Land evaluation is very important because the land has the physical, social, economic, and varied geography (Rossiter, D.G. 1996). Varying nature of the land may affect the use of land. Therefore many variables are involved while selecting a suitable site in this study.

It is now possible to assess the suitability of multiple sites in a rapid and systematic way to enhance the planned progression of land-based coastal aquaculture towards a more sustainable future with geographic information systems (GIS) (Mcleod I, 2002). GIS has been widely used for evaluating sites for various cultured species and environments, e.g., Aguilar-Manjarrez and Ross, 1995, described the use of a geographical information system (GIS) to construct environmental models for land-based aquaculture development in the State of Sinaloa, Mexico.Giap, D.H., Yi, Y., Yakupitiyage, A., 2005,to identify appropriate sites for shrimp farming development in Haiphong province of Vietnam using geographical information systems (GIS). The objective of this study was to evaluate of land suitability for shrimp pond in the mahakam delta using GIS techniquest.Shrimp farming in the Mahakam delta has lasted for more and less 25 years and present it has experienced a significant decline in production .A land evaluation program was implemented to determine land suitability and limiting factors for brackish water pond production as an effort to elevate productivity and to propose appropriate management practices.

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2. Materials and Method

2.1 Description of the study area

The Mahakam Delta is located on the east coast of the island of Borneo in position 117 0 15 '- 117 0 40' east longitude and 0 0 21 '- 1 0 10' south latitude. Administratively located in the Kutai Kartanegara regency. The Mahakam Delta consists of 46 small islands. It is divided to 5 (five) subdistricts. Those subdistricts above are Samboja, MuaraJawa, Sanga-Sanga, MuaraBadak and Anggana. Covering an area of 110,000 ha.

Mahakam delta is included in climate type A, a classification based on Schmidt – Fergusson classification, in which the number of wet months (rainfall ≥ 100 mm) greater than the dry months (rainfall ≤ 60 mm). The rainy season occurs in December to April, while the dry season from May to January. Monsoon winds are dominant eastern and western monsoon. While the air humidity is high.

Mahakam delta region is alluvial, fan-shaped with outer suburbs that make up nearly half the loop, which occurs through the process of sedimentation since 5,000 years ago. Geo- morphologically delta consists of the mainland (brackish muddy swamps. It divided into pro delta, delta front and deltaic plain. Pro delta is the deeper area bordering the delta with the Makassar Strait. Front delta is the deltaic fringe immerged at high tide and is a major area for sediment deposition. The deltaic plain consists of many small deltaic inlands separated by tributary channels where freshwater from the river and salt water from the sea are mixed and flows through(Bappeda Kukar,2003).

2.2 GIS software

The GIS software used this study was the Arc Gis 10 from The Environmental Systems Research Institute(ESRI), USA, 2011.

2.3 Remotely sensed data and thematic maps

The secondary data sources were SPOT satellite imagery 2011 and Fishpond map 2007 from PT. Total Fina Elf Indonesie,Administration map and Land use map (ALOS 2011) from Bappeda Kutai Kartanegara. Digital topographic maps of study area with a scale of 1 : 50,000 from the National Agency for Survey and Mapping.

2.4 Weight and score

Suitability ratings were established according to FAO classification and other references on the appropriateness of land for defined uses. The range of land characteristics was divided into three classes: (i) Highly suitable (HS = 3), (ii) Suitable (S=2) and (iii) NotSuitable (NS=1) on the basis of requirement for shrimp pond. There are many factors to select the suitable area for shrimp pond. The present study focused on some basic factors such as soil quality, water quality, infrastructure and socio-economic, potential for pond construction and water availability. Weight has been given according to the effectiveness of the criteria, Each class has also given a score according to the level of suitability (Table 1).

Figure 1. Mahakam Delta in Kutai Kartanegara regency, East Kalimantan,Indonesia

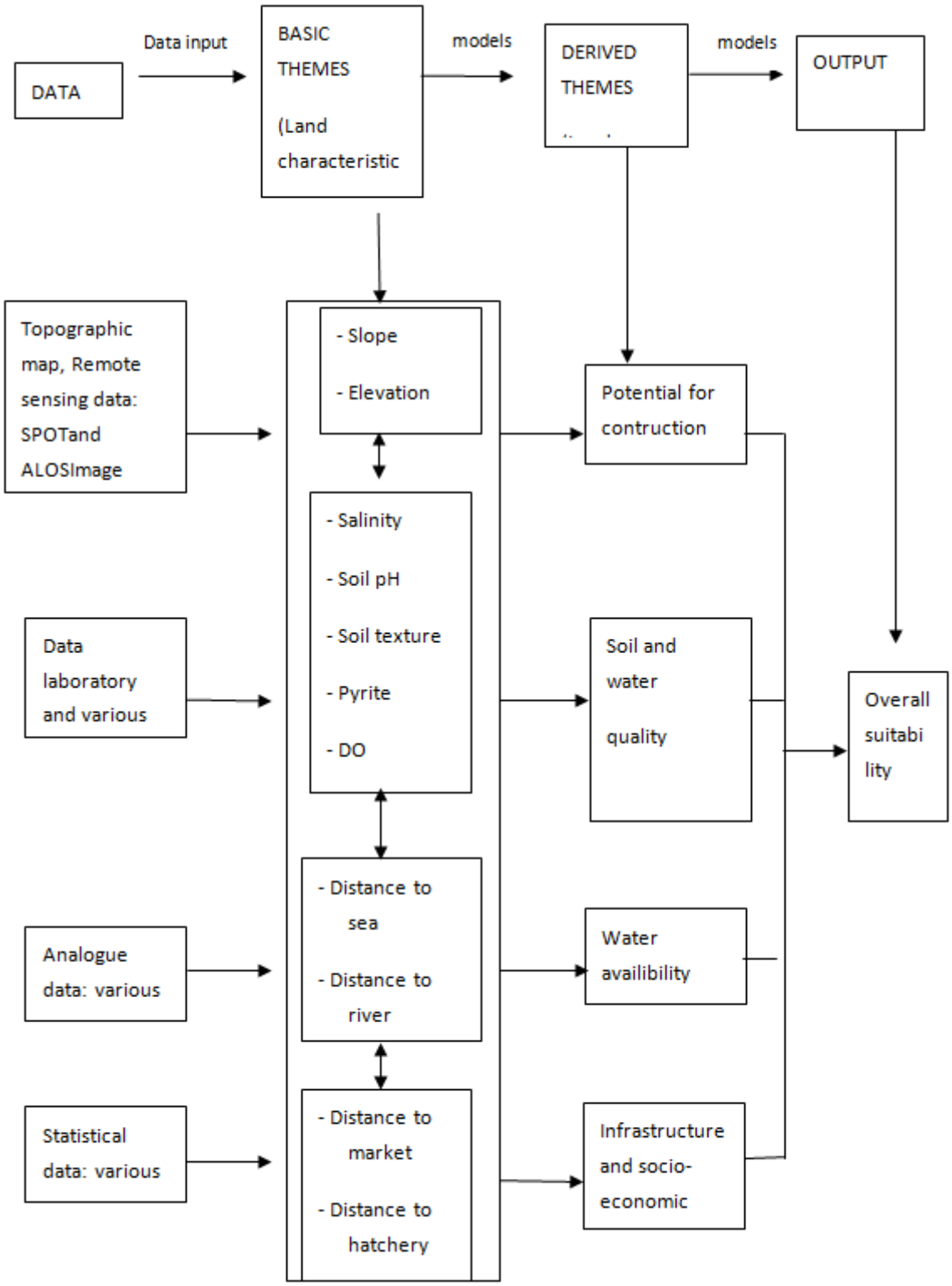


Figure 2. Schematic model of land suitability for shrimp farming in Mahakam Delta(Modification of Giap,*et.al,*2007 model)

Table 1 Weighting and scoring of land characteristic for shrimp pond

Criteria	References	Class		
		High Suitable (HS)	Intermediate Suitable (IS)	Low Suitable (LS)
		Score		
		3	2	1
Clay contents	FAO(2002)	> 35	18 – 35	< 18
Soil pH	New(2002), Hossain *et al*(2003b)	6 - 8	4-6, 8-9	>9 ; <4
salinity	FAO	15 - 20	> 20 – 35	>35 ; 0 - < 10
Pyrite	FAO	Nothing	< 1.0	> 1.0
Slope (%)	Giap*et al*(2005) Hossain*et al* (2009)	0 - 2	2-5	>5
Elevation	Giap*et al*(2005)	2.0 – 2.5	2.5-4 or 1- 2	>4
Distance to river (m)	Distance to river (m)	0 - 1000	1000 – 2000	2000-3000
Distance to sea (km)	Giap*et al*(2005)	<1	1 - 2	>2
Distance to market(m)	Giap*et al*(2005) Hossain*et al* (2007, 2009)	< 2000	2000-4000	> 4000
Distance to hatchery(Km)	Salam *et al*(2005), Hossain*et al* (2007, 2009), New(2002).	< 2000	2000-4000	> 4000
DO	Janssen et al(1988)	4 - 7	2.5 - 4	<2.5

The weight for each factor was determined by pair-wise comparisons in the context of a decision-making process known as the analytical hierarchy process (AHP). AHP is based on different evaluation scales to determine the importance of alternatives regarding each criterion and criteria weights. All the weights are calculated through pair-wise comparison based on a one to nine scale for quantifying verbal expressions. These expressions describe the strength of importance among alternatives or criterion. Much criticism has been towards the ranking of weights which reflects the relative importance of alternatives in a multi-attribute judgment problem.(Saaty, 1980). .

Table 2. A pair-wise comparison matrix for assessing the relative importance of land characteristic factors for each land use requirement (number show the ratings of the row factor relative to the column factor). Based on expert opinions

	Soil quality	Potential for pond construction	Water availability	Infrastructure and socio-economic factors	Water quality	Weight
Land suitability for shrimp farming						
Soil quality	1	2	8	2	1	0.33
Potential for pond construction	1/2	1	2	1	1/2	0.14
Water availability	1/8	1/2	1	1/3	1/4	0.06
Infrastructure and socio-economic factors	1/2	1	3	1	1/2	0.17
Water Quality	1	2	4	2	1	0.30
Total	3.125	6.5	18	5.33	3.25	1

Consistency ratio (C.R.) = 0.02

3. Results and Discussion

3.1 Results

The classified areas for five land requisites containing 11 land characteristics are summarized in Fig 3. The highly suitable areas not founded for shrimp pond are recognized as those with soil of good quality (pH soil : 6 – 8 and no pyrite).

The most suitable areas with regard to topography were found 23 % of the land area along the coastal embankment with low slope (0 – 2 %) and elevation of less than 2.5 m with appropriate with access to water.

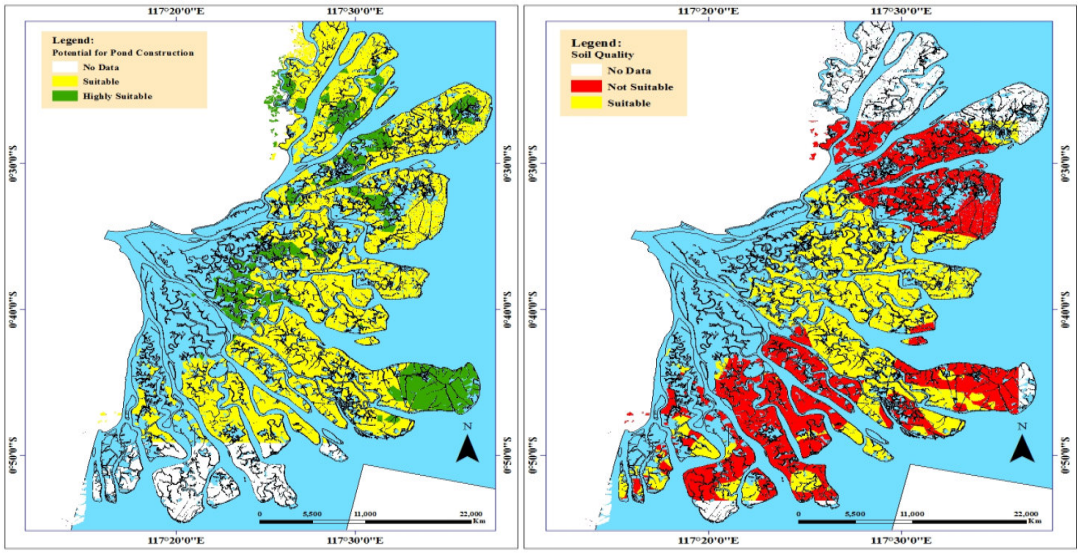
In terms of water availability almost 72% of total shrimp pond area was suitable for shrimp farming and 22 % was highly suitable, only 6.5% not suitable

Infrastructure and socio-economic factors such as availability of sources of shrimp fry and easily accessible well-established marketing facilities of shrimp farming development in the study area, approximately 100% of the total area were classified as not suitable for shrimp farming.

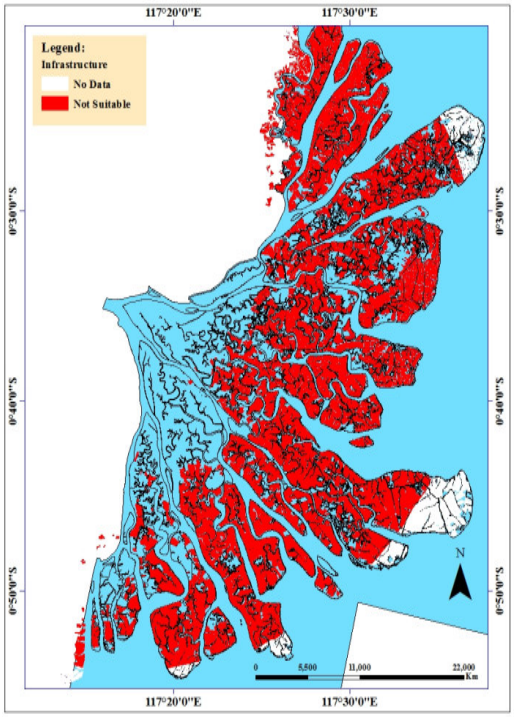
Total land area with water of good quality which is salinity (15 – 20 ppt), and well-oxygenated /DO (4 – 7 mg/l) approximately 27 % washighly suitable for shrimp pond, 55% was suitable and 17% not suitable (table 3).

Table 3. Areas (ha) and different suitability levels (%) of land for shrimp farming in the study area (total land area is 39226.38 Ha).

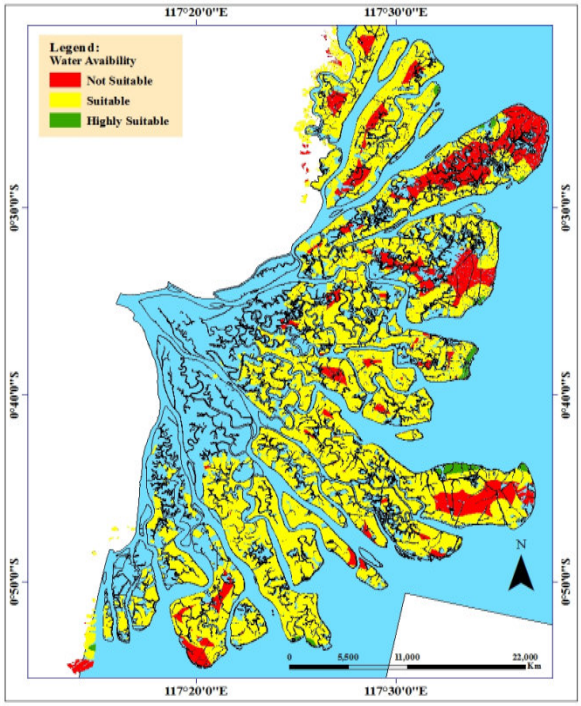
Land use requirement/land characteristics	Highly suitable		Suitable		Not suitable	
	(Hectare(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Soil quality	0	0	10097.83	25.74	29128.55	74.26
Potential for pond construction	9082.83	23.15	30143.55	76.84	0	0
Water availability	8525.10	21.73	28142.98	71.74	2558.30	6.52
Infrastructure and socio-economic factors	0	0	0	0	39226.38	100
Water quality	10634.14	27.11	21768.67	55.49	6823.56	17.39
Overall suitability	1184.71	3.02	32136.67	81.93	5905.00	15.05



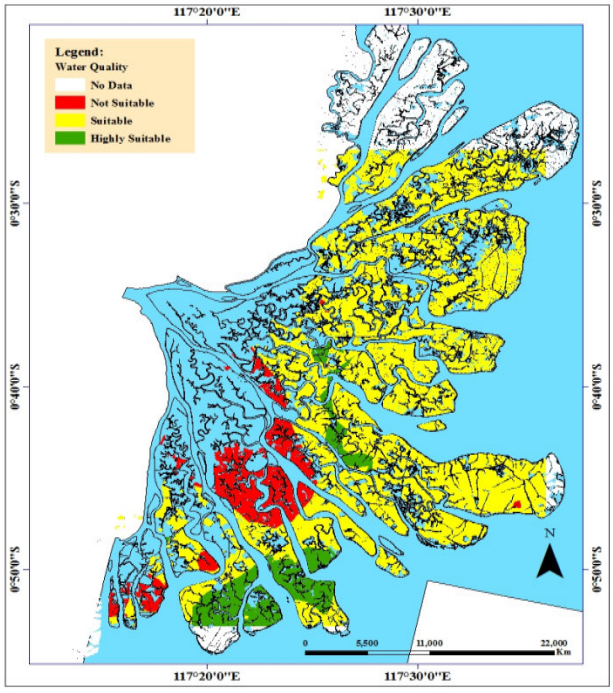
Potential for pond construction **Soil quality**



Infrastructure and Socio-Economic



Water availability



Water quality

Figure 3. Suitability maps of different land use requirements for shrimp farming

From the analysis can be concluded that area of highly suitable for shrimp pond was1,185 Ha, suitable was 32,107Ha, and not suitable was 5,905 Ha of 39,226 Ha total land area that was studied (Fig. 4).

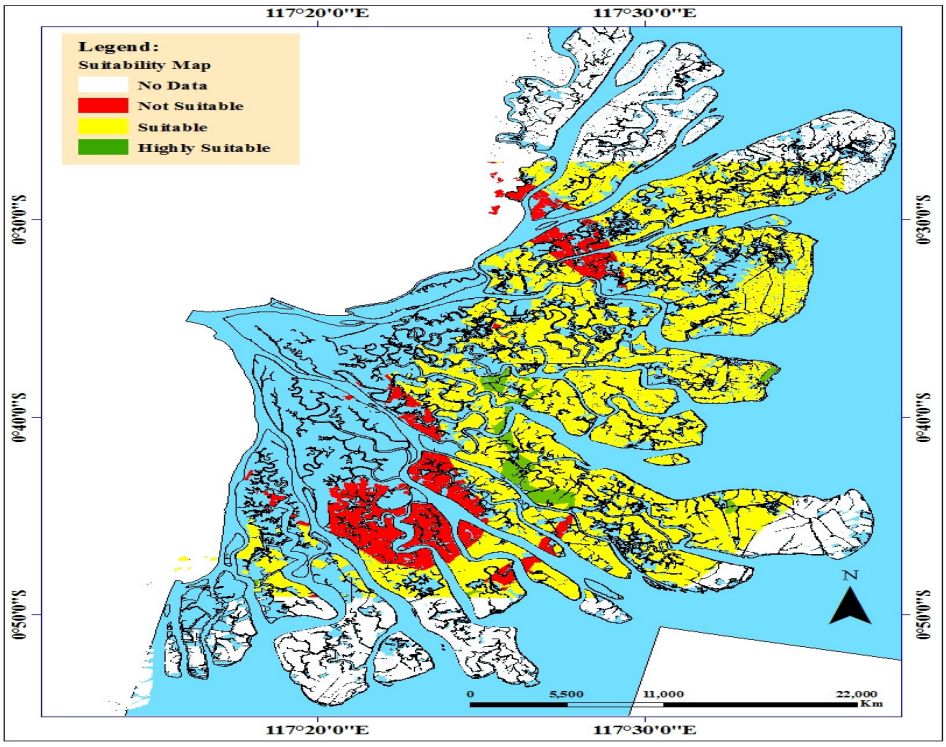


Figure 4. Overall land suitability map for shrimp farming in the Mahakam Delta

3.2 Discussion

This study suggest that land should be divided into three different zones on the basis of suitability for shrimp pond, i.e. highly suitable, suitable and not suitable zones. The zoning approach can provide important information enabling potential development to identify suitable zones that meet requirements ensuring maximum benefit for a long period. Zoning of land and water for shrimp farming development can help in the control of environmental deterioration at the shrimp farming level and in the avoidance of adverse social and environmental interactions.

Shrimp farming activities exists in Mahakam Delta since 1980, with type of the pond is traditional (no feed is put on the pond) on 4 – 7 Ha area (some are 10-30 Ha). Shrimp pond productivity in 2006 (average : 40 kg, minimum : 20 kg and maximum : 350 kg / Ha/ harvest (FPIK,2006). Based on interviews with farmers this time, productivity has declined dramatically from previously, 3 Ha could produce 1 ton every one harvest now only capable of 50 - 100 kg, and the harvest only once or twice a year. This figure is much lower when compared to average of traditional pond in Indonesia (600 – 1000 kg / Ha / harvest(DKP,2007)There are many factors that result in decreased productivity. The main factors are (i) no best practice nor irrigation system (only 1 water gate for inlet, (ii) use of wide area and (iii) no management and maintenance during culturealso (iv) the age of shrimp pond was very old, the age of the shrimp ponds between 15 - 25 years old, so the shrimp pond no longer suitable for shrimp farming which caused a high content of pyrite and the outbreak of disease.

The main limiting factor of land suitability for shrimp pond in Mahakam Delta is soil quality. Most of the land area is not suitable (74 %). The characteristics of soil in the ex-Nypa area are acid sulphate soil indicated with low pH, high concentration of organic matters and pyrite(Hopley, D. 1999). Influence of low soil pH cause phosphorus do not available for the growth of natural food because absorbed by iron and aluminum. Increasing of pH can be done with remediation. It is an activity or process which is done to reduce the toxic elements in the soil namely soil management, soil drying, soil flooding, flushing, and then liming.

4. Conclusion

From the results ofthe study, showedthat thecompliance of land for shrimp farming have declined due declining of soil qualityof shrimp pond. The main problem of declining soil quality pond is an old age of the pond so that toxins accumulate in the soil. To overcome the problem required a comprehensive land management and needed remediation of ponds.

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