The GIS Application of Marine Protected Area Site Selection, in Trenggalek, East Java Province

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Abstract—**Marine Protected Area (MPA) is one of the best tools for maintaining coastal fisheries sustainability. District of Trenggalek, which has 96 km coastline and 57 small islands, categorized as one of most productive coastal areas in Southern coast of East Java. On the other hand, the demand of MPA in this region become urgent as the decline on its coastal natural resources in recent years. Methods used in this research include: site suitability analysis using GIS multi-criteria analysis, divided into three criteria: ecology, socio-cultural and economy. Ecological survey and data ground check conducted in three locations, Bay of Panggul (Panggul), Bay of Sumbreng (Munjungan) and Bay of Prigi (Watulimo). Focus Group Discussion (FGD) with key stakeholders to obtain more precise information, continued with set of scoring and weighting (data analysis) to obtain MPA's site suitability and category. The results show high suitability areas for MPA includes Wonocoyo, Munjungan, Karanggandu and Karanggongso. Each site has a high value in ecological criteria (ecosystem and biodiversity),** social criteria (social acceptance) and economic criteria (importance to species and value for marine tourism).

Keywords—Coastal conservation, environmental planning, GIS, mangrove, coral reef

I. INTRODUCTION

Marine Protected Area (MPA) or Marine Conservation Area (MCA) describes as the areas of waters including flora, fauna, cultural and historical patterns associated with all variables mentioned, are protected by law or other effective policies, which aimed to protect part or all of the surrounding environment (Kelleher, 1999). Clark (1996) describes the purpose of MPA, includes (1) maintaining the quality of the environment, (2) Protecting species diversity, (3) protect ecologically sensitive areas, (4) protecting critical habitat and (4) the adaptive strategies of hazards through conservation.

Need of MPA is unavoidable, because of the condition of world fisheries are already hugely depleted (FAO, 2008). Roberts (2007) stated that to obtain 1 kg of fish consumption, fishermen have destroyed more than 20 kg of fish resources includes their habitat.

In Indonesia, MPA is the main program of coastal resource management. Reference legislation used for MPA includes Law No. 31/2004, as revised by Law No. 45/2009 on Fisheries, Law No. 32/2014 on Local Government, Law No.27/2007 jo Law No.1/2014 on the Management of Coastal Areas and Small Islands, and some of Regulation Government (PP), includes PP 30/2010 on Zoning Management Plan and Water Conservation Area.

POKMASWAS is a local community inspector group, which is a component of society that could potentially participate actively in fisheries surveillance and may consist of elements of religion, elements of traditional, fishermen, farmers and entrepreneurs in the field of fisheries. POKMASWAS establishment constituted by Law No. 31/2004 Article 67 on Fisheries; Law No. 32/2004 on Regional Government; Regulation of the Minister of Marine Affairs and Fisheries No. KEP.58/MEN/2002 on SISWASMAS (Supervisory Systems Society). In fact, POKMASWAS plays a vital part in the monitoring the use of coastal natural resources, which is the heart of coastal conservation.

II. METHOD

MPA site selection variables based on Government Decree No. 60/2007 Article 8, paragraph 3 consist of following criteria: (A) Ecology: include biodiversity, naturalness, ecological relevance, representativeness, uniqueness, productivity, migratory habitat, protected fish habitat, fish spawning areas, and areas of care; (B) Social and cultural: include the level of community support, potential conflicts of interest, potential threats, local wisdom and customs; and (C) Economy: include the importance of fisheries, recreation and tourism potential, aesthetics, and ease of reaching the region. This criteria similar with Salm et al. (2000).

TABLE I. MPA SITE SELECTION CRITERIA

Criteria		Score		
		3= highly suitable	2= moderate suitable	1= less suitable
Ecological criteria	Biodiversity (H')	H'>3	H' 1 – 3	H' <1
	Naturalness (Or)	Or >75%	Or 50 – 75%	<75%
	Ecological linkage	75 – 100%	50 – 74%	<50%
	Representativeness (Pr)	75 – 100%	40 – 74%	<40%
	Uniqueness	Unique	Moderate	Not unique
	Productivity	>1200 kg/Ha	600 – 1200 kg/Ha	<600 kg/Ha
	Migratory habitat	>1 Sp migratory	1 Sp migratory	No Sp migratory
	Endemic/protected	>2 Species	1 – 2	1 Species

Criteria	Score		
	3= highly suitable	2= moderate suitable	1= less suitable
species habitat		Species	
Spawning ground	>2 areas	2 areas	1 area
Nursery ground	Mangrove and seaweed	Mangrove or seaweed	None

Source: KKP, 2016

Criteria		Score		
		3= highly suitable	2= moderate suitable	1= less suitable
Social criteria	Social acceptance	>75%	40 – 75%	<40%
	Threat	<2 threats	2 – 5 threats	>5 threats
	Potential conflict	Low	Moderate	High
	Local customs	Effective	Less Effective	Not available
Economic criteria	Fisheries importance (LQ)	>1	1	<1
	Tourism value	>3	1 – 3	Not available
	Ease of access	≥75%	41 – 74%	≤40%

Source: KKP, 2016

Prior to the field survey, several satellite images processing performed to identify critical habitat, especially mangrove and coral reef, as presented in the following table.

TABLE II. MAPS, SATELLITE IMAGERY AND PROCESSING METHODS

No.	Maps	Satellite image	Methods
1	Mangrove	Landsat 8 OLI	False color composite band 564
2	Coral reef	Landsat 8 OLI	Lyzenga algorithm (Lyzenga, 1978)
3	Topography	SRTM/TOPEX Poseidon	Contour extraction
4	Bathymetri	Topex Poseidon (2015)	Contour extraction
5	Land Use-Land Cover	Landsat 8 OLI	Supervised classification
6	Road	RBI Database (BIG, 2014)	Vector analysis
8	Administrative	RBI Database (BIG, 2014)	Vector analysis

Coastal critical habitat which categorized as conservation feature made up of mangroves and coral reefs, analyzed using false color band combination (5-6-4) and Lyzenga algorithm respectively. The image classification was done by observing the differences in the spectral responses and image contrast. Visual analysis is done to improve the accuracy in the identification of habitat locations, using both habitat and topo-bathymetric maps combined with Google Earth. Land Use-Land Cover (LU-LC) mapping was performed by maximum supervised likelihood algorithm.

There are four sites selected for the field survey, based on the reference obtained from image analysis, includes Wonocoyo village (located in Bay of Panggul), Munjungan village (Bay of Sumbreng), Karanggandu and Tasikmadu villages (Bay of Prigi).
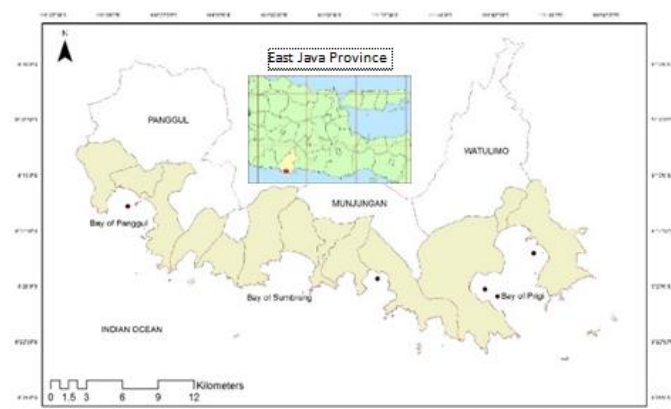

Fig. 1. Map of study areas.

The locations visited in October 2016 to obtain more in-depth information related to the MPA criteria. Ecological survey for mangrove and coral reef refers to standard survey methods from English, et al. (1997), while socio-economic informations obtained from interviews with key-stakeholders (POKMASWAS) and local communities. POKMASWAS role as key stakeholders who assumed to provide in-depth information on social situations. Other stakeholders involved are regional government (Department of Marine Affairs and Fisheries of Trenggalek) and local communities.
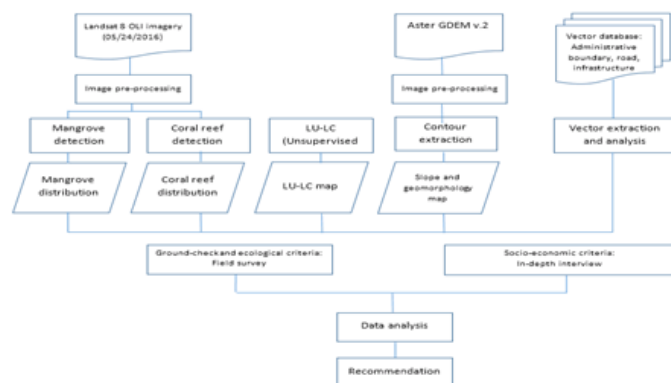

Fig. 2. Data processing and field observation.

III. FINDING AND DISCUSSIONS

A. *Geomorphology and coastal ecosystems*

Geomorphological map extracted from Aster GDEM v.2 indicates the hilly contours along coast of Trenggalek, reflected a typical characteristics of uplifted landforms from the result of tectonic formations, which located near plate subduction zone, southern coast of Java. The coastal landforms characterized by small bays bounded by cliff coasts with strong hydro-oceanography and dissipative regions. Contour roughness causing difficulty of road access to the most beach in Trenggalek. Gentle slopes located in the divergence zone of the four biggest bays, the Panggul, Sumbreng, Damas and Prigi at the center of human activity and ruled as capital of all three coastal districts (Panggul, Munjungan and Watulimo). This condition produces patchy distribution in coastal ecosystems. Substrate predominantly composed by sand. Water quality visually categorized in good conditions, characterized by a high brightness and the lack of discharge from major rivers.
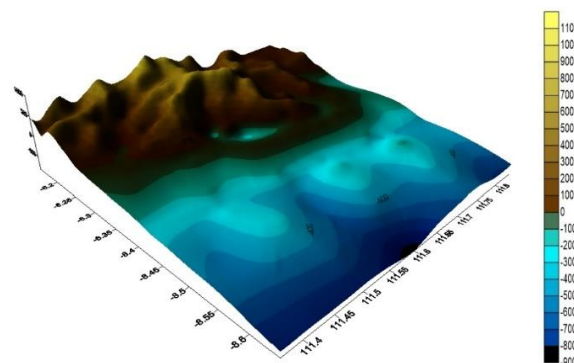

Fig. 3. Slope and bathymetry map of Trenggalek

From the false color composite, the mangrove can be differentiated from other features such as terrestrial forest, agriculture area and human settlements. Visual interpretation from Landsat 8 OLI imagery identify the mangrove distribution along coast of Trenggalek with a total area of 44 Ha. Biggest extent of mangrove located in Pancer Cengkrong, mudflat region in Watulimo sub-district (44 Ha).
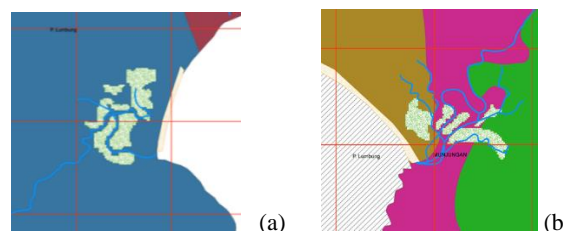

Fig. 4. a) Mangrove distributions in Blado (Munjungan) and b) Pancer Cengkrong (Watulimo).

Coral reefs are scattered particularly in the sheltered regions, with an area of narrow, elongated in the front of the cliffs or surrounding the rock islands. An abundant amount of cliff caves, sea stacks and wave-cut formations alongside Trenggalek coasts provide favorable habitats for lobster (Panulirus spp.). All three coastal habitats (mangroves, coral reef and lobster's cliff caves) formed categorized as primary conservation features in coastal ecosystems of Trenggalek. Field survey resulted in the identification of ecological conditions at each location, as presented in Table 3.

TABLE III. FIELD SURVEY RESULT FOR ECOLOGICAL CRITERIA

Variable	Regions			
	Panggul	Munjungan	Watulimo	
	T. Kili Kili	Munjungan	Karanggandu	Tasikmadu
Naturalness	> 75% The Isle of Godho is the primary habitat for lobster and coral reef. Coastal vegetation in turtle nesting sites includes rehabilitation area of *P. tectorius* and *C.equisetifolia*	>75% Most part of coral reefs (in Bendoroto) and mangrove in Blado categorized as natural habitat	<40% Mangrove Pancer Cengkrong rehabilitation area since 2002	>75% Reef in Isle of Rembeng, Karang Malang and Songdruwo beach categorized as natural. Coral transplantation located in Besetan beach
Diversity	Moderate	Moderate	Moderate	moderate
Ecological linkage	Kili Kili: highly suitable as turtle landing and nesting site Isle of Godho: favorable habitat for lobster	Blado estuary: riverine mangrove Bendoroto: high suitability for coral reef habitat	Pancer Cengkrong: largest mudflat for true mangrove (*C. decandra, A. marina, Xylocarpus sp.* and *S.*	Carbonate deposit substrate and sheltered region in Karanggongso as ideal habitat for coral reef, reef fish,lobster and megabenthos
Representative ness	>75% Kili Kili: sandy beach completed with *P. tectorius* Isle of Godho: rock isle with sea cave	>75% Blado: River with high organic matter deposit Bendoroto: sheltered bay and bedrock formations Cliff coasts and offshore isles of rocks, plays as isolated lowlands forest for seabirds and wildlife	>75% Intertidal mudflat with mangrove vegetation	>75% Sandy beach and isle of rocks in the sheltered regions
Uniqueness	Lobster habitat and turtle nesting site might be abundant in eastern parts of Indonesia, but left in small numbers in Java	Lobster and small isle habitat might be abundant in eastern parts of Indonesia, but left in small numbers in Java	Semi-natural mangrove found abundant in Indonesia	Lobster and small isle habitat might be abundant in eastern parts of Indonesia, but left in small numbers in Java
Productivity	Difficulties in empirical data, but information about the ease of lobster fishing from local fishermen could be represent the actual conditions	Difficulties in empirical data, but information about the ease of lobster fishing from local fishermen could be represent the actual conditions	Difficulties in empirical data, but information about the abundant of mangrove crabs could be represent the actual conditions	Difficulties in empirical data, but information about the reef fish valuable species from local fishermen could be represent the actual conditions
Migratory areas	Sea turtle and marine mammals	Glass eel	Mangrove	Marine mammals
Endemic/protected species habitat	Sea turtle (IUCN red list)	n/a	n/a	High economic value of reef fishes
Spawning ground	Isle of rock and coral reef	Mangrove, coral reef and cliff coasts	Mangrove	Coral reef and isle of rocks
Nursery ground	Isle of rock and coral reef	Mangrove, coral reef and cliff coasts	Mangrove	Coral reef and isle of rocks

B. *Social criteria*

Social acceptance (represented by POKMASWAS performances) could be the most decisive variable, which describe involvement of local communities in the coastal conservation activities. Depth interviews with POKMAWAS in each region show four sites which classified as good management and potentially proposed for the MPA management, includes POKMASWAS Taman Kili Kili (Bay of Panggul Region, Panggul), POKMASWAS Bintang Panikan (Bay of Sumbreng Region, Munjungan), POKMASWAS Kejung (Cengkrong Beach, Karanggandu) and POKMASWAS Karanggongso (eastern part of Bay of Prigi). The following explanations for each variable on social criteria (Table 4).

TABLE IV. ASSESSMENT RESULT FOR ECONOMIC CRITERIA

Variable	Sites selected			
	Panggul	Munjungan	Watulimo	
	T. Kili Kili	Munjungan	Karanggandu	Tasikmadu
Fisheries importance (LQ)	LQ>1	LQ>1	LQ>1	LQ>1
Tourism value	Sandy beach, sea turtle conservation	Mangrove tracking, boating, snorkeling,	Mangrove tracking and boating	Sandy beach, snorkeling, diving and boating
Aesthetics	Sandy	Beach,	Mangrove	Beach,

Variable	Sites selected			
	Panggul	Munjungan	Watulimo	
	T. Kili Kili	Munjungan	Karanggandu	Tasikmadu
value	beach	mangrove, coral reef and sea stacks		coral reef, sea stacks
Ease of access	Direct access (collector road)	Direct access (collector road) for mangrove and boat for coral reef	Highway (JLS)	Highway and boat

C. Scoring

Scoring and weighting is performed by simple vector operations, aimed to obtain the conformity difference between regions. The weights on variables referred to MMAF's MPA Site Selection Guidelines for Habitat Conservation of Coastal and Small Islands, (HCCSI or KKP3K, Ind).

TABLE V. VARIABLES AND ENVIRONMENTAL FEATURES BASED ON ADMINISTRATIVE BOUNDARIES

Subdistrict	Village	Biogeografi	Ecosystem feature			Economic value				Management
			CR	M	Cli/Isl	Tou	CF	Lo.	Meg	POKMASWAS
Panggul	Besuki	Bay of Panggul	+	-	+	+	-	+	n/a	-
	Wonocoyo		+	-	+	+	+	+	n/a	Kili Kili
	Nglebeng		+	-	+	-	-	+	n/a	-
Munjungan	Ngulung W.	Bay of Sumbreng	+	-	+	-	-	+	n/a	-
	Ngulung K.		+	-	+	-	-	+	n/a	-
	Craken		+	-	-	-	-	+	n/a	-
	Masaran		-	+	+	+	-	+	n/a	-
	Munjungan		+	+	+	+	+	+	+	Bintang Panikan
	Tawing		-	-	-	+	+	+	n/a	Bintang Panikan
	Bendoroto		+	-	+	-	+	+	+	-
Watulimo	Karanggandu	Bay of Prigi	+	+	-	+	+	+	n/a	Kejung Samudera
	Prigi		-	-	-	+	-	+	n/a	-
	Tasikmadu		+	-	+	+	+	+	+	Karanggongso

Source: Primary data

TABLE VI. VALUES FROM EACH CRITERIA

No.	Variables	Proposed areas for MPA/MCA			
		Panggul	Munjungan	Watulimo	
		Kili Kili	Munjungan	Karanggandu	Tasikmadu
A	**EKOLOGI**				
1	Diversity	8	12	8	12
2	Naturalness	12	12	4	12
3	Ecological linkage	12	12	12	12
4	Representativeness	9	9	9	9
5	Uniqueness	6	6	3	6
6	Productivity	6	9	6	9
7	Migratory areas	9	9	3	6
8	Endemic/protected species habitat	6	6	3	6

No.	Variables	Proposed areas for MPA/MCA			
		Panggul	**Munjungan**	**Watulimo**	
		Kili Kili	**Munjungan**	**Karanggandu**	**Tasikmadu**
9	Spawning ground	8	12	4	12
10	Nursery ground	6	9	9	6
B	**SOSIAL**				
11	Social acceptance	3	3	2	2
12	Threat	2	1	2	2
13	Potential conflict of interest	3	3	1	1
14	Local customs	1	1	1	1
C	**EKONOMI**				
15	Fisheries importance (LQ)	6	6	6	6
16	Tourism value	4	6	4	6
17	Aesthetics value	4	6	4	6
18	Ease of access	6	4	6	6
		111	126	87	120
	SCORE	**1,01**	**1,18**	**0,85**	**1,08**

Source: Primary data

The results show a high suitability for category HCCI, considering its geomorphological and ecological features. Selection and recommendation of Marine Protected Area (MPA) or Marine Conservation Areas (MCA) based on ecological and economic values in the coastal zones, includes coastal land and coastal water. Administration boundary of the coastal villages used to identify conservation management (POKMASWAS) and to identify potential threat on the base of coast land. In fact, the boundary area of MPA or MCA can surpass the administrative boundaries of the coastal village, because of the conservation area is terms as ecological region. From these considerations, maps of proposed MPA are as follows.
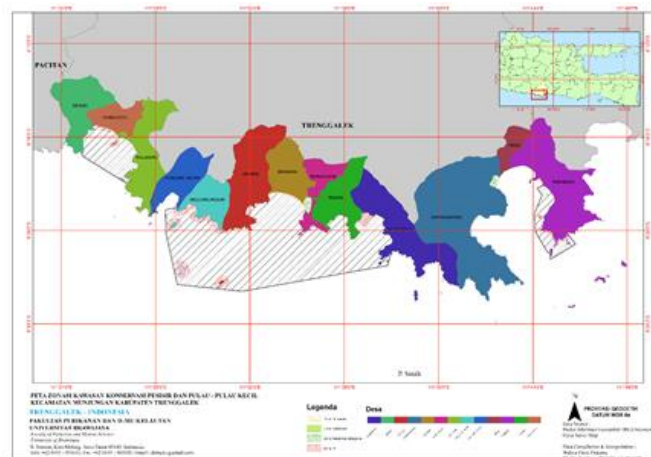

Fig. 5. MPA sites recommendation in Trenggalek.

IV. CONCLUSIONS AND SUGGESTIONS

Based on the results of this research show high suitability areas for MPA includes Wonocoyo, Munjungan, Karanggandu and Karanggongso. Each site has a high value in ecological criteria (ecosystem and biodiversity), social criteria (social acceptance) and

economic criteria (importance to species and value for marine tourism).

ACKNOWLEDGEMENTS

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