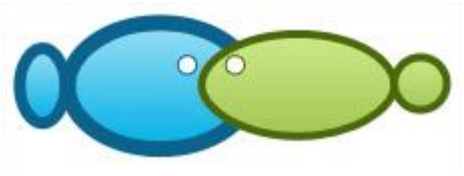

Coastal area spatial modelling using water ecological parameters, regarding the utilization zone development of Kupang Bay, Indonesia

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Abstract. The interests and utilization of coastal areas in Kupang have increased, causing concerns regarding the safety of its natural resources. Therefore, the management of coastal areas is important and must be based on carrying capacity so that it is in accordance with its utilization. The main purposes of this study are: (a) analysing the suitability value of Kupang Bay, East Nusa Tenggara province; (b) establishing utilization zone for fisheries, mariculture, conservation, and tourism on Kupang Bay area. Spatial mapping and geostatistical analysis were used as the basic spatial modelling. Coastal area of Kupang bay has an area of 29184.29 ha. An overlay of ecological coastal parameters found four division of utilization zone: (a) mariculture zone with an area of 9538.79 ha; (b) tourism development zone with an area of 2127.71 ha; (c) capture fisheries development zone with an area of 2583.85 ha; and (d) conservation zone with an area of 9074.84 ha.
Key Words: natural resources, spatial mapping, suitability matrix.

Introduction. Global climate change is predicted to play an important role in the changes of coastal areas. The changes are in line with the discourse of international society towards protection and management of marine aquatic resources. Therefore, the increasing activities on coastal areas may threaten the conservation and ecological balance due to the resource extraction, ecological changes, economic and social changes (Kathijotes 2013; Levine et al 2013; Metchalf et al 2015). Furthermore, it creates an emergence of scientific uncertainty, multi-administrative heritage, overlapping between institutions within the government, established authorities and regulations, as well as a weak level of coordination between institutions and irregularities in spatial planning (Chatterjee 2017; Ministry of Marine and Fisheries of Indonesia 2009; Wakita & Yagi 2013; Yi et al 2018).

Ecological changes on the coastal area become complicated if it is related to the affair allocation between provincial and district governments. Administrative boundaries usually become the reference for authority allocation between government and relevant department. Even though the allocation is for the use of coastal areas, it would be better if it involves ecological aspects, and not only administrative aspects (Qu et al 2016). Recent studies found some ecological damage in Kupang Bay, such as the declining of the coral reef ecosystem that reached 16.7 % (Kangkan et al 2017).

Environmental changes and sustainability issues have reached our awareness on restoring the role of the environment (BenDor et al 2015; Elmqvist et al 2015). Therefore, we need to adopt an effective and sustainable environmental management (Buffa et al 2018; Kungolos et al 2018; Neves et al 2017). On the other hand, environmental management needs spatial synergy and carrying capacity of natural potential, including activities with regard to the minimum standards of coastal zone

management (Chang & Lin 2016). Utilization zone can be modelled using statistical analysis, earth's surface modeling, ecological systems, and spatial modeling (Danilov et al 2018; Yue et al 2016). Coastal management gives benefits on economical, social, and ecological aspects, also creates a balance and sustainable utility of natural resources.

Recently, the interest and utilization of coastal area on Kupang Bay by local people and government has been increasing. On the other hand, the overlapping between some concerns become a threat for the resources on Kupang Bay. Ecological degradation and deterioration of coastal area requires government to equip facilities and policies in order to regulate the use of coastal resources (Nasution 2012). In contrast, the governments face some problems in maximizing the utilization of coastal resources, including the limitation of land use, no gap between each utilization zone, and no regulation of spatial arrangement yet. The utilization zone on coastal area needs a suitable ecological condition as one of important factors. Therefore, the utilization of coastal area on Kupang Bay is expected to be suitable with all intention of resources used.

Material and Method

Study area. Study was conducted in Kupang Bay marine area, East Nusa Tenggara province (10°00'–10°20'N and 123°23'-123°45'E) as shown in Figure 1. There were 19 spots designated as observation/sampling points along the waters of Kupang Bay. Sampling point was determined by using the purposive method based on physiography and coordinates were recorded using Global Positioning System (GPS). In-situ and ex-situ measurements on ecological parameters included dissolved oxygen, pH, water temperature, salinity, total suspended solid, chlorophyll-a, current velocity, water transparency, water depth, substrate type, wave height, coverage, coral reefs, coral fish, and some additional ecological parameters, such as seagrass and mangrove areas. Secondary data comprised of zoning map of Kupang Bay with scale 1:250.000, and map detail spatial plan of Kupang City with scale 1:50.000. Ex-situ variables were analyzed in the laboratory. Sampling point was determined by using purposive method based on physiography. Coordinates were recorded using Global Positioning System (GPS).

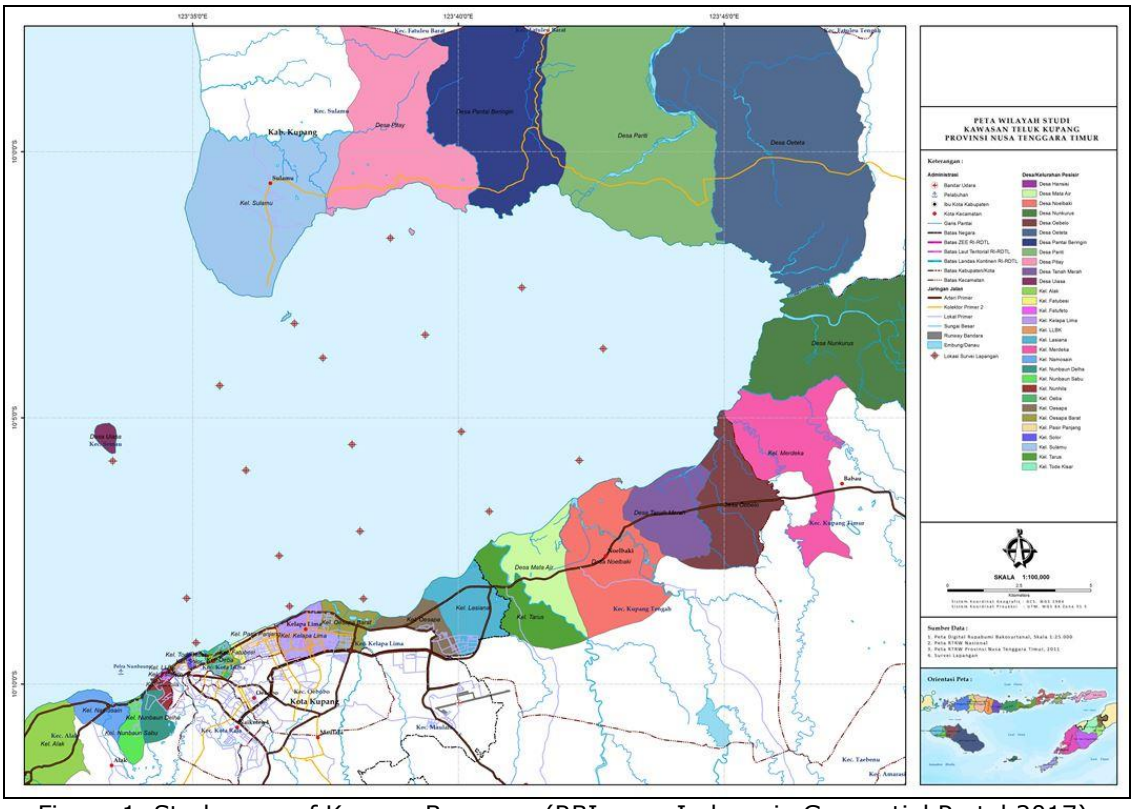

Figure 1. Study area of Kupang Bay zone (RBI map, Indonesia Geospatial Portal 2017).

Spatial mapping. Spatial modeling by recording the coastal ecological parameters was used in this study. Utilization zone was in Kupang Bay was divided into fisheries zone, mariculture zone, conservation zone, and tourism zone. First, some spatial distribution derived from each analyzed ecological parameter, then overlaid into one extraction map. The construction of utilization zone was the basis of spatial analysis by evaluating suitability matrix (Ministry of Marine and Fisheries of Indonesia 2011). Suitability rate was divided into three classes: S1 (highly suitable), S2 (moderately suitable) and N (not suitable).

The next step was spatial modeling that was transformed into layer distribution form (XYZ) by determining the closest point whose value is known using the natural neighbor interpolation model technique (Bhunia et al 2018; Teka et al 2012). The visualization of spatial distribution provides some instructions that was created from those phenomenons (van Riper et al 2012). Modeling was based on single value of geodetic/position (Degree, Minute, Second/DMS) using numerical formula as the following equation (1) (Rofatto et al 2018):

$$(\text{Lat; Long}) = \text{Degree} + \{[\text{Minute} + (\text{Second}/60)]/60\} \quad (1)$$

where Lat is latitude and Long is longitude. Furthermore, it was arranged based on the combination of suitability values in the form of isoline (Çetinkaya et al 2018).

Results

Location description. Kupang Bay has an area of 1.267 ha enriched with some small islands, including Semau, Kera, Burung, and Tikus islands. It is relatively sheltered from the waves and storms with a type of diurnal tide. Coastal area of Kupang Bay has a slope of 0-0.73 % with elevation of 1-50 m above sea level. Wind pattern in East Nusa Tenggara is mostly affected by east and west monsoons. West monsoon generally started in October, while east monsoon usually blows during April to September with a high intensity of wind. East monsoon leads to a lower rate of rainfall and dryness.

Parameters of ecosystem. Ecological parameters, including current velocity and water transparency were 0.169 $m.s^{-1}$ to 0.710 $m.s^{-1}$ (average of 0.476 $m.s^{-1}$ ± SD 0.21) and 1.95 m to 15.00 m (average of 6.32 m. ± SD 4.302), respectively. Water temperature varied from 26.56 ºC to 28.95 ºC with an average of 28.01 ºC ± SD 0.63. The salinity of Kupang Bay ranged from 30.50 ppt up to 36.50 ppt with an average of 33.36 ppt ± SD 1.36. The results of in situ measurement, of pH and dissolved oxygen, were 6.20 to 8.95 (average of 8.00 ± SD 0.76) and 5.12 ppm to 8.54 ppm (average of 7.405 ppm ± SD 1.061), respectively. The measurement on total suspended solid and chlorophyll-a resulted 3-45 $mg.L^{-1}$ (average of 19.11 $mg.L^{-1}$) and 0.03-0.52 mg L^{-1} (average of 0.12 $mg.L^{-1}$ ± SD 0.011), respectively. Observations on the type of bottom substrate of the waters found texture classes, namely clay, sandy loam, and silty loam as the bottom layer of Kupang Bay. In addition, loamy sand types and sand types were also found in the area around the entrance of the bay which is associated with open waters. The analysis using radar for wave height showed values that ranged from 0.15 m to 0.25 m (average of 0.19 m ± SD 0.05).

The spatial distribution of mangrove ecosystems was mostly found in the eastern part of Kupang Bay with an area of 646 ha, the highest density reached 2583 trees/ha, while the lowest was 467 trees/ha with an average of 1394 trees/ha. On the other hand, the seagrass ecosystem which laid in the southern part of Kupang Bay, and Kera Island had an area of 56 ha, the highest cover percentage was 33.79 %, while the lowest was 0 % (average of 14.12 %). Coral reefs ecosystem flourished at the mouth of the bay with an area of 7 ha, the highest cover percentage was 14 % and the lowest was 3.2 % (average of 10.5 %) (Figure 2).

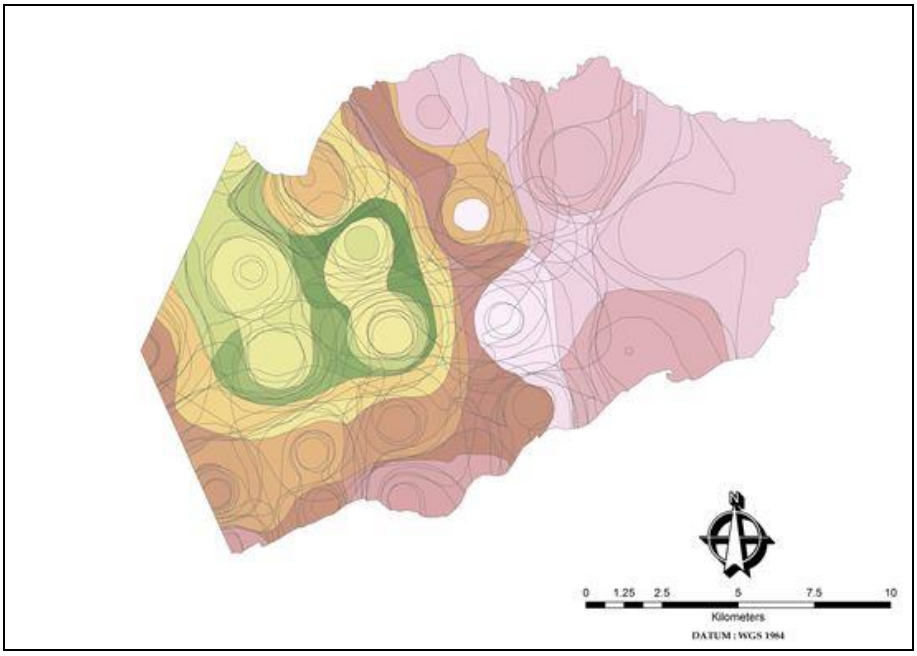

Figure 2. Simulation of overlay model on the distribution of ecological parameters in Kupang Bay marine area (Field data; WGS 84).

Utilization zone on Kupang Bay. The evaluation results were combined based on the suitability values from four zones, and then developed into fisheries zone, mariculture zone, conservation zone, and tourism zone. There were differences on the wide area: (a) utilization zone of mariculture with an area of 9538.79 ha; (b) tourism development zone of 2127.71 ha; (c) fisheries development with an area of 2583.85 ha; (d) conservation zone of 9074.84 ha (Figure 3).

Discussion. Management of Kupang Bay is involving sectoral outlook, such as policies and strategies, that concerned on fisheries, tourism, conservation, and cultivation aspects. Spatial modeling is constructed with the intention of combining and simplifying all environmental aspects, therefore it may represent the reality (Sahraoui et al 2016). Moreover, the combination between importance value with spatial ecology is needed for the formulation of national or regional regulatory frameworks in East Nusa Tenggara province (Kempenaar et al 2016; van Riper et al 2012).

The results of ecological parameters measurements were used as input on spatial modeling based on the criteria from Ministry of Marine and Fisheries of Indonesia (2011). The matrix was analyzed as shown in Figure 3 and evaluated for obtaining the similar region that will be developed (Bakosurtanal 1996). The evaluation results become a general conclusion for Kupang Bay area.

An arrangement of marine tourism located on the southern part of Kera Island and the northern part of the mouth of Kupang Bay, as showed in Figure 3, indicated that most of nautical activities are carried out on Kera Island, such as enjoying the beach, snorkeling, and diving. This was also supported by Stacey et al (2012) who found whale sharks (*Rhincodon typus*) in Kupang Bay that used to attract tourists. Tibuludji et al (2017) also reported the potential of tourism spots in Kupang Bay, including maritime activities, beach, camping ground, even cultural and religious sites. Therefore, strategy for developing the tourism spots in Kupang Bay should pay attention on the ecological aspects, zoning and also to involving local people (Bennett & Dearden 2014).

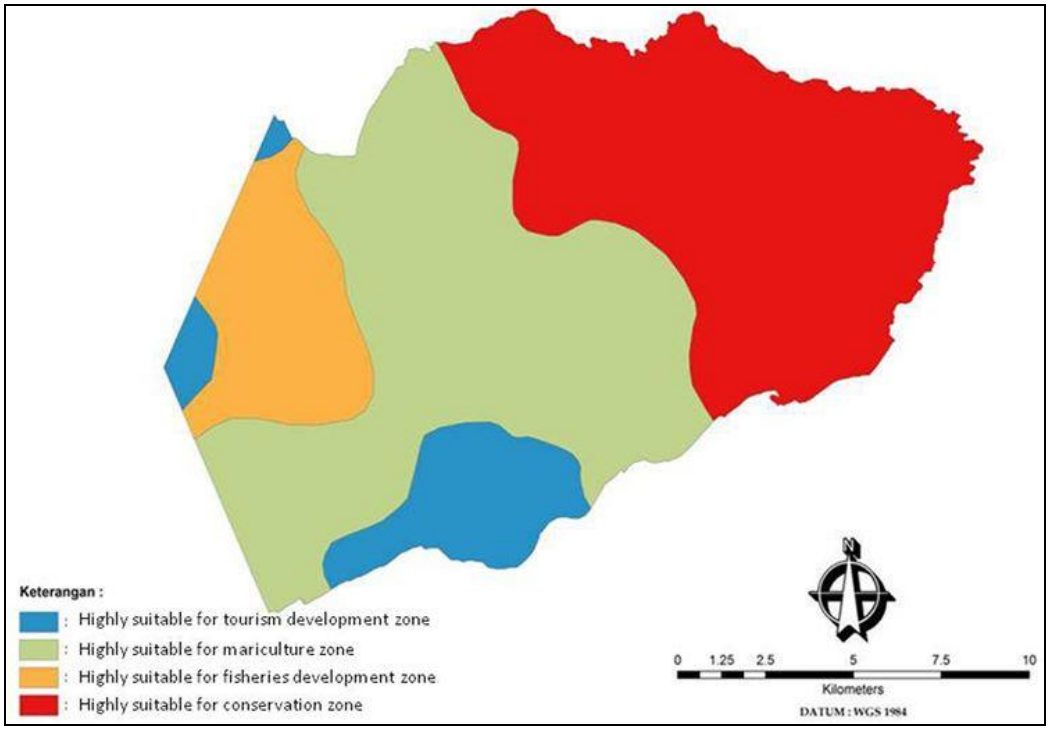

Figure 3. Map of utilization zone in Kupang Bay marine area (Field data; WGS 84).

In the past decade, most of the development of aquaculture in Indonesia was not based on field research data, but was carried out based on the intuition or trials of aquaculture farmers (Rofatto et al 2018). On the other hand, site suitability is urgently needed in order to efectively utilize the coastal area (Mahtab & Zahid 2018). Recent condition on Kupang Bay shows some potential cultivation activities, such as seaweed cultivation. The management of cultivation area is conducted on the northern part of Kupang Bay, more precisely behind Tikus island, with a purpose to emphasize the function of an area.

The construction and management of conservation area is conducted sistematically based on some factors, such as spatial data (Araos & Ferreira 2013). That's why, conservation area is specially developed for protecting the biodiversity (habitat and population of flora fauna) and restricting the utilization of that area. The suitability of conservation area is strongly characterized by the vital ecological parameters, such as mangrove and seagrass ecosystems in Burung Island that can function as protection for germplasm of marine diversity, rehabilitation area, and ecosystem restoration.

Management of fishery areas in Kupang Bay is related to utilization activities that take into account the potential of natural resources, including fishermen on the coast of the area. The potential of small pelagic fish resources is a target for the use of small-scale fisheries resources that are allowed for traditional fishermen. With the stipulation of Kupang Bay as a Marine Natural Park (Taman Wisata Alam Laut; TWAL) by the Central Government through the Decree of the Minister of Forestry Number 83/Kpts-II/1993 dated January 28, 1993, which is designated for tourism, education and conservation, special attention should be paid to traditional fisheries activities. Therefore, the pattern of utilization of the Kupang Bay area must pay attention to the local wisdom model of the community in addition to the fishing regulation system and zoning system arrangements that are jointly determined to protect the original ecosystem of the waters and the welfare of fishermen.

The planning of the utilization area in the waters of Kupang Bay is based on the reference to the values of the ecological parameters in accordance with the criteria for the suitability matrix of the area. Several ecological parameter values become limiting factors in the formation of utilization areas. And this value is difficult to maintain in order to meet the criteria for the suitability matrix of ecological parameter values so that the area becomes ideal according to its designation. Ecological parameters whose values do not match the criteria for establishing an identified use area are the number of coral fish

species and their families, coral reef ecosystems, the value of water depth and the concentration of suspended solids that are easily stirred and exposed to the water column.

Conclusions. The results of the evaluation based on the value of the ecological parameters for the development of the Kupang Bay utilization area are very suitable for the designation of mariculture areas, capture fisheries areas, marine tourism areas and conservation areas. The area of each utilization formed is as follows: a) utilization for mariculture area is 9538.79 ha; b) tourism development area of 2127.71 ha; c) capture fisheries development area is 2583.85 ha; and lastly d) conservation area is 9074.84 ha.

Conflict of Interest. The authors declare no conflict of interest.

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