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Coastal ecosystem model based on environmental suitability and carrying capacity of the fishpond in Banyuwangi Region, East Java, Indonesia

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Abstract. Banyuwangi coastline (175.8 Km) is the longest coastal area in East Java. There are various potential coastal resources, one of them is aquaculture. Unfortunately, the utilization of the fishpond is not optimal and most of the fishpond areas were abandoned. The main cause is a decline in water quality and/or changes in coastal habitats. This study aims: (1) to identify the suitability and the carrying capacity of the fishpond and (2) to determine the coastal ecosystem model in Banyuwangi based on the spatial analysis. A descriptive method was used and direct observation and interview survey were conducted for collecting primary data. The data were analyzed according to the suitability and carrying capacity of the study area. A GIS analysis was used to determine the coastal ecosystem model. The results showed that Banyuwangi has suitable coastal areas for developing aquaculture is 1,220.535 Ha with a carrying capacity of 898.71Ha. Therefore, Banyuwangi coastal area facing critical problems due to ecological constraints of exceeding its carrying capacity limit for about 26.43% or 322.827 Ha.

1. Introduction

Banyuwangi is a regency with the largest area in East Java (around 5,782.50 km^2) and borders with Jember, Bondowoso, Situbondo, and Bali. In addition, Banyuwangi regency has the longest coastal area in East Java (175.8 Km), which is located in nine different sub-districts; one sub-district faces Indonesian Ocean, seven sub-districts face Bali Strait, and one sub-district faces the Java Sea. The northern part, from Bajulmati to Wongsorejo village, almost 60% fishpond is not producing in the last two years. While the eastern coastal area from Bulusan to Muncar Banyuwangi has around 30% unproductive shrimp fishpond both the traditional or intensive ones due to disease, weather, and other reason. Those fishponds are left by the owners.

Fishpond productivity has been increasing since 1985, however, there was a decrease in the 2000s and started to increase afterward. The decrease in fishpond productivity in a given year needs attention, especially related to fishpond carrying capacity in the Regency, so that fishpond carrying capacity can be known earlier that fishpond area resources allocation can be determined more precisely [1]. The final result is the concept of sustainable aquaculture can be realized in Banyuwangi Regency. In the Government Regulation of the Republic of Indonesia Number 26 of 2008 concerning National Spatial Planning, it has been determined that the policy of developing cultivation area including development control of aquaculture activity so as not to exceed environment carrying capacity. The spatial planning act covers both spatial and environmental issues.

Land suitability is the adaptability of land for a particular purpose, through land value determination (class) and land use patterns linked to the area potential, thus, more directed land use along with its sustainability can be attempted [2]. Ecological changes in the fishpond environment will affect environmental carrying capacity which then affects fishpond production. Environmental carrying capacity for fishpond is the natural ability to provide the existence of tolerable fishpond. This natural ability will ultimately affect fishpond production [3]. Carrying capacity is an important concept for ecosystem-based management which helps define the upper limits of aquaculture without causing "unacceptable change" to both natural ecosystem and social functions and structures [4].

Carrying capacity is a factor with a major influence on development. In this context, carrying capacity is a widely used concept that encompasses four aspects namely physical, production, ecological, and social carrying capacity [5] [6] [7]. One of the natural resources and carrying capacity is a physical environment in which the development carried out. Physical carrying capacity assumes the entire water body is leased for aquaculture, being little more than the total area suitable for aquaculture [3]. In the other hand, ecological carrying capacity as the maximum density of fish an ecosystems can naturally support during the period minimum available habitat that effect to ecological process, species, population, or communities in the environment [4] [8]. From this fact, a harmony between development and physical carrying capacity is needed. To achieve this harmony, it is important to know the physical carrying capacity of the environment. By doing so, suitable development activities to that carrying capacity can be determined [9].

Therefore, the ecosystem model in the development of a coastal area in Banyuwangi is needed to optimize the area to be more beneficial for community welfare, especially in the economic context.

2. Method

2.1 Research time and location

We applied the research in 9 sites of Banyuwangi coastal area (Figure 1). The research was conducted from March to August 2018 at fishery laboratory University of Airlangga Surabaya and fishery laboratory University of 17 August 1945 Banyuwangi.

2.2 Data collection

The data needed include biological parameter, water quality, and substrate quality (Table 1). This parameter measurement was carried out at 9 sites points along the coast of Banyuwangi Regency. Besides primary data, secondary data from a biological parameter, water quality, and substrate were also collected.

2.3 Data analysis

The analysis carried out includes the suitability analysis of coastal area for fishpond designation and the carrying capacity analysis of fishpond area, then spatial analysis was conducted. Spatial data processing in this research was data in the form of maps, satellite remote sensing data, and spatial modeling for environmental suitability analysis.

The suitability analysis of fishpond area was intended to determine land and coastal area suitability (physical, chemical, and biological) of designated aquaculture. This analysis was conducted by measuring several environmental parameters of ecological requirements consisting of a physical substrate, water quality, and hydro-oceanography for aquaculture development (Table 2).

Table 1. Parameters of observed aquatic environment and measurement tools/methods

Parameter	Tool/method	Remarks
Biology		
1. Chlorophyll	Filtration	Laboratory Analysis
2. Mangrove	Image & Ground Check Map	Mangrove Mapping
Water Quality		
1. Dissolved Oxygen	DO meter/Winkler	In-Situ/Laboratory
2. Salinity	Salinometer	In-Situ
3. pH	pH meter	In-Situ
4. TSS	Spectrophotometer	Laboratory Analysis
5. Ammonia	Spectrophotometer	Laboratory Analysis
6. Nitrate	Spectrophotometer	Laboratory Analysis
7. Phosphate	Spectrophotometer	Laboratory Analysis
8. Temperature	Thermometer	In-Situ
9.Heavy Metal	Spectrophotometer	Laboratory Analysis
Substrate Quality		
1. pH	pH meter	In-Situ
2. Substrate Texture	Fraction Analysis	Laboratory Analysis

Table 2. Parameters of land and water suitability (score) for fishpond

Environmental Characteristics	Suitability			
	S1 (4)	S2 (3)	S3 (2)	N (1)
Soil				
Slope (%)	0 – 3	3 – 6	6 – 8	>8
Depth (*cm*)	>150	100 – 150	75 – 100	< 75
Texture	Quite Fine	Medium	Fine	Coarse
Distance from the coast (*m*)	200 – 300	>300 – 4000	<200	>4000
Distance from a river (*m*)	0 – 1000	>1000 – 2000	>2000 – 3000	>3000
Drainage	Periodically inundated	Rather rarely inundated	Rarely inundated	Uninundated
Water				
Dissolved Oxygen (*mg/l*)	>5	3 – 5	1 – < 3	<1
Salinity ($^0/_{00}$)	12 – 20	>20 – 35	>35 – 50	>50
Temperature (^0C)	28 – 30	>30 – 35 18 – <28	12 – <18	<12 >35
pH	7.5 – 8.5	>8.5 – 10 6 – <7.5	>10 – 11 4 – <6	<4 >11
Ammonia (*mg/l*)	<0.3	0.3 – 0.4	>0.4 – 0.5	>0.5
Hydro-oceanography				
Tidal Amplitude (*m*)	1.5 – 2.5	1 – <1.5 >2.5 – 3.0	0.5 – <1.5 >3.0 – 3.5	<0.5 >3.5
Rainfall (*mm/th*)	2500 – 3000	2000 – <2500	1000 – <2000 >3000 – 3500	<1000 >3500
Dry Season (<60 *mm*)	1 – 2	>2 – 3	>3 – 5	>5

Source: Modification from Bakosurtanal (1996); Hardjodiwegeno and Widiatmaka (2007).
Note: S1: Very suitable, S2: Quite suitable, S3: Conditionally suitable, N: Not suitable

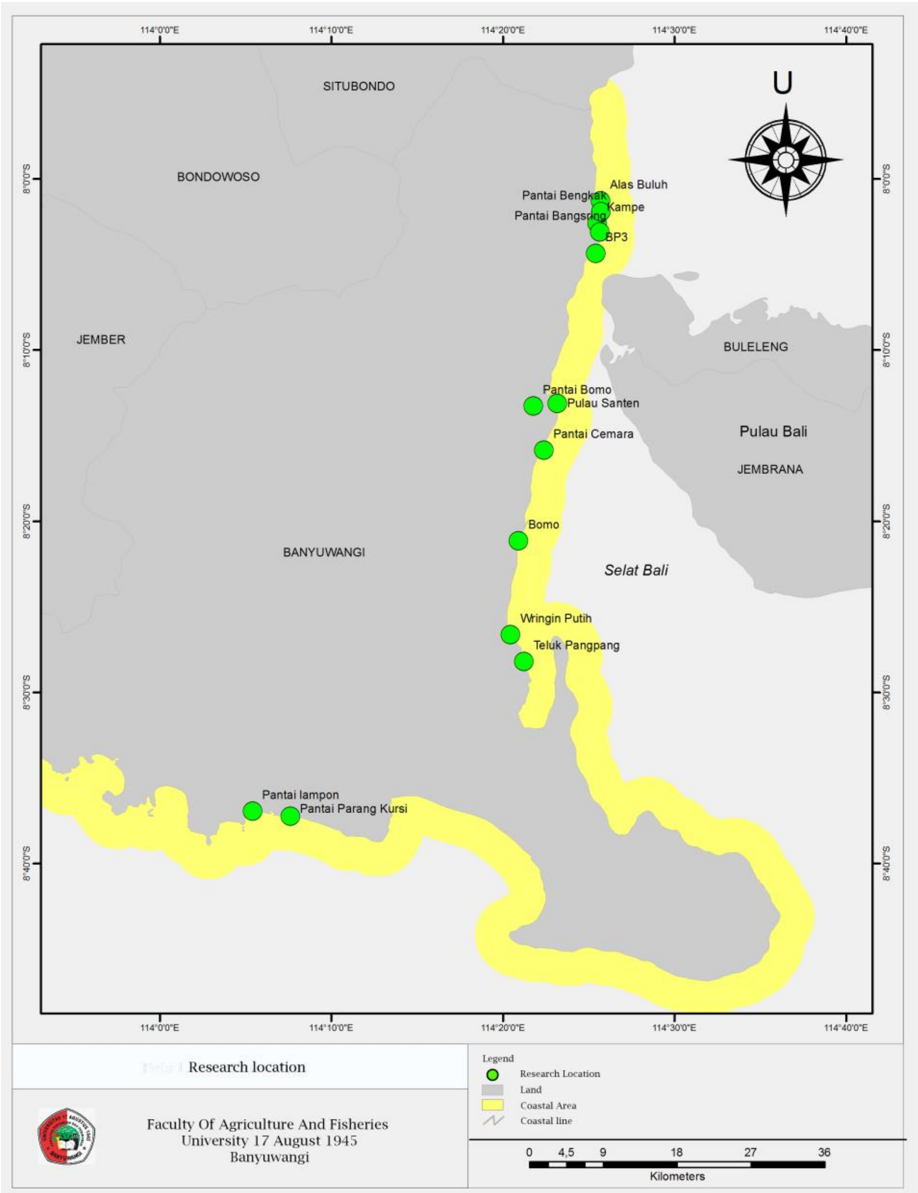

Figure 1. Map of the research area showing the sampling sites located in Banyuwangi coastal area

The coastal area carrying capacity for aquaculture in Banyuwangi Regency was calculated by the ideal land suitability approach in that coastal area. This carrying capacity analysis was carried out on land with S1 (very suitable) and S2 (suitable) suitability. While S3 (conditionally suitable) and N (not suitable) were not recommended for aquaculture development. Land carrying capacity for development was influenced by land suitability. The equation used to calculate fishpond area carrying capacity is:

$$DDT = \sum_{i=1}^{n} \frac{Spi}{4n} \, x \, 100\%$$

Note:
DDT: Fishpond Area Carrying Capacity
Spi: Score of parameter i
n: The number of parameters used

3. Results and discussion

3.1 Water quality of Banyuwangi coastal area

Environmental parameter data taken are water quality such as temperature, salinity, pH, DO, NH_4, NO_3, PO_4, Alkalinity (CO_3, HCO_3) and TOM in Banyuwangi coastal area with 9 sites of data collection points represented all districts along the Banyuwangi coast with three replication (Table 3).

Table 3. Water quality of Banyuwnagi coastal area.

Research Location \ Water Quality		DO	Temperature	pH	Salinity	NH4 (ppm)	NO3 (ppm)	PO4 (ppm)	Alkalinity CO3 (ppm)	Alkalinity HCO3 (ppm)	TOM
Alas Buluh	High	6.7	30.3	7.6	26	0	1	0	12	116	59.04
	Low	6.5	29.7	7.3	25	0	0	0	36	112	52.45
Kampe	High	7.1	30.1	7.3	22	0	0	0	24	100	56.7
	Low	7	28.8	7	23	0	0	0.1	12	144	51.19
BP3	High	8	27.3	7.2	20	0	0	0	24	116	55.61
	Low	6.1	27.5	7.1	20	0	0	0.1	16	136	59.04
Cemara Beach	High	7.5	31	9	25	0	0	0.1	80	88	54.98
	Low	6.4	29.3	8	25	0	0	0	32	100	55.61
Pakem Kertosari	High	7.7	31.6	7.2	24	0	0	0	12	112	54.98
	Low	7.4	29.3	7.4	27	0	0	0	16	124	49.92
Santen Island	High	7.2	29.7	7.2	26	0	0	0	36	92	61.93
	Low	6.5	29.2	7.4	26	0	0	0	36	100	63.2
Blimbingsari	High	6.1	30.3	8.9	27	0	0	0.1	12	120	52.45
	Low	6.4	30.1	8.4	27	0	0	0.1	12	140	53.75
Pangpang Bay	High	7.04	30.3	6.9	23	0.7	0	0	24	98	56.88
	Low	6.9	29.17	6	18	0.8	0	0	24	116	56.88
Lampon	High	6.9	30.6	7.1	25	0	0	3	44	84	50.56
	Low	6.8	30.7	6.9	26	0	0	0	44	80	63.2

Data collection of water quality is categorized in 2 conditions, namely at highs and lows. Based on the data above, it can be seen that there is indeed a difference between the value of water quality at high tide, but the difference is not significant.

The research location is in the waters along the coast of Banyuwangi Regency, where coastal waters are a very narrow part of the ocean when compared to the area of the waters. This region is a meeting area between the influence of land and sea and has very diverse properties with changes in the natural environment occurring very quickly in time and space. Not only experience periodic drying and soaking every day, but also the temperature difference is greater both daily and yearly than in other parts of the sea.

Water temperature can affect the life of aquatic biota indirectly, through its influence on the solubility of oxygen in the water. The higher the water temperature, the lower the solubility of oxygen in the water, and conversely the higher the solubility of oxygen, the lower the water temperature. Temperature indirectly affects metabolism, the solubility of gases and various chemical reactions in water [10].

Photosynthesis is not directly proportional to the intensity of light. In the water column 10-15 m upward, the speed of photosynthesis is lower than the 15-30 m layer, because light at sea level is too intensive for most biota that can be injured by ultraviolet light. Photosynthesis occurs up to 100 meters, where light intensity is only 1% of the surface [11]

NH4 is a form of nitrogen in natural waters. Nitrogen in seawater is absorbed by marine organisms to meet the need for nitrogen as one of the main components of amino acid formation which is the beginning of protein formation. And that happened at the location of the research conducted as stated by Kennish [12]. that nutrient sources were obtained from river water input, through soil washing and rock decay.

Salinity is a very important factor for the growth of plankton. Changes in salinity in the waters cause plankton maintaining the balance of osmotic pressure between protoplasm and water. Therefore salinity can affect plankton abundance and distribution. Naturally, the fluctuations of salinity in tidal areas are caused by two things: heavy rain and large evaporation [13].

3.2 Mangrove Distribution in Banyuwangi Regency

Based on the spatial analysis results, the distribution of mangrove in Banyuwangi is almost evenly distributed along the coast from north to south. The area of mangrove along the coast is 2,608.846 Ha, and that area is larger than fishpond area in Banyuwangi.

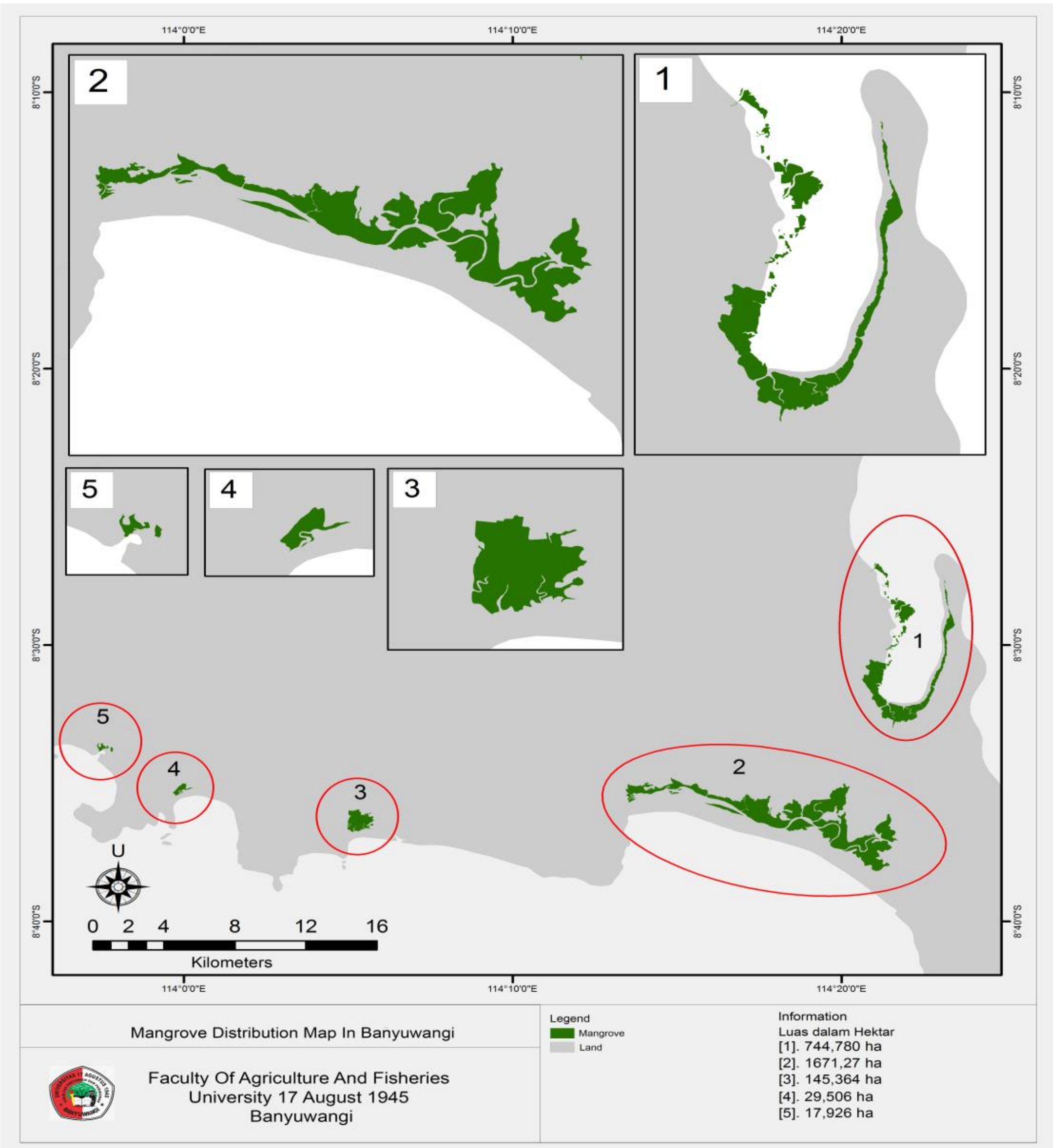

Figure 2. Mangrove distribution in Banyuwangi Regency

3.3 Coastal chlorophyll in Banyuwangi regency

After the sampling collection, it was then taken to Universitas Airlangga Surabaya laboratory to be analyzed. For chlorophyll measurement results, there are three types of chlorophyll in Banyuwangi coastal area, namely chlorophyll-a which produces blue-green color, chlorophyll b which produces yellowish green color, and chlorophyll c which produces brown-green color. Chlorophyll-a is a complex compound between magnesium and porphyrin which contains cyclopentanone ring (ring V). The four nitrogen atoms are bonded together. Chlorophyll-a is a form of chlorophyll which is found in all autotrophic plants. Chlorophyll b is the second chlorophyll found in green plants. Chlorophyll b is also bound to proteins in a cell. It is found in Chlorophyta green algae and terrestrial plants. Chlorophyll a and b are the strongest to absorb red and purple light spectrum, a green spectrum is the least absorbed. Therefore, when white light shines on structures containing chlorophyll such as leaves, a green light will be sent and reflected so that the structure appears green. Carotene is in the chromoplast which is a colored plastide containing pigments besides chlorophyll. Chlorophyll c is found in Phaeophyta brown algae and Bacillariophyta diatoms.

Table 4. Data of Chlorophyll Analysis in Banyuwangi Coastal Area in 2018

Chlorophyll type / Research location	Chlorophyll -a	Chlorophyll -b	Chlorophyll -c	Total Chlorophyll
Alas Buluh	0.06138	0.07764	0.635417	0.23052
	0.23125	0.30776	0.62979	1.1688
Kampe	1.188194	0.37722	0.43438	0.9827
	0.24125	0.49149	0.50901	1.24175
BP3	0.117361	0.05198	0.16242	0.2313
	0.283333	0.33241	0.16434	0.53755
Cemara Beach	0.11172	0.14986	0.31964	0.31964
	0.4734	0.04749	0.18366	0.70455
Pakem Kertosari	0.22056	0.06712	0.20936	0.49704
	0.26148	0.11888	0.27036	0.65072
Santen Island	0.03768	0.0885	0.09484	0.22102
	0.03223	0.01779	0.05335	0.10337
Blimbingsari	0.00853	0.02865	0.05669	0.09387
	0.00588	0.01583	0.04321	0.08734
Pangpang Bay	0.04451	0.13286	0.19279	0.37034
	0.120622	0.360051	0.522461	1.003621
Lampon	0.11399	0.11865	0.19987	0.43251
	0.03069	0.03882	0.04575	0.11526

3.4 Heavy metals (Cu, Hg, Pb, and Sn) in Banyuwangi Coastal Area

Heavy metals analyzed in this research is copper (Cu), mercury (Hg), lead (Pb) and lead (Sn). The following is the results of heavy metal tests conducted in the laboratory of Research Institute and Industry Standardization Surabaya.

In general, the source of heavy metals on the coast can be divided into two, namely sources that enter naturally to the waters and artificial marine waters. While heavy metals that enter the ocean waters can come from three sources, namely:

- Input from the coastal area originating from the river and the results of coastal abrasion by wave activity.
- Inputs from the deep sea include metals released by volcanic activity in deep seas and metals released from particles through chemical processes.
- Inputs from nearshore land environments, including metals originating from the atmosphere as dust particles.

While the source of artificial metals is metal that was released during the metal and rock industry process. Some industries only use certain heavy metals for their production activities. However, in general, most industries use various types of heavy metal elements, making it difficult to trace the origin of sources of pollution.

Of the four heavy metals mentioned above, different concentrations of heavy metals are obtained in seawater. This difference in concentration is possible due to the variability of metals in water caused by currents, adsorption, tides, or deposition [13].

Table 5. Test Results of Heavy Metals (Cu, Hg, Pb, and Sn) in Banyuwangi Coastal Area in 2018

Parameter	Unit	Test Results						Test method
		P. 2169 Alas buluh (low tide)	P. 2170 Alas buluh (high tide)	P. 2171 Kampe (high tide)	P. 2172 Kampe (low tide)	P. 2173 BP 3 (high tide)	P. 2174 BP 3 (low tide)	
Copper (Cu)	mg/L	<0.0223	0,026	0,032	<0.0223	0,026	0,026	SNI 6989.6 : 2009
Mercury (Hg)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	SNI 6989.78 : 2011
Lead (Pb)	mg/L	0.012	0.015	0.015	0.016	0.017	0.015	SNI 6989.46:2009
Lead (Sn)*	mg/L	<0.1050	<0.1050	0.469	<0.1050	<0.1050	<0.1050	APHA Ed.21.311 B,2005

Parameter	Unit	Test Results						Test method
		P. 2175 P. Santen (high tide)	P. 2176 P. Santen (low tide)	P. 2177 P. Pakem (high tide)	P. 2178 P. Pakem (low tide)	P. 2179 P. Cemara (high tide)	P. 2180 P. Cemara (low tide)	
Copper (Cu)	mg/L	<0.0223	<0.0223	0,026	<0.0223	0,03	<0.0223	SNI 6989.6 : 2009
Mercury (Hg)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	SNI 6989.78 : 2011
Lead (Pb)	mg/L	0.017	0.018	0.017	0.022	0.018	0.018	SNI 6989.46:2009
Lead (Sn)*	mg/L	<0.1050	<0.1050	<0.1050	<0.1050	<0.1050	4.136	APHA Ed.21.311 B,2005

Note:
- Parameters were tested according to the parameter
- Symbol “<” shows Limit Of Quantity value of the tests

3.5 Fishpond Land Suitability in Banyuwangi Regency

The area of aquaculture fishpond in Banyuwangi Regency in the last 5 years (2012 – 2016) has been stable as well as the number of fishery households (FH) in the same period, that is 498 RTP. Reviewed from the number of FH compared to the fishpond area, the ratio of fishpond area per FH in Banyuwangi Regency has also been stable, which is 2.77 ha/FH. It shows that the area managed by each FH for the last five years has tended to be stagnant.

The potential of the fishpond in Banyuwangi Regency is relatively high considering the vast fishpond area and relatively good fishpond condition. Due to the problem of fishpond management, shrimp disease, there are many fishponds that are currently not operating.

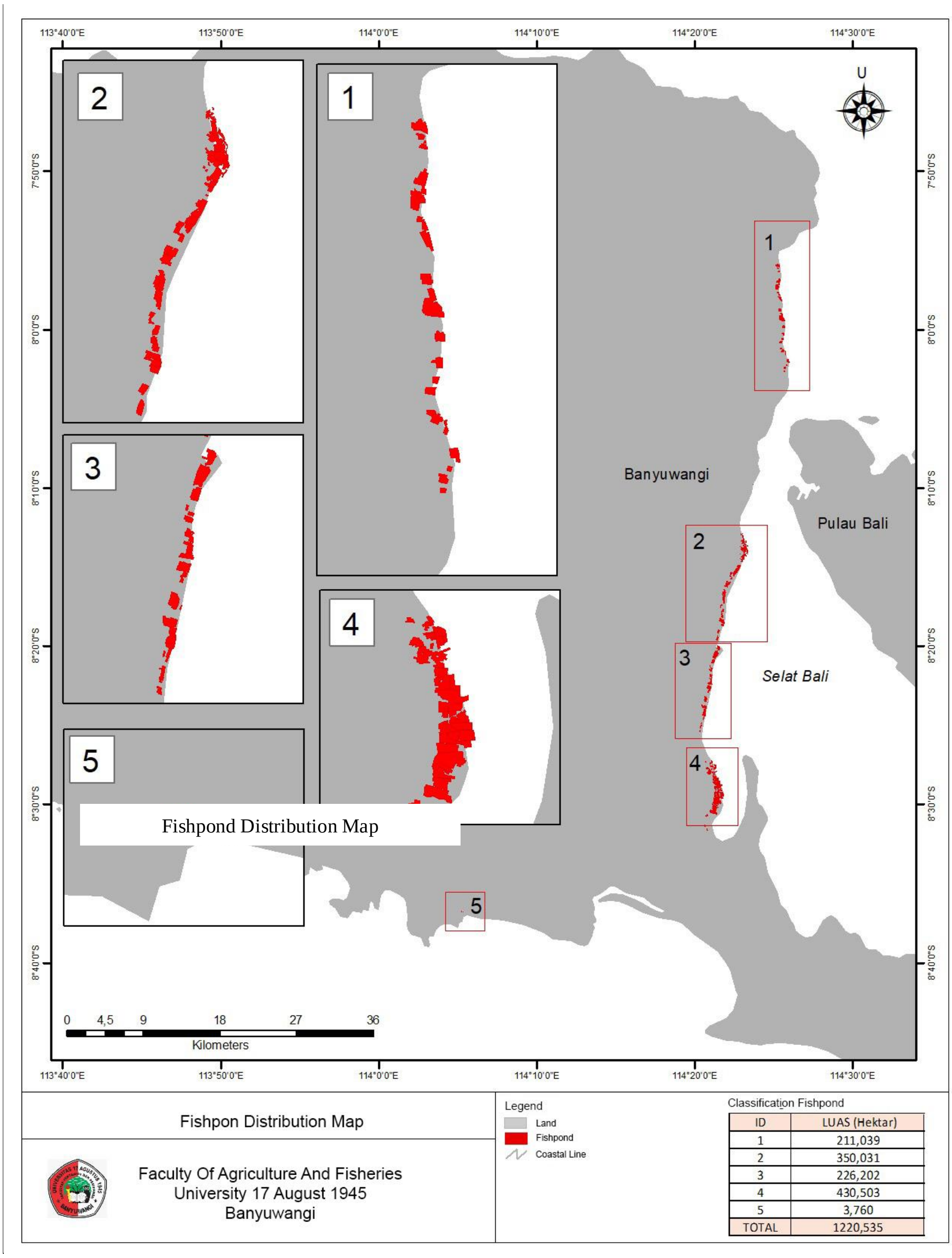

Figure 3. Fishpond area in Banyuwangi Regency

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Table 6. The Development of Area and Number of Fishery Households (FH) in Banyuwangi Regency from 2012 to 2016

Year	Fishpond Area (ha)	Number of Fishery Households (people)	Business Area Ratio (ha/FH)
2012	1381.34	498	2.77
2013	1381.76	498	2.77
2014	1381.76	498	2.77
2015	1381.76	498	2.77
2016	1381.76	498	2.77

Source: Processed from the Department of Fisheries and Food Security Banyuwangi Regency (2018)

Carrying capacity analysis was carried out on the lands with S1 (very suitable) and S2 (suitable) suitability. While land with conditionally suitable category (S3) and not suitable (N) was not recommended for fishpond land development. Land carrying capacity for development is influenced by land suitability level.

Table 7. Suitability Parameter of Area and Water (score) for Fishpond

Environment Characteristics	Suitability				
	Wongsorejo Sub-district Coastal Area	Banyuwangi Sub-district Coastal Area	Blimbingsari Sub-district Coastal Area	Pangpang Bay Coast (Muncar and Tegaldlimo Sub-district)	Lampon Coastal Area (Pesanggaran Sub-district)
Soil					
Slope (*%*)	13.39 (N)	3.11 (S2)	3.12 (S2)	2 (S1)	15 (N)
Depth (*cm*)	25 (N)	100 (S2)	25 (N)	20 (N)	150 (S1)
Texture	Medium (S2)	Quite fine (S1)	Quite fine (S1)	Quite fine (S1)	Rough (N)
Distance from the coast (*m*)	< 200 (S3)	>300 (S2)	>300 (S2)	>300 (S2)	>300 (S2)
Distance from a river (*m*)	3000 (S3)	500 (S1)	>1000 (S2)	0 – 1000 (S1)	0 – 1000 (S1)
Drainage	Not flooded (N)	Periodically flooded (S1)	Rarely flooded (S2)	Periodically flooded (S1)	Periodically flooded (S1)
Water					
Dissolved oxygen (*mg/l*)	6.9 (S1)	7.12 (S1)	6.1 (S1)	4.88 (S2)	6.85 (S1)
Salinity ($^0/_{00}$)	22.67 (S2)	25.5 (S2)	27 (S2)	20.67 (S2)	25.5 (S2)
Temperature (^0C)	28.95 (S1)	30.02 (S2)	30.3 (S2)	30.12 (S2)	30.65 (S2)
pH	7.25 (S2)	9 (S2)	8.9 (S2)	6.9 (S2)	7 S2)
Ammonia (*mg/l*)	0 (S1)	0 (S1)	0 (S1)	0.45 (S3)	0 (S1)
Hydro-oceanography					
Tidal Amplitude (*m*)	3 (S2)	1.08 (S2)	1.08 (S2)	1.08 (S2)	4 (N)
Rainfall (*mm/th*)	179.21 (N)	179.21 (N)	179.21 (N)	179.21 (N)	179.21 (N)
Dry Season (<*60mm/*year)	2 (S1)	2 (S1)	2 (S1)	2 (S1)	2 (S1)

Note: S1: Very suitable, S2: Suitable, S3: Conditionally suitable, N: Not suitable

Assessment analysis of fishpond land suitability category was conducted on all coastal land in Banyuwangi Regency. From the total of 175.8 km coastal land with 1,381.76 Ha fishpond area, based on the suitability category, estimated fishpond area in Banyuwangi with conditionally suitable (S2) category is 1,220.535 Ha.

The recommended suitability of fishpond designated area is the land with S1 (very suitable) and S2 (suitable) category. However, based on the suitability analysis, the fishpond area along the coast fell into S2 (suitable) category is 1,220.535 Ha meaning that the coastal area in Banyuwangi is suitable for developing fishpond.

Until 2016, according to the Department of Fisheries, this figure is different from the fishpond area in Banyuwangi which is 1381.76 Ha. This difference is in accordance with the survey result and ground check carried out in this research that in 2018, there are some fishpond areas are not operating due to the damage, both facilities, and infrastructure. In addition, another serious issue that should be addressed immediately is the occurrence of input channel silting, both in the fishpond irrigation channel and river mouths in some fishpond areas. This problem was also caused by the absence of optimal irrigation arrangements for the fishpond area development. In principle, the designated area for aquaculture must fulfill physical, chemical, biological, technical, social, economic, hygienic, and legal requirements. In order to meet those requirements, according to Fauzi *et all* [2] , three are four main aspects that need to be considered as criteria in determining fishpond location, namely ecological, soil, biological, and social aspects. Those four aspects are supporting elements for developing aquaculture in Banyuwangi coastal area and can be used as assessment bases in designing land suitability model.

In addition, another factor affecting the decrease in fishpond production was land-use change, mostly becoming housing. Dwipradnyana [15] explained that land-use change is an issue that can give significant effects on production, as well as social and environmental aspects. Land-use change is a serious threat to food security since the effect is permanent. Since this change affects more on spatial suitability, long-term economic benefit and other alternative measures can be taken to make it more beneficial instead of giving major damage.

3.6 Fishpond Carrying Capacity in Banyuwangi Regency

Fishpond development with the concept of sustainability requires resource utilization under the area carrying capacity. Besides, fishpond area has exceeded the carrying capacity of Banyuwangi coastal area.

Table 8. Carrying Capacity and Recommendation Fishpond Area in Banyuwangi Regency

Location	Suitable fishpond area (Ha)	Carrying Capacity (%)	Fishpond area in accordance with carrying capacity (Ha)
Wongsorejo	211.039	64.29	135.677
Banyuwangi	350.031	82.14	287.515
Rogojampi	226.202	75	169.652
Pangpang Bay (Muncar and Tegaldlimo Sub-district)	430.503	75	322.877
Lampon (Pesanggaran Sub-district)	3.76	71.43	2.686
Carrying capacity	**1,221.535**	**73.57**	**898.71**

The fishponds in Banyuwangi Regency have exceeded environment carrying capacity showed by mangrove ecological function, irrigation system, and not optimal production. The area carrying capacity for aquaculture development in Banyuwangi Regency is 73.57% of the total area suitable for developing fishpond. From the suitable fishpond area (1,221.535 Ha) can be developed based on the carrying capacity in Banyuwangi Regency 898.71 Ha.

Based on **Table 8**, it can be seen that from several coastal areas with aquaculture potential, almost all of them have exceeded the carrying capacity in which the fishpond utilization needed to be reduced. For fishpond in Wongsorejo coastal area, since the area is large, the reduction of land utilization was greater too, reaching 64.29% or around 35.71% Ha to make it suitable to carrying capacity and fishpond sustainability. Likewise, land utilization should be reduced up to 70%-80% in the coastal areas in Banyuwangi, Rogojampi, Muncar, Tegaldlimo, and Pesanggaran.

Thus, from 1,221.535 Ha suitable area, around 26.43% or 322,827 Ha area should be restored to support fishpond environment. The buffer area is recommended as a green area which is mangrove vegetation.

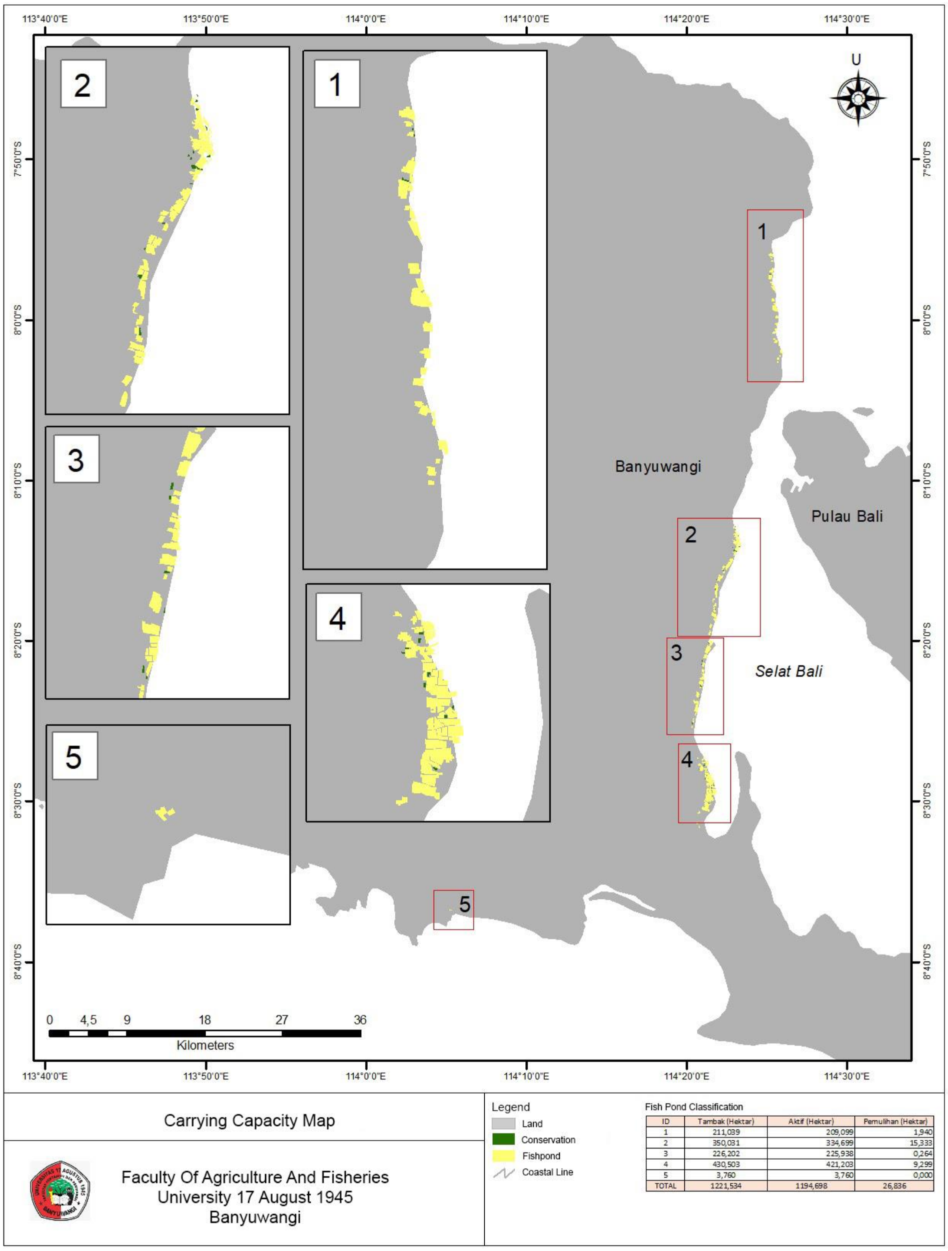

Figure 4. Map of Fishpond Carrying Capacity in Banyuwangi Regency.

The buffer area needs to be provided in an aquaculture bed. This buffer area is an area borders with the sea or river that is not used for aquaculture, instead of the place of mangrove vegetation which is the native of the area. Mangrove is a natural buffer which can withstand the storm and strong wind as well as being care area and foraging place for an economic commodity such as shrimp, crab, fish, and oysters. This buffer area also functions to trap sediment, protect water quality, hold toxic materials, and slow down surface water flow [1].

Presidential Decree Number 32 of 1990 concerning Management of Protected Areas explains that buffer area is needed as median with the minimum width of 130 x average value of the annual difference between the highest and the lowest in meters measured from the lowest ebb line. This is also in accordance with the Government Regulation of the Republic of Indonesia Number 26 of 2008 concerning National Spatial Plan that is the strategy to prevent negative impacts of human activities may cause environmental damage such as protecting environment ability to absorb substances, energy, and or other components that are disposed of into it.

4. Conclusion

The results showed that the Banyuwangi coastal areas were suitable for developing brackish water pond culture is 1.220,535 Ha, with a carrying capacity of 898,71 Ha. Therefore, the Banyuwangi coastal area being faced with critical problems due to ecological constraints of exceeded its carrying capacity limit for about 26,43% or 322,827 Ha.

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