International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Site Suitability of Milkfish Ponds Based on Physical and Chemical Parameters in Kangkung District, Kendal Regency, Using Geographic Information System

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ABSTRACT

Milkfish is the main commodity that is widely cultivated in Kendal Regency, one of which is in Kangkung District. Milkfish cultivation in Kangkung District is carried out semi-intensively, so the water quality is less controlled. The purpose of this study was to analyze and evaluate the suitability of pond land in Kangkung District, Kendal Regency, for milkfish cultivation based on the physical and chemical parameters of the waters using a geographic information system (GIS), as well as the area of suitable pond land for use. The pond water quality measurement activity has been carried out since September 2021. The survey method was used in this study, and the sampling point was chosen using purposive random sampling. Ten sampling points were used to represent a pond area of 266.1 ha spread across Kalirejo Village, Tanjungmojo Village, and Jungsemi Village. Temperature, salinity, brightness, depth, dissolved oxygen, pH, ammonia, nitrate, and phosphate levels were measured in situ and ex situ. ArcGIS 10.8 is used for data processing. The land suitability analysis results show that 235.32 ha of pond area falls into the S1 category (appropriate), and 30.78 ha of pond area falls into the S2 category (sufficiently appropriate).

Keywords : GIS; milkfish; land suitability

1. Introduction

Milkfish is one of the brackish water commodities that is popular with the public because it has a good taste and has a relatively affordable price (Haikal *et al*., 2022). Milkfish has the advantage of being an euryhaline fish (Rosyidi & Hermanto, 2018; Karolina *et al*., 2020), a herbivore that responds well to artificial feeds (Sukmawati *et al*., 2018), can be grown in polycultures, has a relatively stable selling price, and can be quickly absorbed by the market (Handayani *et al*., 2019). Milkfish contains 20-24% protein, amino acids, vitamins, and minerals (Sugito *et al*., 2019).

Milkfish is one of the leading commodities at Kendal Regency. Milkfish production in Kendal Regency in 2019 was 14,348.30 tons, an increase compared to the 2018 production of 12,653.89 tons (BPS, 2019). Milkfish production has increased every year so that it is directly proportional to the increase in market demand (Kurniasih *et al*., 2017). Milkfish cultivation in Kendal Regency is spread across several coastal districts, one of which is Kangkung District, which is spread over three villages, namely Kalirejo Village, Tanjungmojo Village, and Jungsemi Village. Milkfish cultivation in Kangkung District is carried out in a semi-intensive manner so that the quality of the water is not given too much attention and is not controlled. On the other hand, one of the factors that determines the success of milkfish cultivation is water quality. Therefore, it is necessary to evaluate the milkfish ponds in Kangkung District, especially in terms of the physical and chemical parameters of the waters. This research was conducted to evaluate and analyze the most optimal pond land for milkfish cultivation in Kangkung District, Kendal Regency, based on the physical and chemical parameters of the waters using a geographic information system.

GIS studies for aquaculture in general include zoning and land suitability, the impact of aquaculture on the aquatic environment, aquaculture development planning, inventory management, and monitoring of aquaculture activities (Hasnawi *et al*., 2013). The advantage of using GIS for land suitability analysis is that it requires relatively little time, has relatively wide area coverage, and is relatively inexpensive (Pantjara *et al*., 2008).

2. Methods

The method used in this study is a survey method that involves determining the location points by purposive random sampling. Data that has been obtained from direct measurements in the field and laboratory testing is then processed spatially using ArcGIS 10.8.

2.1 Study Area

This research was conducted in September 2021 for field surveys, then continued with field data collection in November 2021. The research location is the milkfish pond area in Kangkung District, Kendal Regency.

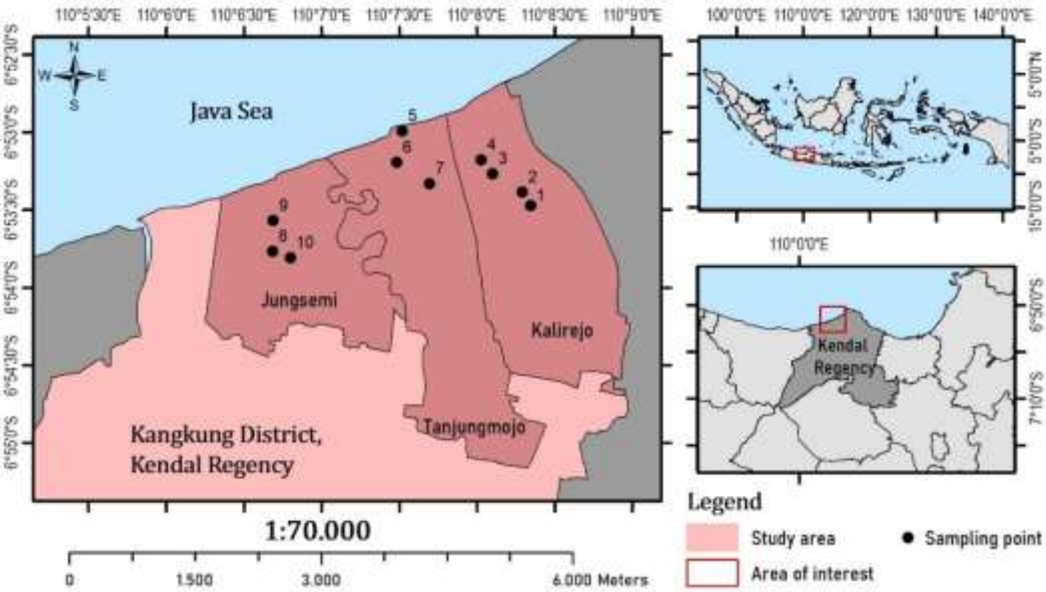

Figure 1. Study Area

2.2 Equipments and Materials

The equipment used in this study included a DO meter DO9100 to measure dissolved oxygen and water temperature, a pH meter to measure water pH, a refractometer to measure water salinity, a Secchi disk to measure water brightness, a scale stick to measure water depth, a sample bottle as a water container, as well as a HACH DR 3900 spectrophotometer to measure ammonia, nitrate, and phosphate levels in waters.

The materials used in this research are ammonia salicylate, ammonia cyanurate, phosphorus, nitrate, earth topography, and a base map.

2.3 Land Suitability Analysis

A land suitability analysis was performed in order to create a land suitability matrix (Table 1). The suitability matrix includes weights for each parameter and scores for each suitability class, which will be used to determine land suitability classes for milkfish farming (Table 2). The amount of weight and scoring have no absolute value because they are only used to facilitate the analysis of regional function division (Rachmah *et al*., 2018). The weighting of each parameter is determined by the limiting factor or parameter's dominance over a designation (Yusuf, 2013).

Table 1. Matrix of Suitability for Milkfish Cultivation Ponds

No.	Parameter	Range	Grade (A)	Weight (B)	Score (A×B)	Reference
1	Temperature (˚C)	27-30	3	6	18	Adapted from Widiana *et al*. (2017)
		31-33	2		12	
		<27 or >33	1		6	
2	Salinity (ppt)	12-20	3	6	18	Adapted from Irawan & Handayani (2021)
		21-30	2		12	
		<12 or >30	1		6	
3	Brightness (cm)	31-40	3	3	9	Adapted from Ramadhani *et al*. (2016)
		20-30	2		6	
		<20 or >40	1		3	

		81-120	3		9	
4	Depth (cm)	70-80	2	3	6	Adapted from Irawan & Handayani (2021)
		<70 or >120	1		3	
		6-8	3		18	
5	DO (mg/l)	3-5	2	6	12	Adapted from Arsandi *et al*. (2017)
		<3	1		6	
		7-8	3		18	
6	pH	5-6	2	6	12	Adapted from Widiana *et al*. (2017)
		<5 or >8	1		6	
		<0,3	3		15	
7	Ammonia (mg/l)	0,4-0,5	2	5	10	Adapted from Irawan & Handayani (2021)
		>0,5	1		5	
		0,9-3,5	3		15	
8	Nitrate (mg/l)	0,2-0,8	2	5	10	Adapted from Setianingrum *et al*. (2014)
		<0,2 or >3,5	1		5	
		0,051-1	3		15	
9	Phosphate (mg/l)	0,01-0,05	2	5	10	Adapted from Daimalindu (2019)
		<0,01 or >1	1		5	

Notes :

1. Grade are scoring figures based on DKP (2020) guidelines :

3 : appropriate

2 : sufficiently appropriate

1 : not appropriate

2. Parameter weights are determined based on consideration of the dominant variable
3. Scores obtained from $\sum_{i=1}^{n} A \times B$

Table 2: Suitability Scoring for Milkfish Cultivation Ponds

Category	Total Score	Suitability Level	The Quality of Pond Waters*
S1	107-137	Appropriate	There are potentially no impediments.
S2	76-106	Sufficiently appropriate	Meet the minimum requirements.
S3	45-75	Not appropriate	Requires a high cost to meet the minimum requirements.

*Adapted from Widowati (2004)

3. Results and Discussion

Water Physicochemical Parameters

The results of measuring the temperature of milkfish pond water are 29.3–32 C. The ideal temperature for milkfish maintenance and growth is between 28 and 30˚C (Cardoso *et al*., 2020). However, the optimum temperature for milkfish cultivation ranges from 27 to 30˚C (Tabun *et al*., 2021). Temperature differences in the water can be caused by topography or water depth, which is related to differences in the amount of sunlight that penetrates the surface layer of water to deeper layers of water (Sidabutar *et al*., 2019). Water temperature can affect all activities and life processes of fish, which include breathing, reproduction, and growth (Chilmawati *et al*., 2018).

The salinity of pond water measured ranged from 15 to 22 ppt. The salinity that can be tolerated by milkfish has a range of 0-35 ppt (Mutiasari *et al*., 2017). Milkfish, on the other hand, prefer salinities ranging from 10 to 20 ppt (Irawan & Handayani, 2021). Several factors can influence pond salinity, including distance to the beach, evaporation in the pond, and the presence of fresh water. Hot weather can cause the air temperature to rise, causing pond water to evaporate, increasing the salt content and salinity (Purnamasari *et al*., 2017). Differences in salinity values are also caused by differences in evaporation and precipitation (Hamuna *et al*., 2018).

The water brightness measurements yielded a range of 19-41.5 cm. The range of good brightness for milkfish cultivation is 20 to 40 cm (Reksono *et al*., 2012; Irawan & Handayani, 2021). The brightness of the water can be influenced by a variety of factors, including suspended particles in the water as well as measurement time and weather. Furthermore, low intensity sunlight entering the waters can inhibit the growth of phytoplankton, which is a natural food that produces oxygen, but too much sunlight can also indicate low primary productivity in ponds (Irawan & Handayani, 2021).

Milkfish ponds in Kangkung District have water depths ranging from 68 to 100 cm. Water depths of 80-120 cm are ideal for milkfish cultivation (Irawan & Handayani, 2021). The temperature of water can be affected by its depth. The colder the temperature, the deeper the water, and vice versa. This will have an effect on milkfish growth because water temperature can affect their appetite. Because light penetration decreases as water depth increases, the water temperature at the surface is higher than the water temperature near the bottom (Patty & Akbar, 2018).

The obtained dissolved oxygen values ranged from 4-6.7 mg/l. Milkfish cultivation is considered feasible when dissolved oxygen exceeds 3 mg/l (Firmansyah *et al*., 2021). The presence of abundant phytoplankton in the pond may contribute to the high dissolved oxygen value. Photosynthesis produces oxygen, which is used in the respiration process of the pond's biota, including milkfish. The amount of dissolved oxygen in the water can be affected by its brightness. This is related to phytoplankton photosynthesis, which requires sunlight and is one of the major sources of dissolved oxygen in water. The photosynthesis of phytoplankton and the diffusion process with air are the primary sources of dissolved oxygen in the waters (Megawati *et al*., 2014). Low dissolved oxygen content in the waters is caused by a lack of sunlight penetration in the water column (Daroini & Arisandi, 2020).

The pH measurement results range from 7.26 to 8.62. The pH range of 7-8 is the optimal pH value for milkfish growth (Andrila *et al*., 2019). The concentration of dissolved gases in the waters, such as CO_2, carbonate, and bicarbonate salts, as well as the process of decomposing organic matter at the bottom of the waters, all influence the pH of the waters (Daroini & Arisandi, 2020). The increase in pH value during the day is caused by chemical and biological processes such as photosynthesis from phytoplankton, microalgae, and other aquatic plants, which produce oxygen and cause the pH of the water to rise (Pramleonita *et al*., 2018).

The ammonia levels in the study ponds ranged from 0.07 to 0.21 mg/l. A good ammonia level is not more than 0.3 mg/l (Irawan & Handayani, 2021). Because the ponds where the sampling site is located are semi-intensive ponds with low fish densities, the remaining fish metabolism and feed residue, which are the ponds' main sources of ammonia, are also small. The decomposition of organic matter, the excretion of fish metabolic waste through the kidneys and gills, the results of protein decomposition from leftover feed, and dead plankton are all sources of ammonia in the water (Amanda & Suharsono, 2014). Ammonia is toxic at high concentrations because it causes a significant reduction in oxygen (Lembang & Lestari, 2020). Ammonia buildup in the fish's body can be toxic, resulting in slower growth rates, lower feed conversion, and decreased disease resistance (Ismettulloh *et al*., 2019).

Nitrate levels in Kangkung District pond water range from 1-3.3 mg/l. Nitrate content suitable for fish farming ranges from 0.1-4 mg/l (Ganesh *et al*., 2020). Nitrate levels can be high or low due to a variety of factors, including the rest of the milkfish's metabolism, water-soluble feed residue, pond fertilization processes, and the presence of mangroves around the ponds. The use of nitrate-rich fertilizers can cause an increase in the nitrate content of water (Mauddama *et al.*, 2018). Mangrove litter contains high levels of N and P, which can dissolve into water and be used by phytoplankton for growth (Prihatin *et al*., 2018). Nitrate is used in water as a nutrient by phytoplankton, algae, and other aquatic plants. Nitrate is required for the growth of plankton and klekap in traditional and semi-intensive ponds because it is a natural food for milkfish. Sufficient nutrients in the form of nitrogen and phosphorus support the availability of klekap and plankton (Andayani, 2012).

The phosphate content of the milkfish pond water ranges from 0.05-0.61 mg/l. The ideal phosphate level for pond fertility is between 0.051 and 1 mg/l (Daimalindu, 2019). Phosphate, like nitrate, is an important nutrient that affects the growth of phytoplankton and klekap in milkfish ponds. Because of its role as a nutrient for algae and aquatic plants, phosphate can also have an impact on aquatic productivity. Soil erosion, animal metabolic waste, weathering of plants, weathering of mineral rocks containing phosphorus, organic matter deposits, and PO_4 in the soil are all sources of phosphate compounds in waters (Riniatsih, 2016; Hamuna *et al*., 2018; Suhendar *et al*., 2020; Erawan *et al*., 2021).

Table 3. Measurement Results of Aquatic Physico-Chemical Parameters

Study area	Temperature (˚C)	Salinity (ppt)	Brightness (cm)	Depth (cm)	DO (mg/l)	pH (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
T1	29,3	15	37	100	5	7,5	0,09	1,1	0,16
T2	30,2	15	20	80	4	8,62	0,17	3	0,61
T3	29,4	17	19	78	6,7	8,54	0,21	3,3	0,82
T4	29,7	21	22	72	5,3	7,26	0,17	1,1	0,15
T5	31,1	22	22	68	5	7,42	0,11	1,3	0,32

T6	32	19	25	68	6,5	7,66	0,09	1	0,47
T7	30,5	18	41,5	80	5,6	7,58	0,07	1	0,12
T8	29,8	19	25	76	6,2	7,82	0,16	2,3	0,53
T9	30,4	22	19	69,5	5	7,26	0,07	1,1	0,27
T10	30,3	19	25	75	6,5	7,74	0,13	1,5	0,05

Land Suitability Analysis

Based on the results of measuring the physical and chemical parameters of the waters, two classes of pond land suitability in Kangkung District were determined: appropriate (S1) and sufficiently appropriate (S2), with a total score ranging from 105 to 129. The pond area included in the appropriate class (S1) is 235.32 ha, indicating that the pond has potential for milkfish cultivation and no inhibiting factors. Meanwhile, the sufficiently appropriate (S2) pond area is 30.78 ha, indicating that the pond has met the minimum requirements for milkfish cultivation. Nonetheless, pond areas classified as sufficiently appropriate (S2) can be used as milkfish ponds.

The differences in scores obtained for each location are influenced by the results of the water quality measurements. The lower the water quality value at that location, the less suitable it is for milkfish cultivation. Water sources, topography, soil quality, and the availability of infrastructure are all factors to consider when evaluating land for pond cultivation (Mustafa, 2012). Furthermore, water quality is important to consider because it can support the life of aquatic organisms that live in ponds.

According to the findings of the analysis, the limiting factors found in the Kangkung District ponds area are brightness, depth, and pH. The turbidity of pond water is thought to affect the brightness of pond water in areas T3, T7, and T9. The amount of suspended particles in the water can affect its brightness; the more suspended particles there are, the lower the brightness of the water (Ramadhani *et al*., 2016). The pond water depth in areas T5, T6, and T9 is insufficient for milkfish cultivation. Pond water temperature can be affected by depth; the less depth, the higher the water temperature; however, pond water that is too deep can cause a significant difference in water temperature (Faisyal *et al*., 2016; Yuni & Mustaqim, 2020). Pond water in areas T2 and T3, with pH values of 8.62 and 8.54, respectively, is unsuitable for milkfish cultivation. The optimal pH range for milkfish growth is 7 to 8 (Yahya *et al*., 2022).

Brightness, depth, and pH can be limiting factors in milkfish cultivation in Kangkung District because these three water quality variables play a role in klekap, which is a natural food for milkfish. Milkfish cultivation in Kangkung District is semi-intensive, so klekap is still used as milkfish food in addition to artificial feed in the form of pellets. Klekap is a meiofauna-associated microphytobenthos (Zainuri *et al*., 2017). Klekap, which grows at the pond's bottom, requires enough sunlight to thrive. Because it is related to the penetration of sunlight, pond water that is too deep can inhibit the growth of klekap. The amount of phytoplankton in the water can be affected by its brightness (Abida, 2010). The low intensity of sunlight entering the waters can inhibit phytoplankton growth, which is a natural food source for milkfish (Irawan dan Handayani, 2021). Turbid water conditions reduce the penetration of sunlight, lowering the brightness of the water (Patty *et al*., 2020). Ponds that have pH levels that are too low or too high can become infertile (Hantika *et al*., 2020).

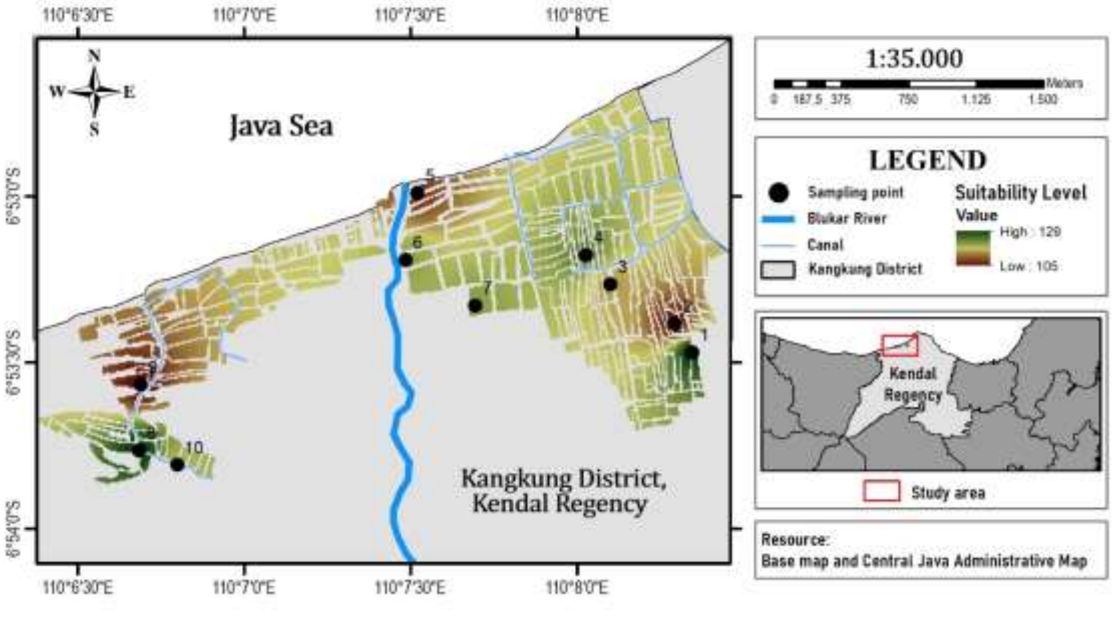

Figure 2. Kangkung District Suitability Map for Milkfish Cultivation

4. Conclusion

Based on the results of the analysis, Kangkung District is included in the appropriate category (S1) because it has physico-chemical parameter values that support milkfish cultivation, and sufficiently appropriate category (S2) because the physico-chemical parameter values of the waters meet the minimum requirements for milkfish cultivation but still have limiting factors in the form of brightness, depth, and pH.

The area of milkfish ponds in the appropriate (S1) Kangkung District is 235.32 ha (88.43%), while the sufficiently appropriate (S2) area is 30.78 ha (11.57%) of a total area of 266.1 ha.

Conflict of interest

The author states that there is no financial conflict of interest in research and writing.

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