Evaluation of the suitability of land for tiger shrimp (*Penaeus monodon*) cultivation with the silvofishery system in Lubuk Damar District, Seruway, Aceh Tamiang

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Abstract. Mangroves are coastal resources substantially affected by the large number of shrimp pond activities. The silvofishery system adopted by farmers has been included in the design and implementation of recovery management strategies for mangrove ecosystems. Silvofishery is a form of low input aquaculture that integrates mangrove cultivation with brackish water fisheries cultivation. The aim of this research is to assess the suitability of land for mangrove and tiger shrimp (*Penaeus monodon*) cultivation using the silvofishery system. The research was carried out by conducting a survey directly in the field, the research location being selected "purposively". The observations made included analysis of land suitability for mangroves and tiger shrimps using the silvofishery system. The data analysis method uses a mangrove land suitability matrix and tiger shrimp cultivation. The research results show that the type of mangrove planted in the silvofishery system pond is in accordance with the biophysical conditions of the growing environment. From the aspect of land suitability for cultivating tiger shrimps using the silvofishery system, the results showed that land suitability was in class S3 (marginal suitable), with the limiting factors being the low pH of the soil and the high levels of ammonia in the water. The land suitability is in class S2 (moderate suitable) with limiting factors on soil texture class. With these improvement efforts, actual land suitability can be increased from S3 (marginal suitable) to potential land suitability class S2. This is because the condition of the soil texture cannot be improved.
Key Words: biophysical conditions, land suitability, limiting factors, mangrove.

Introduction. Brackish water pond aquaculture is one of the potential uses of land in coastal areas. The long coastline in Indonesia has very high potential for developing brackish water ponds. The aquaculture sector in Indonesia has experienced extraordinary growth in its contribution to fish supplies in Indonesia (Nhuong et al 2017). According to the Indonesian Ministry of Maritime Affairs and Fisheries (2018), in 2018, the potential area for fisheries cultivation in Indonesia was 5794871 ha. The fisheries cultivation area is divided into freshwater cultivation area (2830540 ha), and brackish water cultivation area (2964331 ha).

The increase in land use for ponds in recent years is reflected in the increase in brackish water production. Indonesia ranks fourth as the most productive country in the world as measured by gross annual aquaculture production, with total aquaculture production in the third quarter of 2021 amounting to 12.25 million tons, an increase compared to the achievements in the third quarter of 2020, which was 11.53 million tons. Superior aquaculture products exported include shrimp, fish and seaweed (Indonesian Ministry of Maritime Affairs and Fisheries 2021).

On the other hand, the accelerated growth of aquaculture as a result of high global demand for shrimp has disrupted the mangrove ecosystem. This causes a reduction in the function of mangroves from ecological, economic and social aspects, especially for communities in coastal areas. According to Iswahyudi et al (2020), mangrove forests can protect coastal areas from tidal waves, hurricanes and tsunamis, and stabilize coastlines. Mangroves also help in sequestering carbon in the atmosphere.

In the east coast region of Aceh, aquaculture practices have been carried out since the 1980s, aquaculture being one of the employment sectors that absorbs a large number of workers. However, the aquaculture efforts carried out have caused a decline in land quality due to management that is not environmentally friendly and has occurred in almost the entire eastern coastal area of Aceh, which stretches from East Aceh, Langsa City and Aceh Tamiang. This condition causes fish farmers to look for alternative income by expanding their pond areas into mangrove areas.

Aceh Tamiang Regency has a mangrove forest area of 14105.9 ha, being the largest mangrove forest area in Aceh Province, but the area is currently decreasing (WWF 2017). To overcome this, it is necessary to implement an environmentally friendly alternative pond management known as silvofishery. Silvofishery, or "wanamina", is an integrated coastal farming system that combines brackish water cultivation with mangrove conservation to anticipate damage to ponds and the environment (Primavera 2000).

It is important to note that the success of developing silvofishery activities is largely determined by various interacting factors, one of which is the selection of suitable land. Land suitability is the degree of suitability of land for specific uses, such as for aquaculture businesses in ponds. According to Rossiter (2007), land suitability analysis is very important because land has varying physical, social, economic and geographical values that influence land use. This is done to increase pond productivity and to achieve the goal of sustainable aquaculture management. The aim of this research is to assess the suitability of land for cultivating tiger shrimp using the silvofishery system.

Material and Method

Description of the study sites. This research was carried out from June to August 2023 in tiger shrimp ponds that implemented the silvofishery system in Lubuk Damar Village, Seruway District, Aceh Tamiang Regency, Indonesia. The research location was determined purposively. The location was chosen deliberately on the grounds that there was a tiger shrimp pond that implemented a silvofishery system (Figure 1).

Data collection of soil physical and chemical properties, water physical and chemical properties, flooding class and tide frequency was carried out in 4 ponds that implemented the silvofishery system. Measurement of salinity was carried out directly in the field. The physical parameters of the water samples measured include: brightness level (m), measured using a Secchi disc, temperature (^{0}C), measured with a mercury thermometer, salinity (ppt), measured with a refractometer, and pH measured with a digital pH meter. All measurements were done directly in the field. Ammonia (mg L^{-1}) was measured using a spectrophotometer method with phenate.

The physical parameters of the soil included soil thickness (cm) and pyrite layer depth (cm), measured using a mineral soil drill. These measurements were done directly in the field. The soil texture was measured using the pipetting method, and soil pH was determined using the electrometric method. The C-organic content (%) the soil was measured using the Walkey & Black method.

Measurement of water ammonia levels, soil texture, soil pH and soil C-organic levels were carried out in the Soil and Plant Research Laboratory, Faculty of Agriculture, Syiah Kuala University, Banda Aceh. As for inundation class and tide frequency, the data were obtained from secondary data and the results of interviews with pond farmers and fishermen (4 pond farmers who implemented the silvofishery system and 8 fishermen were interviewed at the research location).

Method of collecting data. This research used a descriptive method with survey techniques. The data collected is in the form of primary data and secondary data. Primary data consists of pond biophysical data (sampling of water, soil and mangrove vegetation in tiger shrimp ponds that implement a silvofishery system), and interview data with respondents. Secondary data was obtained from literature studies and research reports from the Aceh Tamiang Regional Development Planning Agency, the Aceh Tamiang

District Maritime and Fisheries Service and Management Unit Forest Region III Aceh. The matrix of types, sources, data collection and analysis techniques, and output based on research objectives are presented in Table 1.

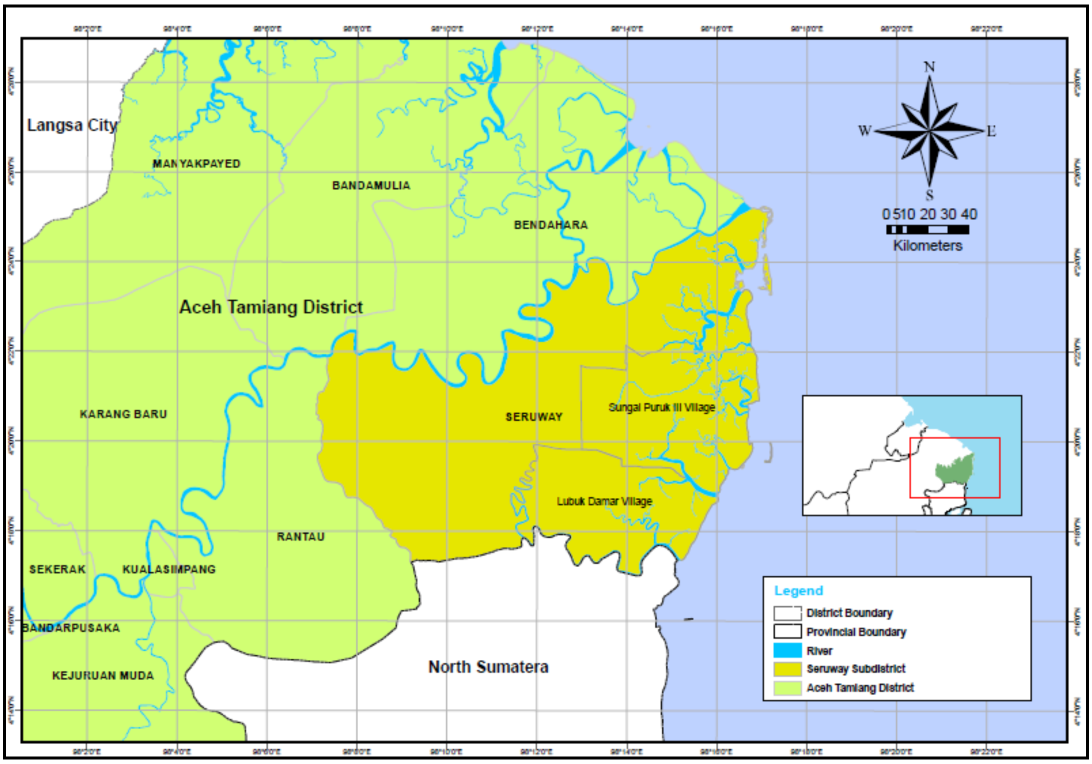

Figure 1. The research location, Lubuk Damar District, Seruway, Aceh Tamiang.

Table 1

Matrix of data types, data sources, data collection techniques, analysis techniques and output based on research objectives

Research objectives	*Data type*	*Data source*	*Analysis method*	*Output*
Suitability of land for mangroves	Primary data (type and frequency of tides, dominant mangrove species, soil physical properties and water chemical properties, slope class); and secondary data (mangrove introduction guide)	Results of field observations, laboratory analysis and literature study	Land suitability matrix for mangroves	Land suitability class for mangroves
Suitability of land for cultivating tiger shrimp in ponds	Primary data (Physical-chemical properties of soil and water) and secondary data (rainfall and dry months)	Results of field observations, laboratory analysis and literature study	Land suitability matrix for tiger shrimp ponds	Land suitability class for tiger shrimp ponds

Land suitability analysis for mangroves. Sampling was carried out at 4 tiger shrimp pond locations that implemented the silvofihery system. Determining the suitability of mangrove forest land is based on tide type, inundation class (salinity and tide frequency) and soil texture type. In this case, a correlation is made between salinity, frequency of tidal inundation (inundation class), type of soil texture and species of mangrove tree that can grow in the concerned area (Iswahyudi et al 2019). The land suitability matrix for mangroves is presented in Table 2.

Table 2

Land suitability matrix for mangroves

Tide type/ Inundation class (Watson 1928)	*Inundation class (Salinity and tide frequency) (de Haan 1931)*	*Soil texture type*	*Dominant mangrove species*
1. All high tides	Brackish to salty, salinity 10-20 ppt, always flooded (1-2 times/day, minimum 20 days/month). Brackish to salty, salinity 20-30 ppt, always flooded (1-2 times/day, minimum 20 days/month). Brackish to salty, salinity >30 ppt, always flooded (1-2 times/day, minimum 20 days/month).	Coral, sandy, sandy loam	*Avicennia* spp., *Sonneratia* spp., *Rhizophora* spp.
2. Medium high tides	10-19 days/month, salinity 10-20 ppt 10-19 days/month, salinity 20-30 ppt 10-19 days/month, salinity >30 ppt	Dusty to dusty clay	*Bruguiera gymnorrhiza*
3. Normal high tides	9 days/month, salinity 10-20 ppt 9 days/month, salinity 20-30 ppt 9 days/month, salinity >30 ppt	Dusty, clay dusty to clay	*Xylocarpus* spp., *Scyphiphora* spp., *Lumnitzera* spp.
4. Spring tides only	Some days/month, salinity is 0 ppt	Sandy to dusty clay	Marginal species in the mangrove environment such as: *Xylocarpus moluccensis, Intsia bijuga, Nypa fruticans, Ficus retusa, Glochidion littorale*
5. Storm high tides only	Fresh to brackish water, salinity 0 ppt (Rarely flooded at high tide)	Sandy to dusty clay	*Oncosperma* spp., *Cerbera* spp.

Note: source: Iswahyudi et al (2019).

Analysis of the suitability of land for cultivating tiger shrimps in ponds. In order for tiger shrimp cultivation activities in ponds to obtain maximum results, it is necessary to evaluate the suitability of the land, which is a key to success in aquaculture activities, influencing success and sustainability (Mustafa 2012). This is necessary because the practice of cultivating tiger shrimps using traditional systems is experiencing a decline in production due to the decreasing suitability of water land (Hukom et al 2013). The land suitability matrix for tiger shrimp cultivation is presented in Table 3.

The assessment of land suitability level classification used as a basis for evaluating land suitability for cultivation according to Hardjowigeno & Widiatmaka (2007) is the following: class S1 (highly suitable) - the land does not have any serious restrictions for sustainable use; class S2 (moderately suitable) - the land has heavy boundaries to maintain the level of management that must be carried out; class S3 (marginally suitable) - land has severe constraints to maintain the level of management that must be carried out; class N1 (not suitable at this time) - land has more severe limiting factors, which might be overcome, but cannot be improved with the current level of knowledge at a rational cost.

Table 3

Suitability of land for cultivating tiger shrimps in ponds

Parameter	*Class*			
	S1	*S2*	*S3*	*N1*
Topography and hydrology				
Slope (%)	<0.1	0.1-1	1-2	> 2
Tides (m)	1.5-2.5	1-1.5; 2.5-3	0.5-1; 3-3.5	<0.5; >3.5
Soil conditions				
Thickness of soil until it reaches rock (m)	>2	1.5-2	1-1.5	<1
Pyrite depth (m)	>2	1-2	1-2	<0.5
Clay (%)	10-20	20-30	30-60	<10; >60
pH	<1	1-3	3-5	>5
C-organic (%)	1.5-2.5	0.5-1.5	<0.5; 2.5-8	>8
Water quality				
Brightness (m)	0.3-0.4	0.25-0.3; 0.4-0.5	0.2-0.25; 0.5-0.6	<0.2; >0.6
Temperature (^{0}C)	28-30	20-28; 30-35	12-20; 35-40	>12; >40
Salinity (ppt)	15-20	10-15; 20-30	<10; 30-50	>50
pH	7.5–8.5	6–7.5; 8.5-9.5	4–6 9.5–11	<4; >11
Ammonia (mg L^{-1})	<0.1	0.1-0.2	0.2–0.3	>0.3
Climate				
Annual rainfall (mm $year^{-1}$)	2500–3000	2000–2500	1000-2000; 3000-3500	<1000 >3000
Dry months	1-2	2-3	3-5	<1; >5

Results

Land suitability analysis for mangroves. The initial stage was carried out to determine the suitability of the land for mangroves first by compiling a land suitability matrix (Table 4). The suitability of this land is based on criteria developed by Watson (1928), and de Haan (1931).

Table 4

Mangrove land suitability assessment matrix

Sample point	*Tidal type/ Inundation class*	*Inundation class (Salinity and tide frequency)*	*Soil texture*	*Species of mangrove planted*	*Land suitability*
1	All high tides	Brackish to salty, salinity 23 ppt, always flooded (2 times/day).	Sandy loam	*Rhizophora* spp.	Suitable
2	All high tides	Brackish to salty, salinity 25 ppt, always flooded (2 times/day)	Sandy loam	*Rhizophora* spp.	Suitable
3	All high tides	Brackish to salty, salinity 16 ppt, always flooded (2 times/day).	Dusty clay loam	*Rhizophora* spp.	Suitable
4	All high tides	Brackish to salty, salinity 20 ppt, always flooded (2 times/day).	Silty loam	*Rhizophora* spp.	Suitable

Table 4 shows that the type of tide/inundation class at the research location at all sampling locations was all high tides. In general, all sampling points were flooded 2 times/day. These tides are very determining in the formation of mangrove zoning at the research location.

The salinity value at the research location ranged from 16 to 25 ppt, slightly below normal sea salinity values. The highest salinity value was obtained at sample point 2, with a salinity value of 25 ppt. This location is close to the coastline and traversed by a large river (Krueng Tamiang River), which is influenced at all times by sea tides. The lowest salinity value was obtained at sample point 3, far from the river channel which carries tidal water, so the salinity was lower than in the other sample locations. In general, sea salinity has a salt content of 33-37 ppt (Wang et al 2011). The variation in salinity values at the research location is influenced by the high rainfall and the location of the research location, which is the estuary of the River Basin (Krueng Tamiang). The freshwater flows downstream and empties into the coastal area at the research location causing lower salinity.

Soil texture in a mangrove forest ecosystem is one of the factors that determines the species of mangrove that can develop in that area (Iswahyudi et al 2019). The results of the analysis show that the soil texture at the research location consisted of two types, namely sandy loam, and dusty clay. The mangrove plants planted in the silvofishery system pond area consist of 1 family, Rhizophoraceae, with 4 species: *Bruguiera cylindrica*, *Bruguiera gymnorrhiza*, *Rhizophora apiculata* and *Rhizophora mucronata*. Precise selection of the species of mangrove planted in ponds that implement the silvofishery system ensures that tiger shrimp cultivation has optimal results and the pond environment remains sustainable. According to Melana et al (2000), *Rhizophora mucronata* is suitable for growing on muddy land and is influenced by the presence of rivers.

To assess the land suitability class for mangroves in ponds that implement a silvofishery system, data analysis of three parameters (tidal type/inundation, salinity/tide frequency and soil texture class) was carried out. The suitability of the characteristics of the living area greatly influences mangrove growth. In general, the biophysical factors at the research location were very suitable for the species of mangroves planted. Tidal types, tidal fluctuations and salinity also allow mangrove growth. Tides bring sea water into the estuary against the outflow of fresh water, allowing mangroves to grow along river flows and bringing nutrients to the mangrove ecosystem.

Tidal fluctuations are very important in areas with high evaporation rates, because they help prevent hypersalinity conditions in the soil that are detrimental to mangroves. Fresh water brought in when seawater recedes can reduce the high salinity in the soil where mangroves grow. According to Iswahyudi et al (2020), mangroves grow in depositional areas with low sea waves. High sea waves can uproot mangroves with shallow root systems and reduce the deposition of sedimentation consisting of mud and clay, which contains organic material, a nutrient for mangrove growth.

The soil texture at the research location presented soft mud, being very suitable for the growth of *Rhizophora* spp. Mangroves grow on substrates that have a combination of sand, mud and clay, rich in organic material (Iswahyudi et al 2019). Soil substrate can influence the distribution of mangrove species. Melana et al (2000) added that suitable substrates for *Brugueira* spp. are sandy loam or dusty clay. *Rhizophora* spp. can grow well in soft (not yet mature) and muddy soils.

Sandy loam substrate is very suitable for the growth of *Rhizophora* spp. The root forms of *Rhizophora* spp. can help in forming a substrate, especialy as they are dense and are well anchored, capturing particles in the water. Mud or sandy loam substrates are suitable for the growth of *Rhizophora mucronata* and *Sonneratia alba* (Mirerra et al 2013).

Land suitability for tiger shrimp cultivation

Topography and hydrology. The slope at the research location was relatively flat, <0.1%. This is very suitable for cultivating tiger shrimps in ponds. According to Ristiyani (2012), areas that have the greatest potential to be developed as pond land are areas that are on a slope of 0-2%. The type of tide at the research location is semidiurnal (mid-daily/double daily tide). Within 24 hours, there are 2 high tides and 2 low tides, with a 6 hour high and low tide period. The first tide occurred at 04.24 West Indonesia Time (WIB) and the second tide occurred at 19.38 WIB. The water level at high tide is 2.3 m and the water depth at low tide is 1 m. The difference between high tide and low tide is 1.3 m. According to Mustafa (2012), tidal conditions with a water depth of 1.3 m are included in the class suitable for cultivating tiger shrimps in ponds. A good tidal difference for tiger shrimp pond cultivation is 1.5-2.5 m (Hardjowigeno & Widiatmaka 2001).

Soil conditions. Soil quality is an important factor in the productivity of tiger shrimp ponds in the silvofishery system. Pond soil can function as a buffer for aquatic ecosystems, providing important nutrients and can function as a biological filter through adsorption of organic residues, fish feed excretions and algae metabolites. Thus, it can control the stability of the pond bottom, the pH of the water above it, and the concentration of plant nutrients needed for phytoplankton growth. The results of the physical and chemical properties at the research location are presented in Table 5.

Table 5

Soil chemical and physical characteristics

Sample point	*Parameter*				
	Soil thickness until it reaches stone (m)	*Pyrite depth (m)*	*Soil texture (%)*	*pH*	*C-organic (%)*
1	>2	>2	S=37, Si=42, C =21	6.42	1.45
2	>2	>2	S =32, Si=44, C=24	5.36	2.03
3	>2	>2	S=15, Si=57, C=28	6.32	1.55
4	>2	>2	S=2, Si=69, C=29	5.06	1.85

Note: S - sand; Si - silt; C - clay; C-organic - soil organic carbon.

Table 5 shows that the depth of the soil until it reaches stone at the research location is more than 2 m at all sample points. To cultivate shrimp in ponds, a water depth of 1-1.2 m is required. At the research location, the soil depth is above 2 m. According to Mustafa (2012), this depth is very suitable for tiger shrimp cultivation. The depth of the pyrite is also above 2 m. This depth is very suitable for cultivating tiger shrimp in brackish water ponds. Therefore, the presence of pyrite at the research location is not a serious problem. The high amount of pyrite is one of the causes of the low productivity of brackish water ponds in the Mahakam Delta region, where the high pyrite content in the bottom of pond soil makes cultivated species susceptible to disease. Apart from that, pyrite content can also be toxic to cultivated biota (Rizal et al 2020). Oxidized pyrite will produce sulfuric acid and ferrosulphate, which, when it reacts with water, releases iron sulfate, which, if re-oxidized, produces sulfuric acid. Sulfuric acid causes low pH and high acidity. Factors that influence pyrite formation are the amount of organic matter, sediment temperature, supply of sulfate (SO_4) and bicarbonate, as well as the anaerobic atmosphere and Fe content (Mustafa et al 2020).

The soil texture at the research location consists of three types, namely sandy loam, dusty clay loam and dusty clay. The texture and porosity of pond soil greatly influence the growth of algae that live at the bottom of the pond, which are a food source for tiger shrimp. Ponds with coarse textured soil have high soil porosity, causing permeability. According to Boyd (1995), soil texture is one of the variables that is very influential in determining the productivity of tiger shrimp ponds. In ponds dominated by fine soil textures, production tends to be higher than in ponds dominated by coarser soil textures. The texture of pond soil is closely related to erosion and sedimentation processes, embankment stability, seepage and suitability of pond bottom habitat. Soil textures that are suitable for pond cultivation include clay, clay loam, silt loam, silty loam, sandy loam, and sandy loam (Ahmed 2004).

There is also a tendency for the abundance of 'klekap' (a benthic complex of blue-green algae, protozoa, diatoms, bacteria and detritus) to be higher in pond soil that has a fine soil texture compared to coarse soil texture. Klekap is a natural food important for cultivating fish and shrimp in brackish water ponds, especially those managed using traditional, traditional plus (characterized by the adoption of simple technologies and better management practices) and semi-intensive technology (Mustafa 2012).

Soil pH at the research location ranged from 5.06 to 6.42, which is included in the acid criteria. According to Siddique et al (2012), a location is suitable for shrimp and fish cultivation activities if the soil pH is neutral.

The C-organic value at the research location ranged from 1.45 to 2.03%. The value of C-organic content at the research location is not too high because it is related to the type of substrate. The greater the sand content is at the research location, the lower the C-organic value is compared to locations with a substrate that contains mostly clay. Boyd et al (2002) stated that organic carbon content between 1-3% is the best range for coastal aquaculture.

Water quality. Water quality is important for the development of aquaculture ponds in mangrove ecosystems. This is one of the determining factors in environmental carrying capacity in the development of aquaculture ponds. The suitability of a silvofishery system pond can be seen from the water quality. The physical and chemical characteristics of the research location waters are presented in Table 6.

Table 6

Characteristics of the physical and chemical properties of water in the research location

Sample point	*Parameter*				
	Brightness (m)	*Temperature (^0C)*	*Salinity (ppt)*	*pH*	*Ammonia (ppm)*
1	0.35	25.9	23	7.92	0.18
2	0.29	25.6	25	7.99	0.16
3	0.34	25.7	16	7.72	0.12
4	0.39	25.8	20	7.15	0.30

Table 6 shows that the water brightness value at the research location ranged from 0.29 to 0.39 m. This range is very suitable for cultivating tiger shrimps in ponds. The water transparency value is an indicator of the level of water pollution. In the silvofishery shrimp pond cultivation system, brightness is influenced by the accumulation of organic material from mangrove litter and shrimp metabolic waste that accumulates in the water. The optimum brightness of pond water for tiger shrimp is 30-40 cm (Hardjowigeno & Widiatmaka 2001). If the water clarity reaches less than 25 cm, it is best to change the pond water immediately before the phytoplankton die and DO drops. According to Aziz et al (2015), if the brightness of the pond waters is low, it will affect the DO levels in the pond and the survival of the shrimp. Brightness is influenced by the presence of phytoplankton. The higher the abundance of phytoplankton is, the brightness of pond water decreases.

Water temperature is related to the concentration of DO in the water and the rate of oxygen consumption by aquatic biota. Water temperature is inversely proportional to the saturated concentration of DO, but directly proportional to the rate of oxygen consumption by aquatic biota. At high temperatures, metabolic processes and chemical reactions in water occur more quickly. The results of water temperature measurements at the research location ranged from 25.6 to 25.9°C, which means that the entire research location is very suitable for tiger shrimp cultivation activities using the silvofishery system. The optimal water temperature range for aquaculture in tropical areas is 25-32°C, because, in general, aquaculture in tropical waters is included in the warm water aquaculture group. The suitable temperature for shrimp cultivation is in the range of 24 to 32°C. Lower temperatures can reduce shrimp growth (Maicá et al 2014).

The salinity values for the three research locations ranged from 16-25 ppt. The salinity condition is caused by the river flow, causing the mixing of fresh water and sea water. Thus, there is a dilution of the salinity. The salinity influences the species distribution and size of cultivated tiger shrimps. Although some aquatic organisms have a high adaptability to salt content (euryhaline), their growth depends on their age and requires an optimal range of salinity. Good salinity for tiger shrimp cultivation ranges from 15 to 20 ppt (Mustafa 2012). Therefore, the salinity conditions at the research location are very suitable for tiger shrimp cultivation. Tiger shrimps are able to adapt to a salinity of 3-45 ppt, but the salinity requirement for optimum growth is 15-25 ppt (Andi et al 2013).

Water pH at the research location ranged from 7.15 to 7.99. According to Chatla et al (2017), the suitable pH range for shrimp cultivation is between 7.5 and 8.5. Therefore, the pH conditions at the research location are very suitable for cultivating tiger shrimp using the silvofishery system. Coastal seawaters have a relatively stable pH ranging from 7.7 to 8.4. The pH value of seawater is generally alkaline because it contains relatively high levels of dissolved salts, including bicarbonate (HCO_3-). Water that contains high levels free carbon dioxide (CO_2) usually has a pH lower than 7.0 and is generally found in fresh water with a large organic matter input. The pH of fresh water ranges from 5.5 to 7. Under normal conditions, the pH of seawater ranges from 7.5-9 and is generally more stable because it contains more carbonate and bicarbonate compounds which function as buffers.

The results of measuring ammonia levels in the pond water at the research location ranged from 0.12 to 0.3 ppm. In accordance with the Decree of the Minister of Environment and Forestry Number 51 of 2004, the quality standard for ammonia for marine biota is 0.3 ppm. Thus, based on the ammonia content, the research location is very suitable for developing silvofishery tiger shrimp farming activities. According to Lu et al (2016), the optimal concentration of ammonia in water for healthy growth of fish and shrimp is below 0.2 ppm. Ammonia is a toxic form of inorganic nitrogen produced in ponds. Ammonia comes from the mineralization process of organic material by heterotrophic bacteria. Most aquatic organisms also create it as a by-product of nitrogen metabolism (Cheng et al 2017).

Climate. The distribution of annual rainfall at the research location based on rainfall data for 10 years (2002-2022) ranges between 2000-3000 mm. The average monthly rainfall is 220.83 mm, with the minimum rainfall occurring in February (110 mm) and the maximum in October (354 mm). The average annual rainfall at the research location is 2648 mm per year and the number of dry months is 2 times per year (BPS Aceh Tamiang 2022).

Suitability of land for cultivating tiger shrimps using the silvofishery system. In order for tiger shrimp cultivation activities using the silvofishery system to have optimal results, it is necessary to evaluate the suitability of the land, this being a key activity to success in aquaculture activities. According to Karlina & Pratiwi (2021), the analysis of the suitability of the mangrove bioecosystem for the silvofishery system is related to the suitability of the environmental physical, chemical and biological conditions. The appropriate quality of water, soil and other elements in the mangrove ecosystem must be considered in tiger shrimp pond cultivation in order to support maximum pond cultivation quality, while considering sustainability aspects.

In general, the physical and chemical characteristics of water and soil in ponds are very suitable for cultivating tiger shrimps using the silvofishery system. However, there are several parameters whose land suitability class includes marginal suitability criteria. Class conditions and frequency of flooding and the substrate (soil texture) at the research location is very suitable for the growth of mangroves to be used as cultivation land using a silvofishery system. The land suitability matrix for tiger shrimp cultivation in the silvofishery system is presented in Table 7.

Table 7

Suitability of land for cultivating tiger shrimp (*Penaeus monodon*) using the silvofishery system

Parameter	*Sample point*							
	1		*2*		*3*		*4*	
Topography and hydrology	Value	Class	Value	Class	Value	Class	Value	Class
Slope (%)	<0.1	S1	<0.1	S1	<0.1	S1	<0.1	S1
Tides (m)	1.3	S2	1.3	S2	1.3	S2	1.3	S2
Soil conditions								
Thickness of soil until it reaches rock (m)	>2	S1	>2	S1	>2	S1	>2	S1
Pyrite depth (m)	>2	S1	>2	S1	>2	S1	>2	S1
Clay (%)	21	S2	24	S2	28	S2	29	S2
pH	6.42	S2	5.36	S3	6.32	S2	5.06	S3
C-organic (%)	1.45	S2	2.03	S1	1.55	S1	1.85	S1
Water quality								
Brightness (m)	0.35	S1	0.29	S1	0.34	S1	0.39	S1
Temperature (°C)	25.6	S2	25.6	S2	25.7	S2	25.7	S2
Salinity (ppt)	23	S2	25	S2	16	S1	20	S1
pH	7.92	S1	7.99	S1	7.72	S1	7.15	S2
Ammonia (mg L^{-1})	0.175	S2	0.162	S2	0.121	S2	>0.3	S3
Climate								
Annual rainfall (mm $year^{-1}$)	2.648	S1	2.648	S1	2.648	S1	2.648	S1
Dry months	2	S1	2	S1	2	S1	2	S1

Assessment of actual and potential land suitability classes. The results of the land suitability analysis (Table 8) show that a suitability class of S3 (marginal suitability), with soil chemistry limiting factors (nutrient retention and high ammonia content). Nutrient retention is caused by acidic soil.

Potential land suitability is the suitability of land for which improvement or conservation efforts are made to increase the suitability class, to eliminate the limiting factors that cause low suitability. The improvement efforts carried out must be in line with the level of land suitability assessment to be carried out. The suitability class of the land can be increased by providing technological input that can minimize the influence of existing limiting factors. There are three levels of technology that can be applied, namely: low input (Li), medium input (Mi) and high input (Hi). Efforts to improve silvofishery ponds at the research location are carried out based on the classification of existing limiting factors. There are various kinds of limiting factors that exist in the field, some of which can be corrected and some of which are permanent. Improvement efforts are being made so that tiger shrimp cultivation at the research location can be carried out and produce optimal results.

The main limiting factors that cause the land to be unsuitable for use in the current study are nutrient retention (acidic soil) and high ammonia content. Of the four observation sample points observed, the class of all sample points could potentially be improved. Nutrient retention at all sample points causes the actual land suitability class to be S3. The S3 suitability class can be upgraded to the S2 if the land to be developed for tiger shrimp cultivation is improved by applying dolomite lime (containing $CaCO_3$ and MgO_3) which is a source of alkali. Ammonia in tiger Shrimp cultivation ponds can be controlled by controlling water quality, maintaining water pH, increasing aeration and circulating/changing water, controlling feeding, and providing probiotics regularly. With this improvement effort, the actual land suitability can be increased from marginally suitable (S3) to moderately suitable (S2). As for the condition of the soil texture, improvements cannot be made.

Table 8
Results of land suitability analysis for tiger shrimp (*Penaeus monodon*) cultivation

Sample point	*Actual land suitability class*	*Actual land suitability class*	*Actual land suitability class*	*Actual land suitability class*
1	S3 N nr	Nutrient retention	+; ++	S2 soil texture
2	S3 N nr	Nutrient retention, ammonia	+; ++	S2 soil texture
3	S3 N nr	Nutrient retention	+; ++	S2 soil texture
4	S3 N nr	Nutrient retention, ammonia	+; ++	S2 soil texture

Note: N nr - nutrient retention; improvement of limiting factors: + - liming; ++ - controlling water quality, aeration and water circulation.

Conclusions. Based on the level of suitability of the land, in general, the biophysical factors at the sivofishery pond location are very suitable for the species of mangroves planted (*Rhizophora* spp). The actual land suitability level of tiger shrimp cultivation ponds using the silvofishery system at the research location is classified as marginally suitable (S3), with limiting factors being nutrient retention (acidic soil) and high water ammonia content. The suitability potential is classified as S2, with the limiting factor being the clay content/soil texture.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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