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Research article

Evaluation of water and soil qualities for giant freshwater prawn farming site suitability by using the AHP and GIS approaches in Jelebu, Negeri Sembilan, Malaysia

Rosazlin Abdullah[1,2,*], Firuza Begham Mustafa[2,3], Subha Bhassu[1,2], Nur Aziaty Amirah Azhar[1], Benjamin Ezekiel Bwadi[4], Nur Syabeera Begum Nasir Ahmad[3] and Aaronn Avit Ajeng[1]

[1] Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2] Centre for Research in Biotechnology for Agriculture (CEBAR), University of Malaya, 50603 Kuala Lumpur, Malaysia
[3] Department of Geography, Faculty of Arts and Social Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia
[4] Department of Geography, Taraba State University, PMB 1167, Jalingo, Nigeria

* **Correspondence:** Email: rosazlin@um.edu.my; Tel: 60379674360.

Abstract: Water and soil qualities play significant roles in the farming of giant freshwater prawn. The study evaluated water and soil qualities for giant freshwater prawn farming site suitability by using Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) in Jelebu, Malaysia. The water quality parameters measured were biochemical oxygen demand, chemical oxygen demand, ammonia nitrogen, pH, dissolved oxygen, water temperature, total suspended solids, nitrite concentration and phosphate concentration, meanwhile soil qualities investigated were land use, slope, pH, texture, organic carbon and organic matter. Site suitability analysis can assist to identify the best location for prawn production. Specialist's opinions were used to rank the level of preference and significance of each of the parameter while the pairwise comparison matrix was applied to calculate the weight of each parameter for prawn farming. There are about 45.41% of the land was most suitable, 28.89% was moderately suitable while 25.69% was found unsuitable for prawn farming. The combination of AHP and GIS could give a better database and guide map for planners and decision-makers to take more rewarding decisions when apportioning the land for prawn farming, for better productivity.

Keywords: analytic hierarchy process; soil quality; water quality; giant freshwater prawn; site suitability

1. Introduction

Giant freshwater prawn (*Macrobrachium rosenbergii*) farming plays a significant role in the economic development of Malaysia. It aims to increase economic activity, providing a source of income to local prawn farmers, alleviating the poverty problem within the community [1]. Prawn culture has been improved in recent years targeting increased production. Despite the abundance of freshwater and the natural environment for prawn production in Jelebu, the production remains low. This was attributed to inadequate knowledge of the farmers to select the most suitable site for farming [2]. According to Zafar et al. [3], water and soil quality parameters perform vital roles in the site suitability analysis for sustainable prawn production. Apart from that, Malaysia has high potential for aquaculture growth because of the nation's favorable conditions in terms of natural environments such as lakes, streams, ponds, rivers, estuaries, and coastal areas. This can be seen from the record obtained from world prawn production in 2016 where 551 of 233,989 tons of which came from Malaysia amounted 2.4 billion Malaysian Ringgit contributed by balanced values of international trade from Malaysian aquaculture production [4]. Thus, this aquaculture sector is an alternative way of accelerating the local yield of food security as well as to increase the export earnings in Malaysia [5].

According to New (2009) [6], the requirement to build a freshwater prawn farm is very similar to a freshwater fish farm. To achieve an effective sustainable aquaculture development, the operation of giant freshwater prawn farming should be kept within a suitable area as site selection for aquaculture greatly influences the viability of this economic activity [7]. Apart from that, suitable level of water and soil quality parameters are still under investigations as these are the crucial factors for prawn production [3]. The major challenges in identifying a suitable site for prawn production are the absence of baseline knowledge on the physicochemical and the nature of the relief requirements besides current land use pattern. Inappropriate land use for prawn farming without considering the several important factors can lead to environmental pollution, ecological imbalance, increase salinity, land degradation, destruction of the forest, sedimentation and outbreaks of diseases, breeding poverty as well as any other social conflicts [1,3].

Site suitability analysis is considered to be one of the most significant and functional approaches for identifying the most appropriate places for the purpose of planning and mapping in accordance to specified requirements or criteria [8]. It comprises the choice of suitable sites for farming by mapping out the suitability indicators of a particular portion of land [9]. Geographic Information System (GIS) method has been a powerful tool for planning and management of prawn farming and its consequence to the environment [10]. Site suitability analysis based on GIS is a procedure that targets identifying the most suitable sites for development while bearing in mind the environmental sustainability [11].

Site suitability analysis is the estimation of the level of fitness or the possible behavior of the land for a particular purpose [12]. Baja et al. [13], identified two major types of land suitability assessment methods: qualitative and quantitative. In qualitative methods, it is possible to evaluate land potential in categorical terms, such as highly suitable, moderately suitable, or not suitable. Whereas, using quantitative methods, the evaluation of land suitability is given by numbers in a continuous scale. In practice therefore, land suitability analysis describes a process of land evaluation with a specific land use objective in mind [14]. More specifically, land suitability analysis will propose for farming or not farming a certain aquaculture or crop, in an area of land.

Many authors applied the land suitability analysis in different fields: Identification of the appropriate site of prawn farming [1], allocation of land for agriculture [15], and identification of suitable site for shrimp ponds [16,17]. Other fields comprise selecting appropriate sites for land use planning [18–21], the development of urban aquaculture [22], and prioritize demolitions of city buildings [23]. Also Chandio et al. [24] applied the land suitability analysis to determine a proper site for hillside development, Trinh et al. [25] mapping of areas susceptible to landslide, while Rahmat et al. [26] and Şener et al. [27] applied it to identify possible sites for landfills.

Site suitability analysis for prawn culture is a complicated activity as it involves numerous factors and criteria such as water quality, soil quality and socioeconomic features [1]. In setting the importance of the criteria used and calculating the weights of factors, GIS techniques must be combined with other techniques such as Analytic Hierarchy Process (AHP) and Weighted Linear Combination (WLC) to improve the results of the site suitability analysis. The incorporation of GIS techniques with multi criteria decision analysis (MCDA) is an effective procedure for analysing land suitability [15,28].

MCDA is a method that incorporates multiple and different criteria, attributes, and objectives, which allows solving a large kind of complicated spatial problems encountered and convert them into decision-making [29]. It consists of diverse methods in which the most important ones include; analytic hierarchy process (AHP), preference ranking organization enhancement (PROMETEE), and multiple-attribute utility theory (MAUT) [30]. The AHP hasmore advantages in land suitability analysis over the other multi-criteria approaches; it provides a structure for evaluating suitability by 'decomposing' the suitability analysis factors into hierarchical levels or order. This allows for an in-depth analysis of the factors which may be better understood when de-coupled or deconstructed into their lower and more specific forms or indicator. The AHP also gives room for the expert's opinions and observations about the deferent factors. Also the technique is more transparent and therefore more likely to be acceptable especially when the suitability will eventually serve as a basis for land identification. Furthermore, the AHP gives room for the participation of both experts and stakeholders in providing the suitability measures of a place relative to quantitative criteria for evaluating suitability [31]. According to Dehe and Bamford [31] site suitability analysis is an organized decision that may positively or negative affect the activities to be carried out. It requires an investment of resources which could have an important influence on the cost, speed, reliability and flexibility of the projects. Nevertheless, the procedures are complex and required logical decision making, usually subject to change [32].

It is essentially valuable in breaking the decision into smaller and more understandable segments, analysing each segment and combining the segments to produce a meaningful solution. MCDA gives a unique opportunity to analyse and discuss complex trade off among alternatives. The five key components of MCDA are the decision makers, the goal, the decision alternatives, the evaluation criteria and finally the outcomes or consequences associated with the alternative or criteria. However, the technique was not well researched in Jelebu. Bwadi et al. [33] applied the tools to analyze the spatial suitability of water quality in Negeri Sembilan but the study was not specific to Jelebu and was only restricted to water quality but could not cover other qualities of the land. The objective of this study is to evaluate water and soil qualities for giant freshwater prawn farming site suitability by applying GIS and MCDA in Jelebu, Negeri Sembilan, Malaysia. An evaluation of the major parameters used to select the most suitable locations for prawn farming were presented. We hypothesized that combination of GIS with AHP could relevant to determine the suitability of a site for prawn farming. This study can be utilized to determine potential sites and essentially solve the problems and limitations of the existing land suitability methods.

2. Materials and methods

2.1. The study area

Jelebu district is situated in the northeastern part of Negeri Sembilan between 2 º55’N and 2 º25’N latitude 102 º4’E and 102.10’E longitude, occupying about 1367.5km^2 (136,751.49 ha) with the population of about 37,287 people in 2010. It is the second largest district of Negeri Sembilan after Jempol. It is located about 34.1 km to the North-East of Seremban. It borders the districts of Seremban, Jempol, Kuala Pilah, and the states of Pahang and Selangor. The district is covered by 61.8% (84,556.25 ha) of high forest vegetation. The Jelebu district is one of the possible fields for prawn production [34].

The climate in Jelebu is tropical equatorial. As in most equatorial countries, rainfall is expected all year round, but the wettest months tend to be from September to November. Temperatures normally vary from 23 ℃ to about 33 ℃, and humidity is usually above 82%. Underlain types of soil consist of brownish-yellow colours and granite parents derived from the soil at the hilly and undulating mountains. Naturally has coarse angular quartz grits and sand all through the profile, sandstones, quartzite, iron-rich sandy shales, and conglomerate parent material.

The samples were taken for ten months from February to November 2018 including dry and wet seasons.. Twelves (12) sampling locations were chosen covering the area located in Ulu Klawang, Kuala Klawang, Peradong, Pertang, Triang Hilir, Kenaboi, Glami Lemi and Ulu Triang (Figure 1). Each sampling site was determined by considering less than 1 km from the existing water sources around the sampling area. This is due to the fact that water resources are extremely important in prawn farming. The sampling site locations were determined randomly by using Portal Geospatial Information System Negeri Sembilan (GIS9 Portal). The GPS was utilised to obtain the exact coordinates of each sampling site and the type of GIS software applied for this study is ArcGIS version 10.3 for desktop produced by Environmental Systems Research Institute Inc., USA. Besides water source, industrial area in Jelebu will not be considered as a sampling point because the possibility to run prawn farming in industrial area are low. Furthermore, samples will not be taken in regions where there are constraints such as forests and highlands. Each sampling site must be the land use area closest to the access road and the river system.

2.2. Water quality analysis procedure

The procedure of analysis was designed based on six main parameters of Water Quality Index (WQI) provided by the Department of Environment (DOE) [35] which covering biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen (NH3-N), pH, dissolved oxygen (DO) and total suspended solids (TSS). Furthermore, several water quality parameters that are directly involved with giant freshwater prawn metabolism were also introduced in this analysis such as temperature, nitrite and phosphate concentration. The calculation for Water Quality Index (WQI) was referred from the Department of Environment Malaysia for river water and it was made based on the derivation of WQI (Table 1). The result obtained from the derivation of WQI was used to evaluate the class of the water (Table 2): ("National Water Quality Standards for Malaysia", 2019) [36]. For each sampling site location, the total volume of water taken is 1 litre and the sample analysis of each location were replicated both in wet and dry season.

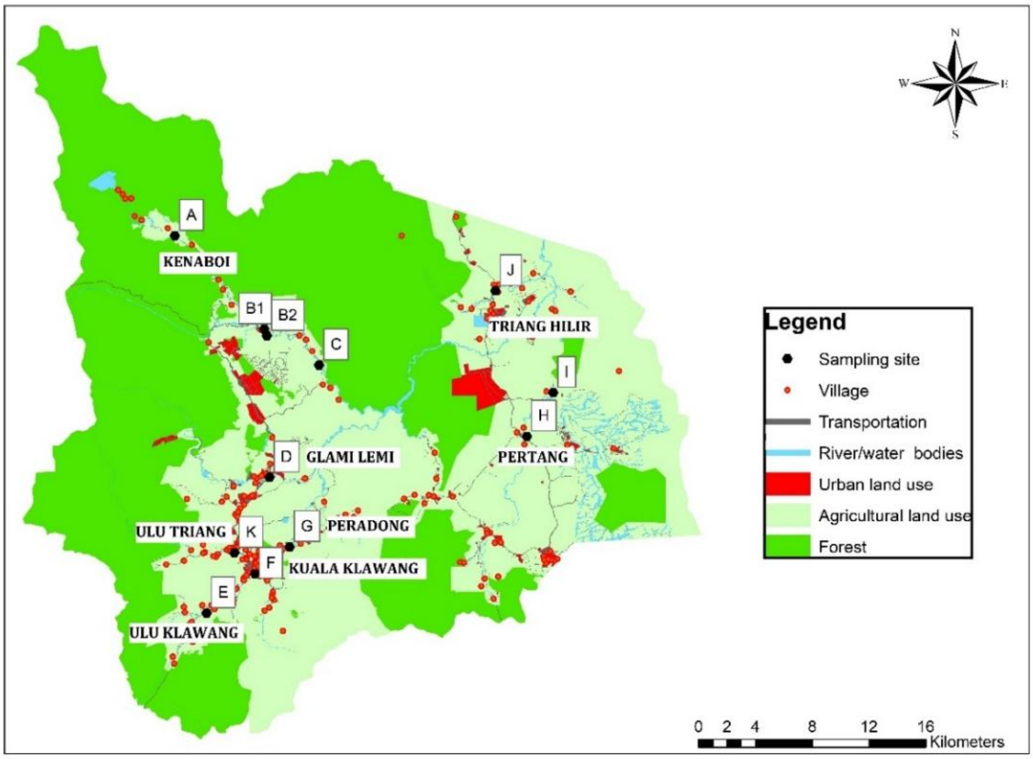

Figure 1. Map of Jelebu district showing the sampling site locations; label A-H refers to sampling location site.

The biochemical oxygen demand (BOD) is an experimental analysis to ascertain the relative oxygen requirement of the water. The method was adopted from the American Public Health Association, (APHA) Method. The chemical oxygen demand (COD) analysis is a test of the oxygen equivalent of that part of the organic matter in a sample that is susceptive to oxidation by a strong chemical oxidant (Wastewater Sampling Method, 2013) [37]. The reagent kits used for this study is HI 93754B-25 MR. 2ml of water sample was added into the vial and were cap tightly. After that, the samples were mixed in the vial by inverting it a couple of times and the vials were inserted into the COD reactor and heated for 2 h at 150 ℃. Once the digestion period was completed, the vials are left to cool for twenty minutes in order to reach 120 ℃. Each of the vials was inverted many times while still warm and the reading was taken by using COD and Multiparameter Bench Photometer (Hanna HI83099). Total Suspended Solids (SS) is the analysis that a well-mixed sample was filtered through a weighted standard glass-fiber filter (0.45 μm) and the residue retained on the filter was dried to a constant weight at 103 to 105 ℃. The method was adapted from APHA Method 2540 [38].

Table 1. Derivation of WQI.

WQI = 0.22 × *SIDO* + 0.19 × *SIBOD* + 0.16 × *SICOD* + 0.15 × *SIAN* + 0.16 × *SISS* + 0.12 × *SIpH*

Where,

- *SIDO* = Sub – Index DO (in % saturation)
- *SIBOD* = Sub – Index BOD.
- *SICOD* = Sub – Index CoD
- *SISS* = Sub – Index SS
- *SIAN* = Sub – Index NH_3N
- *SIpH* = Sub – Index pH

Best fit equations for the estimation of the sub-index values are:

Sub-index for DO (in % saturation):

SIDO $= 0$ for $x \leq 8$

$= 100$ for $x \geq 92$

$= -0.395 + 0.030x^2 - 0.00020x^3$ for $8 < x < 92$

Sub-index for COD:

SICOD $= -1.33x + 99.1$ for $x \leq 20$

$= 103 * \exp(-0.0157x) - 0.04x$ for $x \geq 20$

Sub-index for AN:

SIAN $= 100.5 - 105x$ for $x \leq 0.3$

$= 94 * \exp(-0.573x) - 5 * |x - 2|$ for $0.3 < x < 4$

$= 0$ for $x \geq 4$

Sub-index for SS:

SISS $= 97.5 * \exp(-0.000676x) + 0.05x$ for $x \leq 100$

$= 71 * \exp(-0.0016x) - 0.015x$ for $100 < x < 1000$

$= 0$ for $x \geq 1000$

Sub-index for pH:

SIpH $= 17.2 - 17.2x + 5.02x^2$ for < 5.5

$= -242 + 95.5x - 6.67x^2$ for $5.5 \leq x < 7$

$= -181 + 82.4x - 6.05x^2$ for $7 \leq x < 8.75$

$= 536 - 77.0x + 2.76x^2$ for $x \geq 8.75$

Table 2. Guideline for water use.

Class	Uses
Class I	Conserves the environment
	Water Supply I—hardly any treatment required
	Fishery I—can be tolerated by very sensitive species
Class IIA	Water supply II—normal treatment necessary
	Fishery II—can be tolerated by sensitive species
Class IIB	Can be used for body contact recreational
Class III	Water supply III—full treatment necessary
	Fishery III—exist in abundance, has economic potential, livestock drinking for tolerant species
Class IV	Agriculture
Class V	Cannot be used for any of the above activities

For temperature (℃), pH, dissolved oxygen (mg/l) and ammoniacal-nitrogen (NH_3-N) were measured directly in the field by using YSI 60145 Professional Plus (Pro Plus) Multiparameter instrument by dipping the probe in the water and the reading were taken three times and the average reading was recorded. To analyze the concentration of anions presence in the water such as nitrite (NO_2^-) and phosphate (PO_4^{3-}), 1ml of water samples was filtered by using nylon syringe filter 0.45 µm. Next, the water samples were run for the analysis by using ion chromatography.

2.3. Soil quality analysis procedures

A clinometer was used to measure the slope. When looking through a clinometer, the measuring line was placed on the target, and % slope was read from the scale. The clinometer has both a positive and negative scale. The positive (+) section is for measuring uphill slopes while the negative (−) section is for measuring downhill slopes. With the clinometer lined up in this manner, the graduation was read at the cross-hair. The preliminary assessments of particle sizes, permeability and plasticity were performed using simple field methods by applying Single Edelman Auger that was used to samples down to the depths at which the expected soils will be moved. From this, the number of samples required for detailed analysis can be determined. Three sampling points were picked randomly in order to get 1 kg samples for every 1 m^2 of land with a range of depths typically every 20 cm down to 30 cm below the excavation level [6].

Soil texture analysis was conducted using mechanical analysis (pipette method) and the result was based on the soil texture class consists of sand, silt and clay develop by the United States Department of Agriculture (USDA). For the soil pH analysis, 10 g of soil samples were weighted and transferred into the specimen vials. The soil and distilled water were mixed in a 1:1 ratio (weight: volume). Then, the samples were shaken for 1 h by using Digital Orbital Shaker Type SHO-1D Daihan WiseShake. The reading was taken by using Hach Sension + PH1 Portable pH Meter after the pH meter has been calibrated. The method was adapted from Thunjai, Boyd & Dube [39]. The soil organic carbon was determined by using LECO TruMac Series Macro Determinator. The system uses a combustion method that provides results within 5 minutes, and 1.5 g of soil samples were placed into a large ceramic boat is inserted into the furnace regulated at a temperature of 1100 to 1450 ℃. The combustion gases are then swept from the furnace into a thermo electric cooler where the moisture is efficiently removed without the use of chemical anhydrone. The final result displayed as weight percentage (%).

The soil organic matter was analyzed by using loss of ignition (LOI) procedure that was adapted from Chaikaew and Chavanich [40] where the soil samples were air dried and sieved through a 2 mm sieve. The samples were then oven-dried at 105 ℃ overnight and let it cool in a desiccator and the weight were measured before they were combusted at 550 ℃ for 4 h in a muffle furnace. The determination of nitrite (NO_2^-) and phosphate (PO_4^{3-}) concentrations were done by using ion chromatography where 10g of soil samples were mixed with 10ml of distilled water. The mixture was shaken thoroughly, and the soil solution was filtered by using nylon syringe filter 0.45 µm. 1 ml of the soil solution was injected into the ion chromatography (IC) machine for the analysis [41].

2.4. Data base

The spatial data base regarding selected parameters that is land use types, slope, soil pH, soil texture, soil organic carbon, soil organic matter, water temperature, water pH, dissolved oxygen, total suspended solid, ammonia nitrogen, phosphate and nitrite concentration for water and soil samples were utilized for the present study. The digital elevation model (DEM) for the preparation of the GIS layers namely land use types, and slope. Whereas shapefiles of the study area obtained from the Department of Survey and Mapping Malaysia were used to prepare the soil texture, soil organic matter, water temperature, water pH, dissolved oxygen, total suspended solids, phosphate and nitrite concentration maps were evaluated using the interpolation techniques and the data obtained from laboratory analysis of water and soil samples. Water and soil quality data were collected from twelve (12) sampled location from the study area for ten months including dry and wet seasons. The measurement was replicated twice a month that is the first and third week of the month to determine the variation in soil and water qualities at deferent period. (Figure 1). Information collected was used in explanations with occasional descriptive statistics in the form of tables and graphs.

2.5. Selection and preparation of criteria maps

Significant criteria were utilized in designing the AHP to select the most suitable locations for prawn aquaculture. Nevertheless, choosing the criteria used was based on expert’s decision and the availability of data. Table 3 shows various parameters that will be used in designing the model based on the type of application and data availability. Most important data that were used for studies to selecting the suitable locations for prawn farming, comprise water quality criteria (i.e., water temperature, water pH, dissolved oxygen, total suspended solid, phosphate and nitrite) [42] and soil quality criteria (i.e. land use types, slope, soil pH, soil texture, soil organic carbon and soil organic matter).

2.6. Standardization of criteria map

The maps selected were from different sources with different projections and units of measurement originally. Hadipour et al. [43] stated that these criteria maps needed to be changed to the same unit of measurement, thus to standardize to the same value before conducting the weighted overlay. Standardization method is applied to change the measurement to a uniform unit such that the resulted scores lose their dimension alongside their measurement units of all criteria [15].

The vector layers of the criteria maps were converted to raster layers. After that, all the raster layers were reclassified and used as input data for the weighted overlay technique, which is the last stage where the map is generated for identifying an appropriate location for prawn production. The reclassified technique is carried out in the ArcGIS 2010 model software using the spatial analyst toolbox, which standardizes the value of all chosen criteria for the testing of relative importance.

Table 3. Suitability rating of water and soil parameters for prawn farming.

Parameter	Most Suitable	Moderately Suitable	Unsuitable	References
Water temperature (°C)	28–31	31–32 or 20–28	>32 or <12	[1] [44]
Water pH	7–8	5–6 or 8–9	<4 or >9	[1] [6]
Dissolve oxygen (mg/l)	5–7	4–5	<2.5	[2]
Total suspended solid (mg/l)	<0.3	0.3–0.4	>0.5	[2]
Ammonia nitrogen (mg/l)	<0.3	0.55	0.7	[45] [46]
Phosphate (mg/l)	<0.2	0.2–0.5	>0.5	[2]
Nitrite (mg/l)	<0.1	0.1–0.2	>0.2	[1]
Land use type	Aquaculture pond	Paddy cultivation	High forest	[47] [48]
Slope (%)	<2	2–10	>10	[1]
Soil pH	7–8	5–6 or 8–10	<4 or >10	[1]
Soil texture (% clay)	>35	18–35	<18	[1] [45] [7] [49]
Soil organic carbon (%)	<1	1–2	>2	[1]
Soil organic matter (%)	<2	2–3	>4	[1]

2.7. Determining the weights of the criteria

The AHP pairwise comparison matrix (PCM) was applied to calculate the weight for each criterion by using the Saaty's 9-points scale (Table 4). Specialists' opinions are normally needed to evaluate the suitability rating and allocate weight to each criterion [50]. Specialists were carefully chosen from the Department of Fisheries Malaysia that are experienced and have useful information to allocate weight to each criterion [51,52]. The pairwise comparison was then used as the input to produce a ratio matrix, and the relative weights are generated as the output [20].

The AHP pairwise comparison matrix, calculates the weight for each criterion and factor (wi) by taking the eigenvector corresponding to the largest eigen value of the matrix, and normalize the sum of the component to 1 as expressed below

$$\sum_{i=1}^{n} wi = 1 \tag{1}$$

Then the final importance of each criterion was calculated. The main input is the pairwise comparison matrix "A" of n criteria proposed by Saaty's scale (Table 5.16), in the order of (n × n) as described in equation (2).

$$A = [aij],\ ij = 1,2,3...n \tag{2}$$

Where A is a matrix with elements aij. The matrix usually has a reciprocity defined as:

$$aij = 1/aji \quad (n(n-1)/2) \tag{3}$$

After creating this matrix, it is then normalised as matrix B.

$$B = [Bij], ij = 1,2,3 \ldots n \tag{4}$$

In which B is the normalised matrix of A (Table 7 and 8) with the elements bij expressed as:

$$bij = \frac{aij}{\sum_{i=1}^{n} aij = 1,2,3,\ldots n} \tag{5}$$

Each weight value is computed as shown below:

$$wi = \frac{\sum_{i=1}^{n} bij}{\sum_{i=1}^{n} \sum_{i=1}^{n} bij}, i, j = 1,2,3 \ldots, n \tag{6}$$

Table 4. Saaty's 9-points scale of relative importance.

Level of importance	Explanations
1	Equal importance
3	Slightly important
5	More important
7	Strongly more important
9	Extreme importance
2,4,6,8	Intermediary values
1/3, 1/3. 1/5…	Reciprocal values

The PCM has the criteria reciprocity which is represented mathematically as follow:

$$\frac{n(n-1)}{2} \tag{7}$$

Where n is the number of elements.

When performing the PCM of the criteria, a certain degree of inconsistency or mistakes may be made. Therefore, the logical consistency of pairwise comparisons must be checked [15]. Consequently, Saaty [53] introduces the consistency ratio (CR) to check the mistakes and inconsistency of the judgment. The consistency ratio is mathematically expressed as:

$$CR = \frac{CI}{RI} \tag{8}$$

Whereas: (CI) refers to consistency index. (RI) refers to random index on the computed matrix order by Saaty (1977) as in Table 5. The consistency ratio (CR) relied on the consistency index (CI) and random index (RI).

$$Cl = \frac{\lambda_{Max} - n}{n-1} \tag{9}$$

Whereas: (n) is the number of criteria. (λMax) is the mean value of the eigenvector.

Table 5. Random Index (RI).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The CR simplify the evaluation of likely event and measure logical inconsistencies of the Specialist's judgments [54]. It signifies the likelihood where the matrix judgment was arbitrarily formed [55]. Saaty proposed the upper limit for the CR to be "0.10", in a situation where the CR calculated is below 0.10, the judgment is considered to be consistent, and the evaluation can be continued. But in a place where the CR calculated is above 0.10, the judgment is considered inconsistent. In this situation, the quality of the judgment needs to be enhanced. The inconsistency rate can be reduced by reviewing the judgment [56].

AHP is performed to solve a spatial problem by applying the weight of criteria subjected to PCM. Weights of criteria are calculated by normalizing the PCM. For this normalization, "a normalized pairwise comparison" is gotten by dividing the column elements of the matrix by the total of each column. The row elements in the obtain matrix are totaled, and the total value is divided by the number of elements in the row. In this way, a priority vector is gotten [57]. Weights are within the range of 0–1, and their total is equal to 1 [15,58].

3. Results and discussion

3.1. Water quality index

In Malaysia, the conservative water quality monitoring programs and sustainable use of water have been promoted by water authorities for the purpose to get the access for a clean and safe water supply. The Department of Environment (DOE) uses Water Quality Index (WQI) and National Water Quality Standards for Malaysia (NWQS) to assess the status of the river water quality [59]. WQI also used to express the overall water quality in a given place and time based on different hydrobiochemical variables and this technique allows the quantitative classification into representative classes of conditions ranging from excellent to very poor of water quality [60]. Based on Table 6, it presents the rate of Water Quality Index (WQI) of the river for all sampling sites location were classify under Class III with the range from 62.84 to 75.89. The highest WQI was observed in location F with the rate 75.89 followed by location A, location B1, location G, location D, location J, location C, location E, location I, location K, location H and location B2 with the rate 75.11, 74.07, 72.87, 70.52, 69.91, 68.41, 67.53, 65.28, 63.45, 62.97 and 62.84, respectively. Figure 2 shows the locations where all 12 sampling sites were categorized under Class III of WQI rate which mean it is suitable for aquaculture purposes due to it is tolerable for fishery type III.

3.2. Site suitability percentage and suitable area for prawn farming in Jelebu, Negeri Sembilan

Based on Table 7 and Table 8, the result of the consistency ratio (CR) of the AHP pairwise comparison matrix shows how consistent the judgment by the Specialists in determining the importance and preference of the criteria for prawn farming. The consistency ratios of water quality criteria were found to be 0.038 (Table 7) and soil quality was 0.036 (Table 8). The overall consistency of the overlay criteria of water and soil qualities was found to be 0.000. These results were considered appropriate and consistent in the standardization of the criteria for prawn farming in the study area. The overall weight of the criteria was 67% for water quality and 33% for soil quality according to their ranking (Table 9). The weight of the selected parameters calculated in the AHP pairwise comparison matrix and the assigned scores for the sub parameters were used in weighted overlay analysis to produced site suitability map for prawn production. The site suitability for prawn production was categorized into three major classes as most suitable, moderately suitable, and unsuitable.

Table 6. The mean water quality index (WQI) for each sampling sites in Jelebu, Negeri Sembilan.

No.	Sampling sites	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	Class
1.	A	2.51	14.57	15.86	15.08	15.60	11.49	75.11	III
2.	B_1	2.18	14.31	15.86	15.08	15.60	11.04	74.07	III
3.	B_2	0.00	6.94	14.37	15.08	15.60	10.85	62.84	III
4.	C	1.44	8.71	15.86	15.08	15.60	11.45	68.14	III
5.	D	1.42	12.62	14.15	15.08	15.60	11.65	70.52	III
6.	E	2.00	7.28	15.86	15.08	15.60	11.71	67.53	III
7.	F	1.55	16.26	15.86	15.08	15.60	11.54	75.89	III
8.	G	1.34	13.83	15.86	15.08	15.60	11.16	72.87	III
9.	H	1.12	10.10	10.10	15.08	15.60	10.97	62.97	III
10.	I	1.41	8.21	13.94	15.08	15.60	11.04	65.28	III
11.	J	1.58	11.78	14.58	15.08	15.60	11.29	69.91	III
12.	K	1.03	4.59	15.86	15.08	15.60	11.29	63.45	III

Notes: SI: Sub-index of WQI parameter; DO: Dissolved Oxygen (%); BOD: Biochemical Oxygen Demand(mg/l); COD: Chemical Oxygen Demand (mg/l); AN: Ammonia Nitrogen (mg/l); TSS: Total Suspended Solids (mg/l); pH: Water pH.

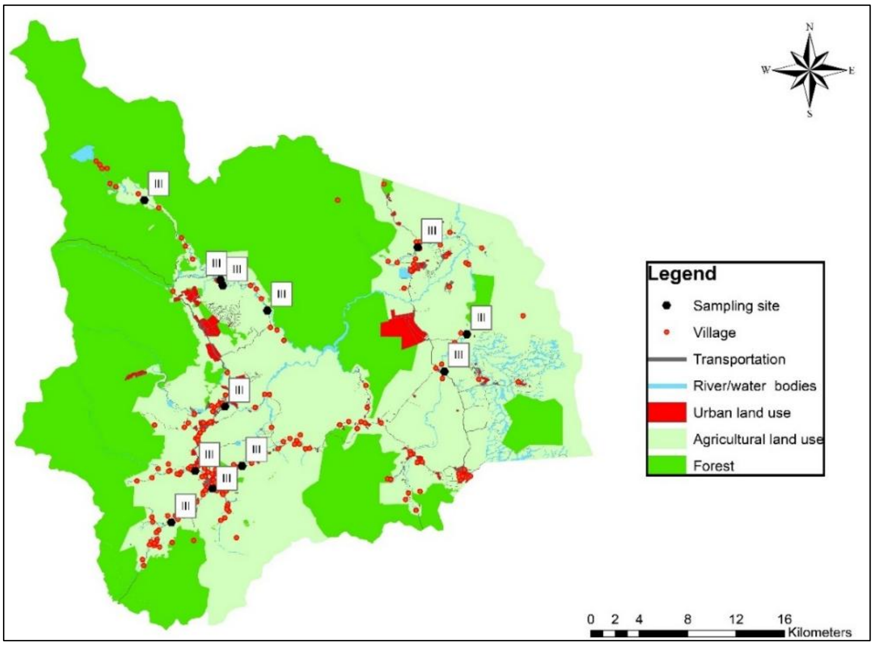

Figure 2. The map of river classes in Jelebu, Negeri Sembilan according to WQI.

Table 7. AHP Pairwise comparison matrix for water quality for prawn farming.

Parameters	1	2	3	4	5	6	7	Weight	Rank
[1] Temperature	1	2.00	3.00	3.00	4.00	4.00	5.00	0.321	1
[2] DO	0.50	1	2.00	3.00	3.00	4.00	4.00	0.228	2
[3] pH	0.33	0.50	1	2.00	3.00	4.00	4.00	0.167	3
[4] Ammonia	0.33	0.33	0.50	1	2.00	3.00	3.00	0.112	4
[5] TSS	0.25	0.33	0.33	0.50	1	2.00	3.00	0.079	5
[6] Nitrite	0.25	0.25	0.25	0.33	0.50	1	2.00	0.053	6
[7] Phosphate	0.20	0.25	0.25	0.33	0.33	0.50	1	0.040	7
Total								1.00	

Note: Consistency Ratio CR = 0.038.

Table 8. AHP Pairwise comparison matrix for soil quality for prawn farming.

	1	2	3	4	5	6	7	8	Weight	Rank
[1] Landuse	1	2.00	3.00	3.00	4.00	4.00	5.00	5.00	0.300	1
[2] Slope	0.50	1	2.00	3.00	3.00	3.00	4.00	4.00	0.211	2
[3] pH	0.33	0.50	1	2.00	3.00	3.00	3.00	4.00	0.155	3
[4] Texture	0.33	0.33	0.50	1	2.00	2.00	3.00	3.00	0.107	4
[5] Organic carbon	0.25	0.33	0.33	0.50	1	1.00	2.00	3.00	0.071	5
[6] Organic matter	0.25	0.33	0.33	0.50	1.00	1	2.00	3.00	0.071	5
[7] Nitrite	0.20	0.25	0.33	0.33	0.50	0.50	1	3.00	0.051	7
[8] Phosphate	0.20	0.25	0.25	0.33	0.33	0.33	0.33	1	0.034	8
Total									1.00	

Note: Consistency Ratio CR = 0.036.

3.3. *The most suitable site*

There were about 45.41% (61309.80 ha) area of land evaluated classified as most suitable site (Figure 7 and Table 9) with more than half of the area fall under agricultural land uses that can be easily changed for prawn farming [8]. Water quality analysis and the overall water quality parameter are shown in Figure 3 and Figure 4 respectively. The class was recorded to have a maintained mean of water temperature within the range of 28.60 ℃ to 31.00 ℃. The result was supported by the finding conducted by Cheng and Chen [61], water temperature is the most important environmental variables for prawn production because it affects prawn growth, feeding, reproduction, and behavior. Thus, prawns need an optimum temperature in order to survive [62]. The mean of dissolved oxygen for this present study were within the range of 5.26 mg/l to 7.73 mg/l were obtained due to the amount of DO in water is mainly dependent upon the water temperature whereby colder water can carry more dissolved oxygen than warmer water [63]. According to Che Osmi et al. [64], DO is among the most important water quality parameter in assessing the river water quality status and the higher DO values indicates the good aeration condition of a place. Thus, adequate DO is necessary for good water quality in intensive aquaculture systems [65].

The mean water pH obtained for this present study were within the range of 7.38 to 7.97. As compared with the results obtained from previous studies, water pH of 7.5 to 8.5 was regarded to be the most suitable for prawn production. Thus, water pH is an important factor to be measured and monitored for prawn pond because water reactions are based on the pH level [2]. The mean total suspended solids for this present study were recorded within the range of 0.01 mg/l to 0.04 mg/l and also 0.00 mg/l for ammonia nitrogen concentration, nitrite concentration and phosphate concentration reading in all sampling site locations measured. The water source condition in Jelebu, Negeri Sembilan were considered safe for prawn farming, this is due to high concentrations of suspended solids should be avoided because an additional source of ammonia, which in its unionized form is extremely poisonous to fish and crustaceans [65]. Nitrite (NO_2^-) is very poisonous to aquatic life, though, is usually available only in negligible quantities in most natural freshwater systems because it is quickly oxidized to nitrate [66]. In giant freshwater prawn farming ponds, phosphorus is available in the form of inorganic and organic phosphates (PO_4) with less than 0.010 mg/l concentration is regarded as oligotrophic. The concentration between 0.010 and 0.020 mg/l is regarded as mesotrophy, while the concentrations exceeding 0.020 mg/l are considered as a eutrophic. Phosphates are not poisonous to animals, unless they are present in very high levels [63].

The soil quality analysis and overall soil quality parameters are depicted in Figure 5 and 6 respectively. These sites have gentle to moderate slopes within the range of 1% to 2% consisting of soil texture categorized under clay loam and sandy clay loam with high capacity to retain water. The slope of the land has an important effect on pond constructions and its operations in relation water supply. The result obtained for this present study were supported by the finding from FAO (1993) and FAO (2002), where the best topography required for prawn farming is a low slope or flat land of 1 to 2% close to a good sources of water supply. According to Boyd et al. [67], pond soils with fine texture such as sandy clay and clay contents of about 20–30% is able to withstand permeability of water. The mean soil organic carbon for this study were within the range of 0.08% to 0.64%. Soil organic carbon is vital for maintenance of soil fertility and the prevention of soil erosion [68]. The concentrations of soil organic carbon in the bottom of prawn pond rarely exceed 1 or 2%, and values in excess of 3 or 4% are perhaps excessive [69]. The mean soil organic carbon content for this study were within the range of 1.39% to 1.88% where it is suitable to retain the nutrient for the prawn pond's bottom and also 0.00 mg/l for nitrite and phosphate concentrations.

3.4. The unsuitable site

The area classified as unsuitable occupied 25.69% (34682.37 ha) of Jelebu district (Figure 7 and Table 9). For water quality analysis (Figure 3), the mean for dissolved oxygen recorded in this study was 0.81 mg/l and the mean for total suspended solids recorded was 0.13 mg/l in location B2. The phenomenon happened because the location has the highest bioaccumulation and bacterial decomposition of organic matter activity. That has resulted to the decreased in DO concentration in the water and the high quantity of suspended solids found indicates the strength of waste contained in the water source [64,66]. Furthermore, high concentration of total suspended solids may cause prawn gill damage by fouling, causing stress and increased susceptibility to diseases (hyperplasia in gill tissue). Removal of small suspended solids can be performed by either chemical or biological oxidation [65]. Water temperature ranges between 26 ℃ and 28 ℃ which are considered as the proper for the growth and survival of prawn.

The mean of slope measured within the range of 15% to 25%, these sites have steep slope that consist of soil texture categorized under poor sandy soil with low water retention capacity for the prawn ponds, the mean of soil organic matter recorded within the range of 4.07% to 6.98% and the mean of nitrite concentration was recorded only in location B2 with the reading 0.96 mg/l. The cost constructing and transferring water to the ponds may be high. The sites are characterized by high soil organic matter content and more erosion activities. This class dominated the southern and northern parts of Jelebu, Negeri Sembilan and considered environmentally not productive for prawn farming. Therefore, prawn farming activities cannot be carried out effectively.

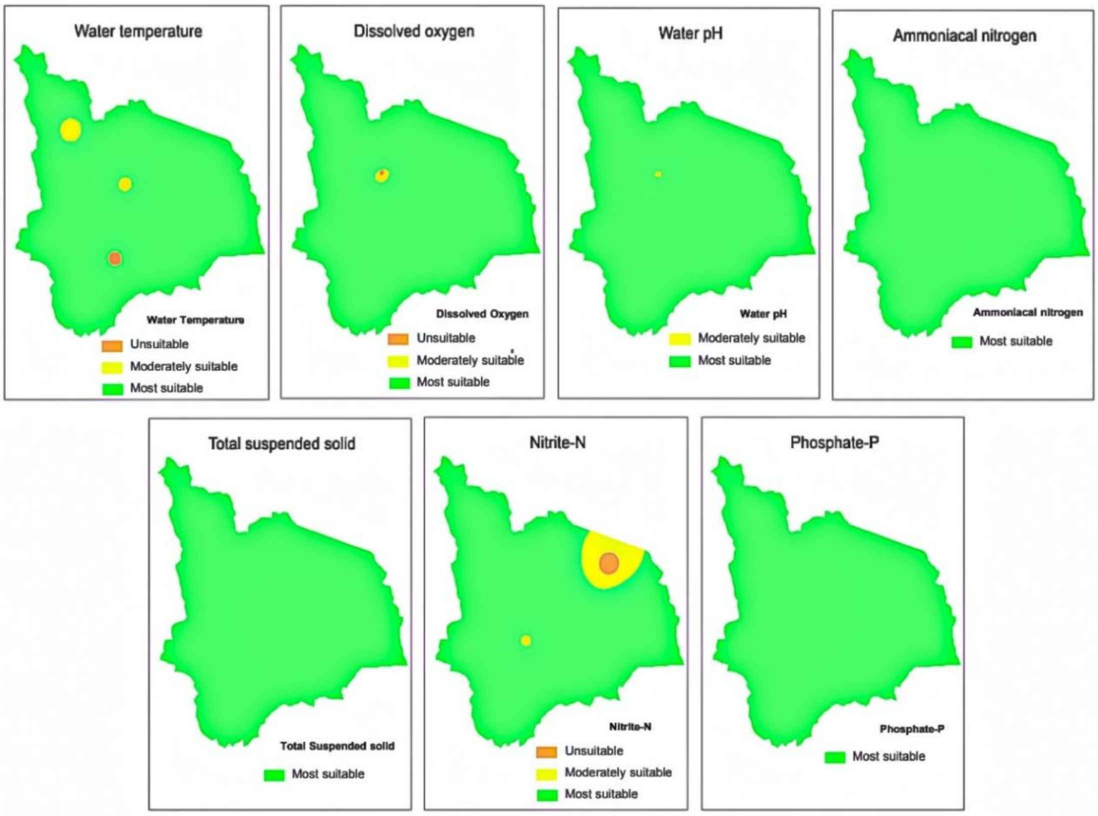

Figure 3. Water quality sub-parameters.

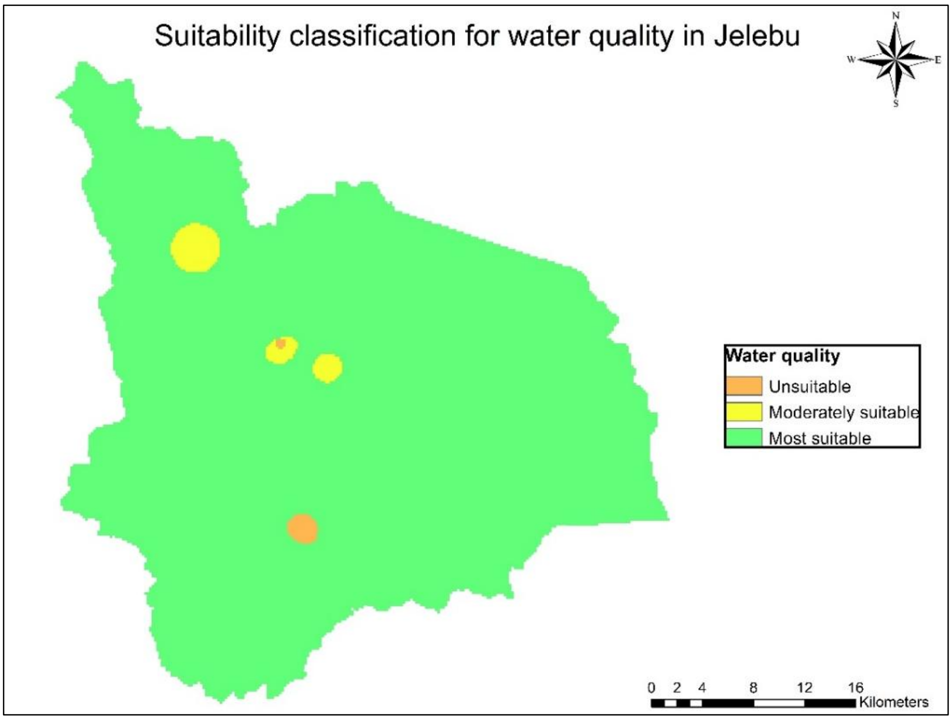

Figure 4. Overall water quality parameter.

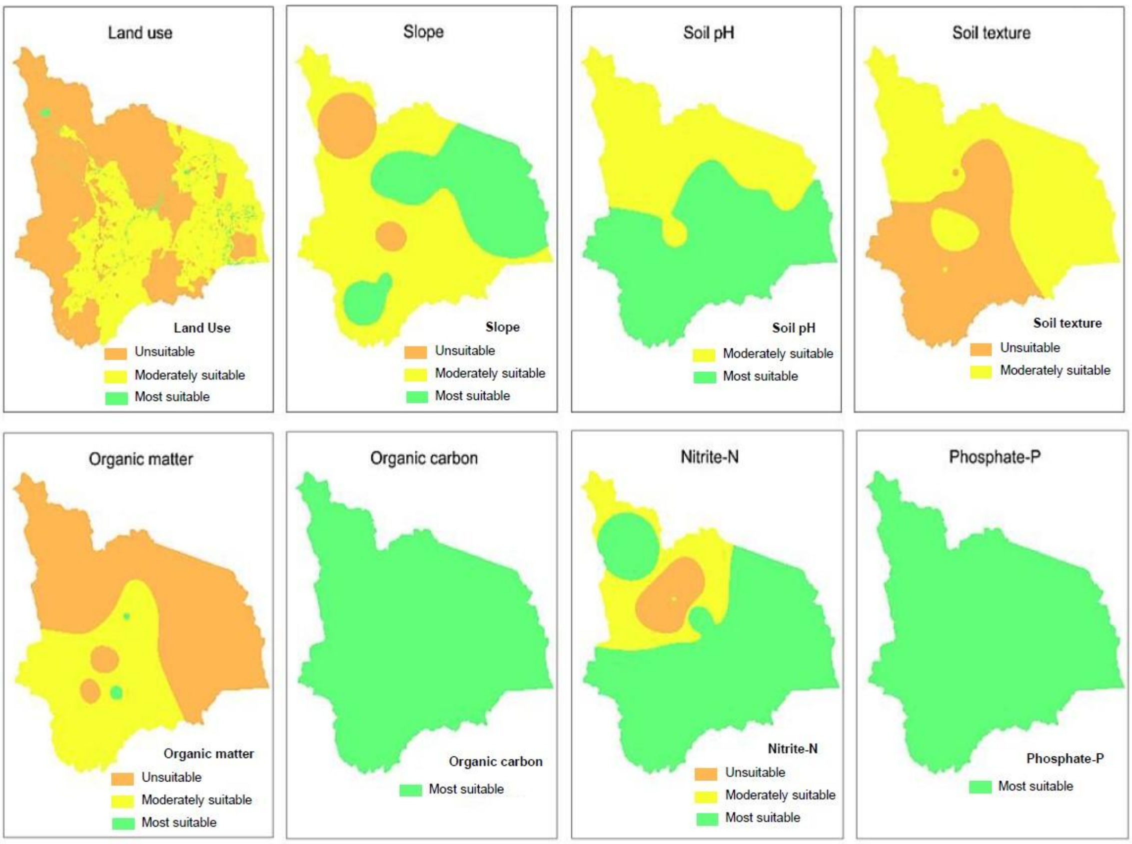

Figure 5. Soil quality sub-parameters.

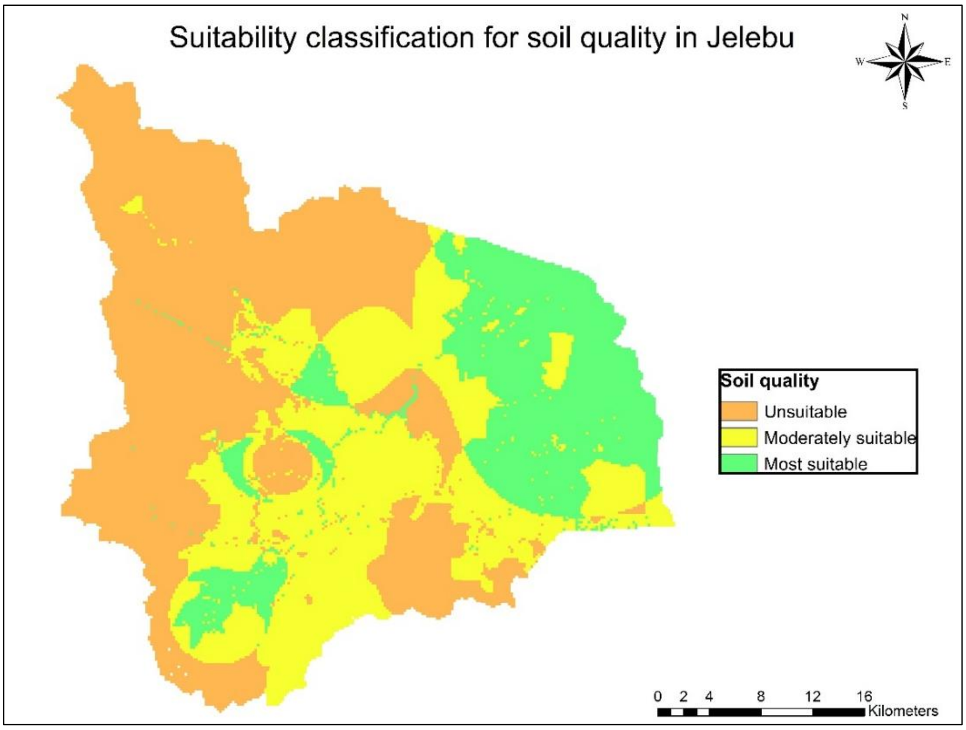

Figure 6. Overall soil quality suitability map.

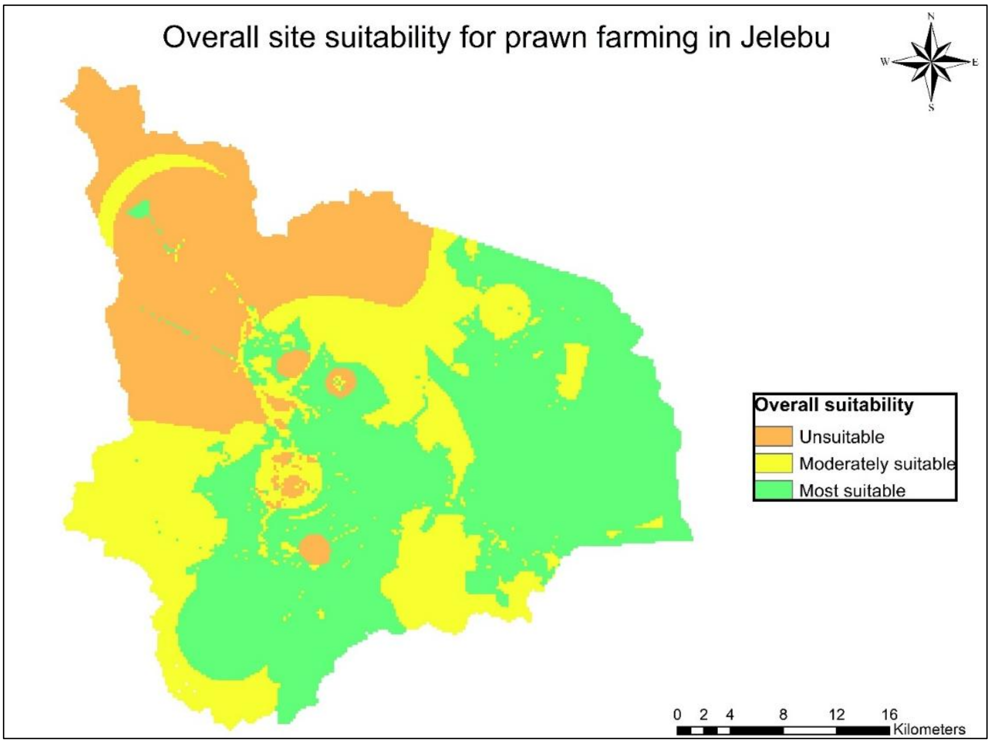

Figure 7. The overall site suitability map for prawn farming in Jelebu.

Table 9. Suitable area of land for the prawn farming in Jelebu.

Overall Suitability	Hectare (Ha)	Percentage (%)
Not suitable	34682.37	25.69
Moderately suitable	39007.83	28.89
Most suitable	61309.80	45.41
Total	135000	100

4. Conclusions

Multi-criteria decision-making analysis applying the AHP and GIS are functional tools for identifying the potential of a land. It defines the capability of a land concerning its essential characteristics either suitable or not suitable. It provides a very significant piece of information in farming development and potential land use planning. It assists in solving conflicting issues between competing land users and minimize the misuse of the land and pollution. The AHP method frequently used in MCDA was discovered to be a valuable method in determining the weights. AHP is considered a better method used for determining weights due to the fact that AHP can deal with the inconsistent judgment and provides a measure of inconsistency of the judgment of the respondents. A GIS method was found to provide better flexibility, speed, efficiency and precision for dealing with numerical spatial data. Previous studies proved that the integration of AHP and GIS methods is a powerful tool to apply for land suitability analysis.

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Conflict of interest

The authors declare no conflict of interest.

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