Chapter

Site Suitability Analysis of Infrastructure Facilities for Giant Freshwater Prawn Farming

Benjamin Ezekiel Bwadi and Firuza Begham Mustafa

Abstract

Infrastructure facilities play important roles in any aquaculture business. This study is to assess the significance of infrastructure facilities in the suitability of site for giant freshwater prawn farming in Negeri, Malaysia. Some of the infrastructure facilities that determine the suitability of a location for prawn farming include road, electricity, market, and availability of hatcheries. Infrastructure facilities data were collected from various institutions for the analysis. Geographic information system (GIS) was used to determine the appropriate area for prawn farming. The result shows that 496,198.75 ha was most suitable, 105,414.82 ha was moderately suitable, and 63,733.73 ha was regarded not suitable. It was further revealed by the study that the infrastructure facilities of the study area have great potential for prawn farming, but the sources of fry serve as a limiting factor. It is recommended that more infrastructural facilities such hatcheries, rural road construction, and electric power supply could be established to facilitate prawn farming in the study area.

Keywords: aquaculture, analytic hierarchy process, giant freshwater prawn, infrastructure facilities

1. Introduction

A successful development of any aquaculture activity and freshwater prawn production in particular does not only require a suitable natural environment and technical method but also adequate and appropriate infrastructure facilities. Significant infrastructure facilities needed may include good and adequate road network system, market, electricity supply, and fry sources or hatchery [1].

Infrastructure facilities influence the production of prawn and need to be taken into consideration in fostering and planning for farming it. Even though the environmental and biological conditions are favourable for the production of prawn, it may fail if the infrastructure facilities are not favourable [2]. Thus, the infrastructure improvement of prawn farming in the area is a major objective for developing and sustaining prawn farming. However, there was limited study in the Negeri Sembilan area on the significance of infrastructure facilities for the suitability of site for prawn farming. The aim of this study is to assess the significance of infrastructure facilities in the suitability of site for giant freshwater prawn farming in Negeri.

2. Methods

2.1 The study area

Negeri Sembilan is located between 2°.43′ 54.5268″ N latitude and 102°.15′ 9.0072″ E longitude, occupying about 6645 km^2 in Malaysia with the population of about 1.7 million people in 2012. It borders Selangor at the northeast, Pahang at the north, Johor at the east, and Melaka at the south with the capital in Seremban. The people are engaged in farming paddy rice at the valley of the steep hills, rubber trees are extensively cultivated, and oil palms are grown. Prawn farming is one of the major livelihoods for the inhabitant. The State contributed about 22% of prawn production in Malaysia in 2014 [3].

2.2 Factors and class weights (standardisation)

The actual factors and class weights of the parameters involved in the study are needed to generate the land suitability map. The AHP was systematically used to determined theses. The AHP criteria were developed based on the expert's survey interviews. The experts were asked to determine the relative importance of each factor. The process assesses the relative importance of all the parameters by allocating weights for each of them in the hierarchy order, and the suitability weight for each class of the factors was assigned in the last level of the hierarchy. Usually, the priority of each factor involved in the AHP analysis is calculated based mainly on the opinions of the experts [4, 5]. Prioritisation is the determination of the relative significance of the criteria which needs brain stomping among experts to assign values on a Saaty's nine-point scale [6] for a pairwise comparison of criteria.

The pairwise comparison matrix was applied to determine the weight and consistency of each criterion at each level of hierarchy by relative rating. The nine-point rating scale was used where 1 represents equal importance (i.e., two factors contributing equally to the objective), 3 represents moderate importance (one factor slightly favoured over another), 5 indicates strongly important, 7 stands for very strongly important, and 9 stands for extreme importance (as earlier mentioned in Chapter 3 of this study). It is a score systematically indicating the relative rating from most important (9–1) or the least important (1/9, 1/8, 1/7… ..1/2, 1). The AHP results in combination with information collected from other methods were used to describe the land suitability analysis for prawn farm identification, as well as the opportunities and challenges for prawn farming in the current site.

The AHP as a multi-criteria evaluation method was applied to determine the weight of each criterion. The principle behind AHP is in the construction of a three-level hierarchy model with the goal, the criteria (objectives), and the sub-criteria (attributes) which are at the bottom layer of the hierarchy [7]. Inputs of experts are considered as the pairwise comparison, and the best criteria will be selected according to the highest rank between the criteria.

Multi-criteria evaluation is a process that incorporates multiple and conflicting criteria, which allow solving a wide range of complex problems and transforming them into decision-making. The AHP developed by Saaty [8] for doing pairwise comparison matrix is a tool required for comparing alternatives with respect to a set of criteria. The criteria were ranked according to the order of importance. Some relative weights were assigned to the criteria indicating the degree of importance or preference of each criterion with respect to the other criterion.

Expert opinion was usually required to rank the criteria by assigning a score to each criterion [9]. For this study 30 experts were drawn from the Department of

Fisheries (DoF) who were knowledgeable in the field of prawn farming and have relevant information to assign weight to each criterion [10, 11]. However, out of the 30 experts, only 20 were found consistent. These pairwise comparisons were then applied as the input to generate a ratio matrix, and the relative weights are created as the output [12].

The AHP pairwise comparison matrix calculates the weight for each criterion and factor (wi) by taking the eigenvector corresponding to the largest eigenvalue of the matrix and normalising 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, in the order of ($n\ x\ n$) as described in Eq. (2):

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

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

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

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

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

in which B is the normalised matrix of A with the elements bij expressed as

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

Each weight value is computed as shown below:

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

A mistake may be made in preference during the survey stage [13]. Therefore, Saaty [14] introduced a single mathematical index to make sure that the pairwise comparison matrix is consistent by applying the consistency ratio (CR). The consistency ratio is computed by dividing the *CI* by the *RI*. The equation is expressed as follows:

$$CR = \frac{CI}{RI} \tag{7}$$

where (CR) = consistency ratio; (CI) = consistency index; (RI) = random index (mean value) depending on the computed matrix order set by Saaty [8].

To ensure the reliability of the relative importance applied, the AHP provides a certain measure to determine inconsistency of the judgments. Based on the priorities of the reciprocal matrices, the consistency ratio can be calculated. $\mathrm{CR} < 0.1$ indicates that the level of consistency in the pairwise comparison is acceptable. But if $\mathrm{CR} > 0.10$ it means that there is inconsistency in the evaluation process and the

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

Table 1.
Table of random index (RI).

process needs to be recomputed or else the AHP may not yield meaningful results [6].

Consistency ratio simplifies the assessment of possible events and measures logical inconsistencies of the decision-maker and judgement [15]. It denotes the probability where the matrix judgments were randomly formed [16].

The consistency ratio depends upon the eigenvector (λ_{Max}) and the consistency index (CI). Therefore, one needs to find the vector w of the order n such that $A \times w = \lambda \times \text{w}$.

where w is the eigenvector (i.e., weight vector) and λ is the eigenvalue.

where $\lambda_{max} \times w \geq \text{n}$ and λ_{max} is the principal eigenvalue of the matrix. Therefore, the inconsistency of the judgement is reflected in the differences between λ_{max} and n. The process computes a consistency index (CI) to check the consistency of the pairwise comparison matrix:

$$\text{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{8}$$

where (CI) refers to the consistency index, (n) refers to the number of criteria used (**Table 1**), and (λ_{Max}) refers to the average value of the consistency vector (the highest eigenvector).

3. Results and discussion

The AHP pairwise comparison matrix results show as follows: The consistency ratio for the infrastructure facilities factors for site suitability for prawn farming was 0.0068. This value demonstrated that the comparison of criteria was consistent. The result show that distance to electricity criteria ranked first with 59.2%, followed by distance to roads with 21.7%, distance to market with 12.6%, and distance to fry source with 6.4% as shown in **Table 2**. According to the key informants (experts), infrastructure facilities play a key role in prawn farming, given good water quality and soil characteristics which are environmental factors; without the infrastructure

Infrastructure facilities	Pairwise comparison matrix				Normalisation and the computation of infrastructure facilities criteria weight							
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]	Sum	Eigenvector (weight)	Weightage (%)	Ranking
[1] Road	1	1/4	3	3	0.18	0.16	0.32	0.21	0.87	0.22	21.7	2
[2] Electricity	4	1	5	7	0.70	0.62	0.54	0.50	2.36	0.59	59.2	1
[3] Market	1/3	1/5	1	3	0.06	0.13	0.10	0.21	0.50	0.13	12.6	3
[4] Fry	1/3	1/7	1/3	1	0.06	0.09	0.04	0.08	0.27	0.06	6.4	4
Total	**5.67**	**1.59**	**9.33**	**14.00**	**1.00**	**1.00**	**1.00**	**1.00**		**1.00**	**100%**	

Table 2.
Pairwise comparative matrix for evaluating the infrastructure facilities for prawn farming.

facilities, prawn farming will not be successful [17]. Major differences in the factors ranking for giant freshwater prawn farming were the relative importance placed on infrastructure where they were higher weights in relation to water and soil as infrastructure plays a vital role in farming in the study area.

3.1 Infrastructural facilities criteria map for prawn farming

The infrastructural facilities aspects of the study comprised of distance to road, distance to market, distance to electricity, distance to fry source, or hatchery layers which were overlay in the GIS environment to generate the overall infrastructure facilities map (**Figure 1**).

Prawn farming operations were affected by infrastructural factors [18]. One of the requirements for successful prawn farming is a good road network. Foods and other necessary equipment are transported to the farm and market. Therefore, prawn farms should be close to the road for easy and quick access. The distance to road suitability classification showed that 90.5% of Negeri Sembilan was close to access roads within less than 2 km. Road accessibility was limited in the hilly and dense forested area where roads construction was difficult.

Electricity is a vital factor in determining the success of prawn farming due to the power supply to power the farm's machines for prawn production [19]. Any area lying within less than 3 km to the main electric power supply line are considered the most suitable site for prawn farming. Major roads and cities coincided with areas with good electricity supply in the study area. The area between 7 and 12 km was considered moderately suitable. In this study, more than half of the area have electricity distribution within the suitable range. The not suitable area falls within areas greater than 12 km away from the main source of electric power line occupying 0.4% of the study area at the extreme north of the study area.

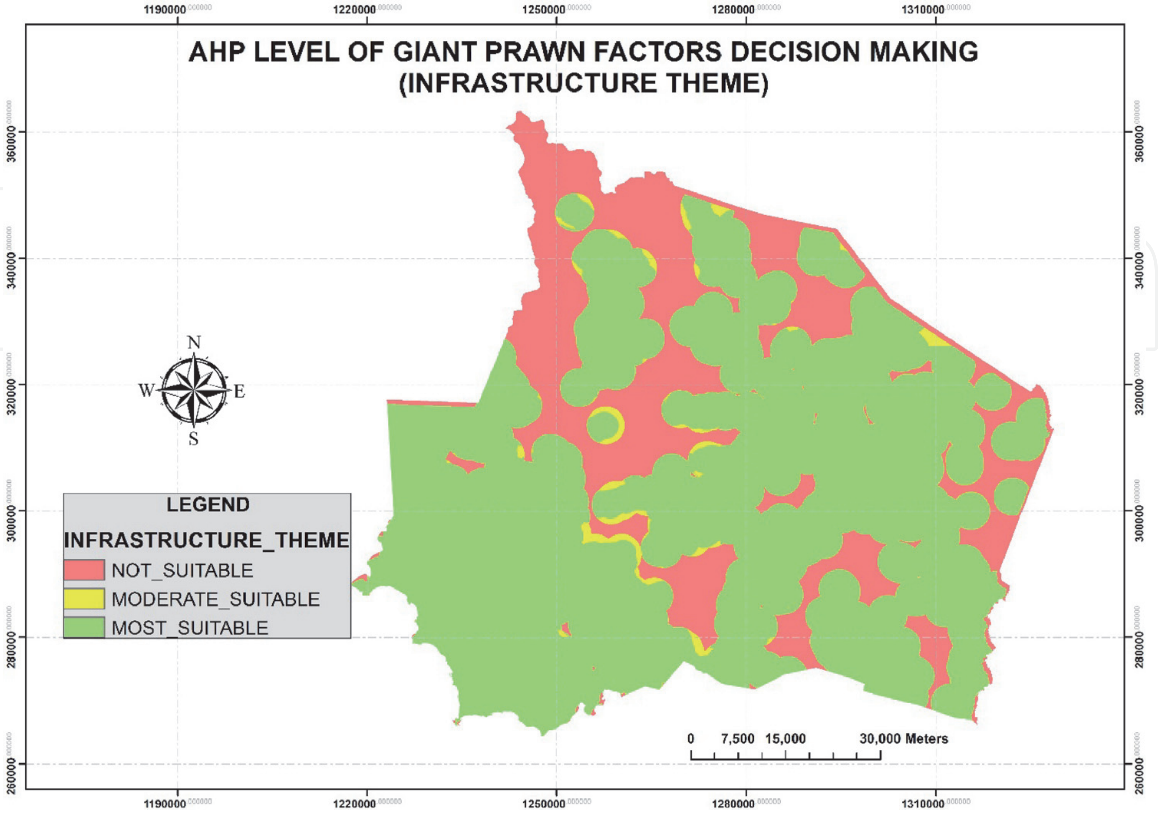

Figure 1.
The infrastructure facilities criteria suitability map for prawn farming in Negeri Sembilan,

No.	Infrastructure layer	Area (Ha)	Percentage
1	Most suitable	496,198.75	75
2	Moderate suitable	105,414.82	16
3	Not suitable	63,733.73	10
	Total area	665,347.31	100

Table 3.
Infrastructure criteria suitable area for prawn farming.

Demand for prawn is very important. Hence, prawn farm should be sited where there is high demand for the product. Quality of prawn deteriorates with time after harvest, and so it requires a prompt and ready market. Therefore, the proximity of farm to the market is very important.

Source of fries to the farm is also very important to the establishment of the farm. Fry mortality increases with long-distance travel as they are susceptible to bad environmental condition; therefore, it is advisable that hatcheries be located nearer the farm. It was discovered from the study that most hatcheries as sources of fries were located some kilometres far away from the study area such as Perak and Kedah where the farmers must travel to purchase fries which takes about 3–4 h to reach and another 3–4 h to come back, which was considered not appropriate for prawn farming. This increases the mortality rate of the fries (juvenile) and cost of production in terms of transportation. According to New [20], prawn farms should be located close to a hatchery because the mortality of the fry increases with long-distance travel to obtain it. From the study, it was found that only a few hatcheries were established in the study area.

The southwestern area of Negeri Sembilan is better equipped in terms of the infrastructural facilities. The most suitable area was basically regions along the major roads linking Negeri Sembilan and Selangor state as one move to the Kuala Lumpur, Seremban the state capital region, and the major towns. Electrification exists almost beside the roads which are significant to prawn farming. The unsuitable areas are in the northern parts with pockets of most suitable around Jelebu. The infrastructure facilities result shown in **Table 3** indicates that 75% (496,198.75 ha) of the area for prawn farming are most suitable, 16% (105,414.82 ha) as moderately suitable, and 10% (63,733.73 ha) as not suitable. This confirmed the study conducted by Olaniyi et al. [21] that good infrastructure determines the productivity of prawn of an area.

The market potential was based on the distance of the farm to the settlements and the population density of an area. The Negeri Sembilan region was largely good in terms of market potential due to the population density of 159 persons per km^2 with high demand for prawn in the region. Seremban District with the highest population density of 586 persons per km^2 was the most suitable market potential, Port Dickson with 191 persons per km^2, Tampin with 99 persons per km^2, Jempol District with 79 persons per km^2, Kuala Pilah with 64 persons per km^2, and Jelebu with 29 persons per km^2 [22]. The relative location of the area near Kuala Lumpur, the Federal capital territory, also provides the area with good market potential as prawns were sold to the restaurant for local consumption. The farms were located relatively near the market areas. The Seremban District with the population of about 555,935 (2012 census) with the land area 397,185 km and Port Dickson provide the most suitable area [22]. The rest of the districts were moderately suitable with pockets of the most suitable area. The extreme north of Jelebu District with less population was considered not suitable for a market potential.

4. Conclusion

The study integrates the GIS and AHP methods to evaluate the infrastructure facility of an area and its suitability for prawn farming. The approaches were able to identify areas with appropriate infrastructures for the sustainable development of prawn farming in Negeri Sembilan. The factor layers considered included distance to road, distance to market, distance to electricity, and distance to fry source.

From the result of the analysis, infrastructure facilities have been identified as major factors that have great influence on prawn farming. This confirms the study by Hossain and Das [1] who identified transportation facilities, electricity, market, and availability of hatcheries as some infrastructure facilities having significant influence on prawn farming.

The infrastructure facilities suitability map generated will be useful to farmers, stakeholders, policy-makers and decision-makers to improve the efficiency of land use by selecting which site is appropriate to farm prawn. They will lead to increased yield and the optimal utilisation of the available land resources. This can reduce the overall cost of production and conflicts among land users. Infrastructural facility developments in the area such as establishment of hatcheries, rural road construction, and electric power supply to facilitate prawn farming are recommended.

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