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Relative importance of evaluation criteria for predicting the optimal location in aquaculture - a pairwise comparison method approach

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ABSTRACT

Identification of optimal location for aquaculture is based on the evaluation of a number of alternatives in terms of a number of decision criteria. In this study, decision criteria were categorized into six broad heads of evaluation criteria, namely; water, soil, support, infrastructure, input, and risk factor. The information about the relative importance of the evaluation criteria was achieved by assigning weightage to each criterion. The relative importance of evaluation criteria under consideration was defined by pairwise comparison method. It takes the pairwise comparisons as the input and produces the relative weights as output. Result of the pairwise comparison method showed that the consistency ratio (0.0347) of evaluation criteria was less than the threshold value (0.1). This indicates that the comparisons of each evaluation criterion were perfectly consistent and the relative weights were suitable for the use in the identification of optimal location in aquaculture.

Keywords: Aquaculture, Evaluation criteria, Optimal location, Pairwise comparison method

Introduction

The selection of optimal location of aquaculture sites is not formulated just from one criterion alone but from multiple criteria (Ramesh and Rajkumar, 1996). The key factors to be considered for selecting the optimal location are the availability of good quality water in abundant quantity, soil quality, salinity, temperature, pollution, exposure to flood, adequate infrastructure facilities and access to essential inputs and markets (MPEDA, 1992).

Properties of soil should be considered while selecting a site, designing earthwork and specifying construction methods inorder to provide a water-tight pond with stable levees and bottom slopes. The water supply must be of adequate quantity to fill the pond and maintain the water level and of sufficient quality to provide an environment suitable for aquaculture. Interactions between soil and water that influence water quality in ponds must not be ignored, because poor soil condition in ponds can impair survival and growth of aquaculture species.

Alavandi *et al.* (1996) opined that the shrimp farmers were greedy to produce more by stocking shrimp in high densities with increased inputs of feed, resulting in aquatic environmental pollution. Venkatesan (1989) reported that most of the shrimp farms in India lacked electricity facilities and hence used diesel pumps for water exchange. Upadhyay (1990) identified the causes for slower development of shrimp farming in Orissa as, unnecessary delay in the allotment of land, poor infrastructure facilities like road, electricity as well as communication and inaccessibility to the potential sites situated in remote areas. According to John (1995), infrastructure facilities had not been developed along the coastline for the orderly development of brackishwater farming in India. In October - December 1994, about 4800 ha area under shrimp culture was affected by cyclone and floods in Andhra Pradesh (Anon, 1994).

The above mentioned different decision criteria can be categorized into six broad heads of evaluation criteria namely; water, soil, support, infrastructure, input, and risk factor. These criteria have their own advantages and disadvantages. The information about the relative importance of the evaluation criteria can be achieved by assigning weightage to each criterion. The purpose of the present study was to assign weightage to each evaluation criterion for predicting the optimal location in aquaculture.

Materials and methods

In the present study, relative importance (or weights) of evaluation criteria under consideration were defined by pairwise comparison method (Saaty, 2000), creating a ratio matrix. Specifically, the weights are determined by normalizing the eigen vector associated with the maximum

eigen value of the (reciprocal) ratio matrix (Malczewski, 1999). It is composed of several concepts and techniques such as, generation of pairwise comparison matrix, normalization of comparison matrix, deriving weights and consistency considerations (Fig. 1)
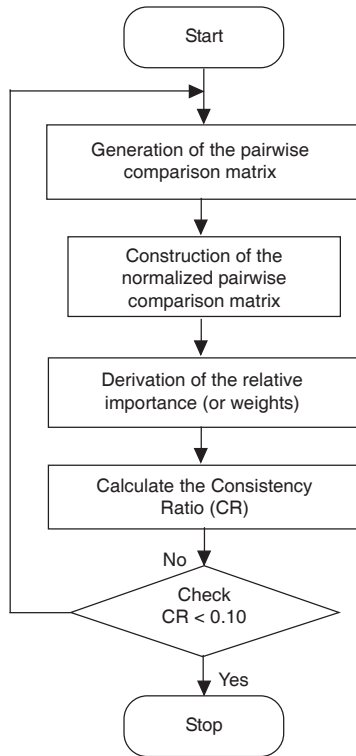

Fig. 1. Computation of relative importance of evaluation criteria

A comparison matrix M is a (L x L) matrix in which L is the number of evaluation criteria being compared. To fill the matrix M, Saaty (2000) proposed the use of a one to nine scale to express the experts preference and intensity of that preference for one element over the other (Table 1). According to this scale, the available values for the pairwise comparisons are members of the set {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}. Since the m_{ij}th element of the pairwise comparison matrix shows how many times the ith element is more important than the jth element, the m_{ji}th element will be its reciprocal. This matrix is positive and reciprocal matrix, *i.e.*, $m_{ij} > 0$ and $m_{ji} = 1/m_{ij}$ for i, j = 1, 2, ..., L. Further, it is necessary to perform (L/2) (L-1) comparisons for a category of L evaluation criteria.

The identified six evaluation criteria namely, water, soil, support, infrastructure, input and risk factor were presented in pairs in all possible combinations. Since six evaluation criteria were considered in the present study, the possible pairs are fifteen. After identification of the possible pairs, judgments were established using a nine continuous scale with values from one to nine to rate the preferences for one evaluation criterion over the other by a

Table 1. Scale for pairwise comparison

Intensity of relative importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very strong to extremely strong importance
9	Extreme importance
Reciprocals of above non-zero numbers	If the activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared to i.

Source: Saaty (2000)

group of 50 aquaculture experts, who are all working as a team. The responses obtained through the consensus (a solution that satisfies every one) method (Guzzo, 1982) were entered into the pairwise comparison matrix. Subsequently the pairwise comparison matrix was converted to normalized pairwise comparison matrix. Then the relative weight vector was calculated by the average of the elements in each row of the normalized matrix.

Table 2. Random indices

L	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Source: Saaty (2000)

Since the aquaculture expert weighs all elements based on his own judgment, inconsistency is possible in building a weight vector. An index of consistency ratio (CR) was used to measure consistency of a pairwise comparison matrix. The consistency index (CI) was estimated by adding the columns in the comparison matrix and multiplying the resulting vector by the vector of the relative importance of evaluation criteria. This yields an estimation of the maximum eigen value, denoted by λ_{max}. The degree of inconsistency was calculated by $\lambda_{max} - L$. The CI values were then obtained using the formula :

$$\text{Consistency Index (CI)} = \frac{(\lambda_{max} - L)}{(L-1)} \qquad (1)$$

The denominator is needed to compute an average deviation of each pairwise comparison from perfectly consistent judgment. A value of one is subtracted from the order of matrix L, because one of the pairwise comparisons is a self-comparison.

The consistency check of pairwise comparison was done by comparing the computed consistency index with the random index (RI), which is the average consistency index of randomly generated reciprocal matrix using the one-to-nine scale. Saaty (2000) provided the random indices for matrices of order 1 through 10 (Table 2). The consistency ratio (CR) was obtained by dividing the consistency index by the random index:

CR = *CI/RI*   (2)

The consistency ratio is designed in such a way that if CR<0.1, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR $\geq$ 0.1, the values of the ratio are indicative of inconsistent judgments. In such cases, one should reconsider and revise the original values in the pairwise comparison matrix.

Results and discussion

The pairwise comparison matrix was generated, according to the scale introduced by Saaty (2000) (Table 3). The diagonal cell entries must be 1, representing equally preferred criteria. The criterion water is equal to moderate importance than the criterion soil (Table 3). It was seen that the criterion water is of extreme importance than the set of evaluation criteria such as support, infrastructure, input and risk factor. The criterion input is of equal importance to the criterion risk factor. A similar interpretation is true for the rest of the entries. Further, the results revealed that the comparison matrix was positive and reciprocal.

The normalized matrix obtained from the pairwise comparison matrix and the relative importance of each criterion derived are shown in Table 4 and also depicted in Fig. 2. The criterion weights obtained are 0.4489, 0.3576, 0.0660, 0.0543, 0.0366, and 0.0366 for water, soil, support,

infrastructure, input, and risk factor respectively. This means that water is the most important criterion followed by soil, support, infrastructure, input and risk factor. The criterion weights for input and risk factor are same.
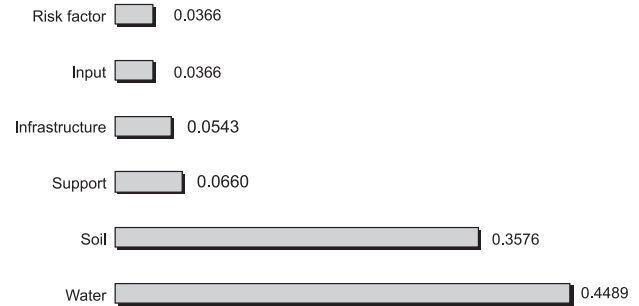
Fig. 2. Relative importance (or weights) of each criterion

The calculation of CI is based on the observation that the value of l_{max} (6.2168) is always greater than or equal to the number of evaluation criteria under consideration (6) for positive, reciprocal matrix. The measure of the degree of inconsistency value (0.2168) was calculated and also the CI value of 0.0434 was obtained by normalizing the measure of the degree of inconsistency. The CI value provides a measure of departure from consistency. The consistency ratio (0.0347) was generated by dividing the value of CI by the value of RI (1.25, for L = 6). Further, consistency ratio obtained was less than the threshold value of 0.1, indicating that the comparison of each evaluation criterion was perfectly consistent. This implies that the relative weights were suitable for the use in the identification of optimal location in aquaculture.

The relative importance was interpreted as the average of all possible ways of comparing the evaluation criteria. The assignment of importance values to the evaluation

Table 3. Pairwise comparison values of criteria

Criterion	Water	Soil	Support	Infrastructure	Input	Risk factor
Water	1	2	9	9	9	9
Soil	1/2	1	9	9	9	9
Support	1/9	1/9	1	2	2	2
Infrastructure	1/9	1/9	1/2	1	2	2
Input	1/9	1/9	1/2	1/2	1	1
Risk factor	1/9	1/9	1/2	1/2	1	1

Table 4. Normalized pairwise comparisons and the relative importance of each criterion

Criterion	Water	Soil	Support	Infrastructure	Input	Risk factor	Weights
Water	0.5144	0.5807	0.4390	0.4091	0.3750	0.3750	0.4489
Soil	0.2572	0.2904	0.4390	0.4091	0.3750	0.3750	0.3576
Support	0.0572	0.0323	0.0488	0.0909	0.0833	0.0833	0.0660
Infrastructure	0.0572	0.0323	0.0244	0.0455	0.0833	0.0833	0.0543
Input	0.0572	0.0323	0.0244	0.0227	0.0417	0.0417	0.0366
Risk factor	0.0572	0.0323	0.0244	0.0227	0.0417	0.0417	0.0366

criteria was based on the experience of the aquaculture expert; hence, the predicted outcomes were indicative of the experts' judgment and may not necessarily reflect actual outcomes. However, the method does provide a means to understand the interactions of a complex set of criteria in a much shorter time than otherwise would be possible. The incorporation of the method as a model in decision making may have a significant impact in aquaculture.

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