ROUGH SET BASED OPTIMAL LOCATION MODEL FOR AQUACULTURE DEVELOPMENT

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Abstract: The success of aquacultural projects without adverse environmental effects largely depends upon the selection of optimal site for the project. The Multi Criteria Decision Making (MCDM) methods and classical rough set approach deals with operation research problems with more than one variable. But these methods just takes the classification characteristic of variables into consideration but ignores the preference-orders of variables is very important in many real applications like aquaculture. Keeping this in view, we have developed an optimal location model using twenty seven variables based on dominance based rough set theory and simple additive weighting MCDM method for aquaculture development. The priority weights for the variables were determined using the dominance rough set theory and subsequently, these weights were used for identifying the optimal location from a number of alternative locales based on the objective function values and ranks assigned to them using the simple additive weighting method. A case study application of identification of optimal location in Kalla mandal, West Godavari district, Andhra Pradesh, India, was used to validate the model.

Keywords: Rough set, MCDM; Optimal location; Aquaculture

I. INTRODUCTION

Aquaculture is the fast growing subsector of agriculture in India with annual growth rate of over 10 per cent. With the rapid increase in world population, the development of aquaculture becomes an alternative source for producing high quality cheap protein food products, particularly for developing countries where protein shortages already exist. On the other hand, the increase of aquaculture units and their farming practices as well as their increasing complexities emphasize the need for the utilization of computer technologies. This will serve as a delivery system bringing decision making models from the esoteric world of academia to the exoteric world of practical application. Furthermore, the recent developments in computer technology provide a challenge for the researcher to bring their models to the decision makers or planners so as to implement their models for decision support in farm applications.

The success of implementation of aquaculture projects without adverse environmental effects largely depends upon adherence to the better management practices. Especially suitability of the site selected for the project plays a key role in better environmental management of aquaculture. The selection of optimal location in aquaculture system is not formulated just from one variable alone but from multiple variables. Multi Criteria Decision Making (MCDM) methods provide efficient tools to deal with this operations research problem with more than one variables or objective.

In the MCDM methods, assignment of weights to the variables is one of the crucial problems for identification of optimal location in aquaculture. Now there are three types of methods to assign the weights, viz., objective method, subjective method, and combining of these two methods. However, this kind of methods just takes the classification characteristic of variables into consideration but ignores the preference-orders of variables is very important in many real applications like aquaculture. Moreover classical rough set approach requires dispersing the values of variables, which induces information loss. Greco et al. Hybrid the classical rough sets theory with dominance theory and replace indiscernibility relations or similarity relations with dominance relations to develop the dominance based rough set approach. So the information loss problems can be overcome by applying dominance based rough set theory in the MCDM. In this study, we have developed a model on dominance based rough set theory and simple additive weighting MCDM method for identification of optimal location for aquaculture development.

II. MATERIALS AND METHODS

The framework for rough set based optimal location model was given in Fig. 1.

A. Variables and datasets

A list of twenty seven variables, selected by reviewing the literature and consultation with aquaculture experts were classified into five categories of main-variable viz., water (9 sub-variables), soil (7 sub-variables), support (4 sub-variables), infrastructure (5 sub-variables) and risk factor (2 sub-variables) (Table 1). The water, soil, support, infrastructure and risk factor related data used in this study were collected from 15 randomly selected aqua sites in Kalla mandal, West Godavari district, Andhra Pradesh, India. This area was chosen purposefully in view of the concentration of aquaculture, and also as coastal aquaculture is a major economic activity in this area. The West Godavari district lies between the latitudes of $16^0\,15'$ to $17^0\,30'$ and the longitudes of $80^0\,55'$ to $81^0\,55'$.

Table 1. Main-variable and their corresponding sub-variables

Main-variables	Sub-variables
Water	Salinity, pH, Dissolved Oxygen, TSS, Free Ammonia, Nitrate – N, H_2S, Temperature and Transparency
Soil	pH, Calcium carbonate, Organic carbon, Available phosphorous, Available nitrogen, Textural class and Electrical conductivity
Support	Distance to NGO, Distance to Government office, Distance to Research station and Distance to university/college
Infrastructure	Distance to hatchery/natural fry, Distance to processing plant, Distance to river, Distance to road and Distance to local market
Risk factor	Flood and cyclone and Nearby pollution area

B. Model Development

Optimal location model was developed using the following steps:

- Construct a decision matrix, A (a_{ij}; i = 1,2,3,…,M; j = 1,2,3,…,N, where M is the number of alternatives (aqua sites) and N is the number of sub-variables/main-variables under consideration). Each row of the decision matrix was allocated to one alternative and each column to one sub-variable/main-variable. Therefore, an element, a_{ij} of the decision matrix shows the performance of i^{th} alternative with respect to j^{th} sub-variable/main-variable.
- Normalization of the decision matrix, for eliminating the influence of widely differing units and dimensions in the variables.
- Priority weights (relative importance) of the variables were calculated using rough set theory. It was defined as

$$\gamma_{aj} = 1 - \frac{Card\left(\left\{x_i \in X \mid D^+_{A-a_j}(x_i) \subseteq D^+_A(x_i)\right\}\right)}{Card(X)} \qquad (1)$$

where γ_{aj} is importance of the variables; X is the set of alternatives; $D^+_A(x_i)$ is the set of elements dominating x_i with regard to variable set A; $D^+_{A-a_j}(x_i)$ is the set of elements dominating x_i with regard to variable set after deleting variable a_j, A-a_j.

- Normalizing the importance of variables γ_{aj}.
- Objective function (OF_i) of the model was calculated as follows in the form of simple additive weighting method

$$OF_i = \sum_j a_{ij}\gamma_{aj} \qquad (2)$$

- The optimal alternative was identified based on the ranking according to the descending order of objective function, OF_i. The alternative with the highest value of OF_i was the optimal alternative; next highest value of OF_i was the second optimal alternative and so on.

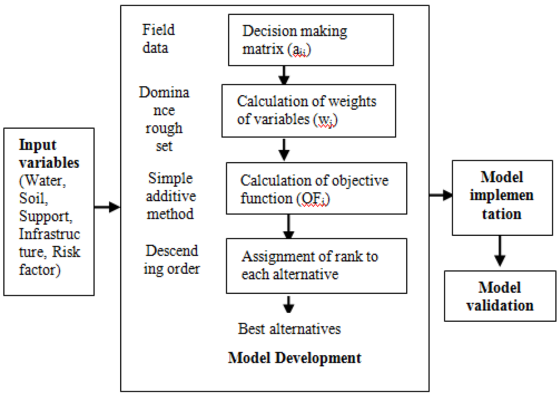

Fig. 1. Framework for rough set based optimal location model

C. Model Implementation

Matlab software (http://www.mathworks.com) was used to develop the rough set based optimal location model. The software has many in-built functions, for matrix calculations, which will be useful for the implementation of rough set theory and simple additive weight method. The coding part is simple and understandable for the end user.

D. Validation of the model

After collecting the required information from the study area, aqua sites were ranked first by the rough set based optimal location model (X) and then the same aqua sites were ranked by existing Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS)-Analytical Hierarchy Process (AHP) model. Mahalakshmi et al. has developed the TOPSIS-AHP based model using the same twenty seven sub-variables and proved that the model was reliable for identification of optimal location for aquaculture development. In this model, the priority weights for sub-variables within the main-variables under consideration were determined using the AHP method and subsequently, these weights were used for identifying the optimal location from a number of alternative locales based on the relative closeness values and ranks assigned to them using the TOPSIS method. Finally, the combination of TOPSIS and AHP methods constituted the model for identification of optimal location for aquaculture farming development.

The Spearman's rank correlation was used to test the significance of the correlation between the ranks obtained by the rough set based optimal location model and ranks obtained based on TOPSIS-AHP model. The cutoffs used correspond to a level of significance of alpha (α) equal to 0.01. The

Spearman's rank correlation coefficient (ρ) is defined as

$$\rho = 1 - \left(\frac{6\sum d^2}{n(n^2-1)} \right) - 1.00 < \rho \le +1.00 \quad (3)$$

Where n is the number of aqua sites that are to be correlated; and d is the difference in the ranks assigned to a particular aqua site.

In this study, the value of Spearman's rank correlation coefficient (ρ) was compared with the critical value of ρ for a dataset with 15 samples and alpha equal to 0.01 (a confidence level of 99 percent). The hypothesis for validation was defined as

H_0 (Null hypothesis, ρ = 0): There is no rank order correlation between ranks obtained by the rough set based optimal location model and ranks obtained based on TOPSIS-AHP model.

H_1 (Alternative hypothesis, $\rho \neq 0$): Positive rank order correlation exists between ranks obtained by the rough set based optimal location model and ranks obtained based on TOPSIS-AHP model.

H_0 is rejected if the value obtained for ρ is greater than the critical value of ρ .

III. RESULTS AND DISCUSSION

First the decision matrix was constructed based on the data collected from 15 sites for aquaculture in Kalla mandal, West Godavari district. In the dataset, twenty six sub-variables were obtained as quantitative information and one sub-variables namely textural class was obtained as prescribed linguistic words such as 'sandy clay', 'sandy clay loam', 'clay loam' or others. While constructing the decision matrix these linguistic words were converted into quantitative information by using the rules: IF (textural class is equal to 'sandy clay' or 'sandy clay loam' or 'clay loam') THEN textural class = 1; OTHERWISE textural class = 0. As all the sub-variables for identifying the optimal aqua sites were having different units and dimension, their values in the decision matrix were first normalized.

The priority weights for sub-variables within the main-variables under consideration were determined using the dominance rough set theory and subsequently, these weights were used for identifying the optimal location from a number of alternative locales based on the objective function values and ranks assigned to them using the simple additive weighting method. Now, the alternatives for identification of optimal aqua sites were arranged in descending order according to their objective function value. From Table 2, final ranking of the aqua sites was S14-S2-S8-S9-S3-S11-S7-S10-S13-S6-S4-S1-S12-S5-S15.

The ranking pattern obtained by the observed TOPSIS-AHP model was also given in Table 2. It showed that there was slight change in the ranks obtained by the rough set based optimal location model and ranks obtained based on TOPSIS-AHP model. In both methods, alternative, S15, (rank 15) was identified as last rank.

Spearman's rank correlation coefficient (ρ) was computed for the dataset of Kalla mandal. The value of the ρ obtained in this correlation was 0.968. The critical value of ρ for a dataset with 15 samples and alpha (α=0.01) is 0.654 according to "reference". As the value of ρ obtained from the spearman's rank correlation was greater than the critical value of ρ, the null hypothesis was rejected. Therefore, the correlation between ranks obtained by the rough set based optimal location model and ranks obtained based on TOPSIS-AHP model was significant (a confidence level of 99 percent), meaning that this rough set based optimal location model is reliable for identification of optimal location for aquaculture development.

Table 2. Results of ranks obtained by rough set based model and TOPSIS-AHP model

Alternatives (aqua sites)	Predicted values by rough set based optimal location model		Observed values by TOPSIS-AHP model	
	Objective function	Rank	Relative closeness	Rank
S1	0.5870	12	0.341	14
S2	0.6861	2	0.668	1
S3	0.6661	5	0.554	5
S4	0.5872	11	0.529	9
S5	0.5462	14	0.472	12
S6	0.6079	10	0.498	11
S7	0.6588	7	0.549	7
S8	0.6799	3	0.559	4
S9	0.6687	4	0.565	3
S10	0.6572	8	0.532	8
S11	0.6627	6	0.552	6
S12	0.5664	13	0.461	13
S13	0.6502	9	0.519	10
S14	0.6914	1	0.583	2
S15	0.5012	15	0.310	15

CONCLUSIONS

The developed model will enhance the decision making capacity of anyone engaged in the design and construction of new / existing aquaculture farming system. These would greatly minimise environmental, social and economic impacts due to the orderly and planned development of aquaculture for its sustainability by using the advanced methods namely rough set theory and MCDM in the presence of multiple variables. The case study results suggest that this model has sufficient predictive power to help extension personnel, fishery officials, bankers and other line departments officials, aqua farmers, and other interested persons who may be unfamiliar with the specific requirements of aquaculture to identify the optimal location for aquaculture development. Case study application and presented results showed that such an approach is comprehensive and relatively simple in computation. It can be easily adapted to other closely related industries such as agriculture and animal husbandry etc.

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