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POSTER ABSTRACT

Application of Fuzzy Logic to Multiple Criteria Decision Making in Aquacultural Planning

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ABSTRACT

The field of regional planning is characterized by the large number of issues and attributes involved, and regional planning for aquaculture development is no exception. Moreover, aquacultural plans do not have clearly defined objectives and require information that, if exist, is often imprecise and uncertain.

This paper applies fuzzy set theory to multiple criteria decision making (MCDM) in aquaculture planning. In effect, the paper demonstrates how fuzzy set theory can be used to explicitly account for the inherent uncertainty encountered when planning for aquaculture development in a given region. A case study for regional aquaculture planning in Northern Egypt demonstrates the proposed fuzzy MCDM framework.

Categories and Subject Descriptors

J.2.5 [**Computer Applications**]: Physical Sciences and Engineering – *Earth and atmospheric sciences.*

General Terms

Management, Economics.

Keywords

Fuzzy optimization; Multiple criteria decision making; Aquaculture planning.

1. INTRODUCTION

Aquaculture systems are biocomplex systems involving a dynamic web of interrelationships that arise when biological, physical, chemical, and human components interact. The complexity of such systems poses significant challenges when planning for regional aquaculture development, most notable are:

- Planning and managing for sustainability.
- Accommodating multiple development goals
- Accommodating uncertainty

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2. LITERATURE REVIEW

Rommelfanger (1996) provides a representative list of fuzzy linear programs (FLP) that tackle problems encountered in real-world application, while Fuller and Carlsson (1996) provide a review of recent development of fuzzy MCDM with particular emphasize on a number of application areas. However, only a handful deals with biocomplex systems. Chang et al. (1997) provide an expanded list of applications focusing on water resource planning as well as present a fuzzy multi-objective programming model for the evaluation of sustainable management strategies of optimal land development in the reservoir watershed. Huang et al. (2002) presents an interval-parameter fuzzy integer programming model for the planning of regional solid waste management systems under uncertainty. The model allows for more in-depth analysis of tradeoffs between environmental and economic objectives. Borges and Antunes (2003) present an interactive approach to model the uncertainty and imprecision associated with the input-output coefficients in an energy-economy planning model.

While the applications of fuzzy MCDM are numerous and diverse, the application in aquaculture planning is non existent. Accordingly, this paper reports the successful technology transfer of fuzzy MCDM to a new problem domain, namely aquaculture planning, and illustrates its application in that area.

3. THE MODEL

In MCDM problems, a decision maker seeks to optimize multiple decision criteria simultaneously subject to a number of constraints. Several techniques are available for handling MCDM problems However, in aquaculture planning, it is often the case where the available (and required) information contains uncertainty. Moreover, the information may not be sufficient to assess the probability distributions required for stochastic programming. A fuzzy MCDM model allows us to explicitly model the uncertainty inherent in planning for regional aquaculture development and can be expressed as:

$$Z(X) = C\,X \underset{\sim}{>} G$$

Subject to,

$$F(X) = A\,X \underset{\sim}{<} B \qquad (1)$$

$$X \geq 0$$

Where,

Z(X): $k \times 1$ vector of decision attributes, k is the number of attributes.

F(X): $m \times 1$ vector of constraints, m is the number of attributes.

A, B, C $m \times n$ matrix of technical coefficients, $m \times 1$ vector of resource/capacity limits, and $k \times n$ matrix of objective function coefficients, respectively.

X: $n \times 1$ vector of constraints, n is the number of decision variables.

G: $k \times 1$ vector of aspiration levels for each decision attribute.

$\underset{\sim}{>}$, $\underset{\sim}{<}$: the fuzzified version of $\geq$ and $\leq$, respectively and have the linguistic interpretation of "approximately larger than or equal to" and "approximately smaller than or equal to"

4. CASE STUDY

4.1 Background

The case study is concerned with resolving issues pertaining to the planning for aquaculture development in Northern Egypt where aquaculture is considered as a viable industry with significant potential for supplying cheap and good quality protein, for helping to balance the foreign exchange deficit, and for creating employment opportunities.

4.2 Model formulation

According to the MCDM framework proposed by El-Gayar and Leung (2001), in aquaculture development, a planner or a policy maker is often confronted with a multitude of goals and objectives that he/she seeks to realize through the development of the region's aquaculture industry. A development plan is comprised of the level of activities (decision variables) that compromise among often conflicting goals. Examples of decision variables include: what species to grow, what technology to use, how much to grow of each species and/or technology, etc. However, in devising such a plan, a set of resource, market and environmental constraints limit the alternatives available to the planner. Since, aquacultural plans often do not have clearly defined objectives (Nash, 1995), by extending El-Gayar and Leung's (2001) framework to incorporate imprecise/uncertain information, the proposed fuzzy MCDM modeling framework could certainly alleviate some of these issues as raised by Nash.

For the particular case study under consideration, three decision attributes are of concern, namely, regional availability of protein, employment, and foreign exchange earnings. The resources included are: land for fresh, brackish, and marine aquaculture, technical and non-technical labor, fresh, brackish, and marine water, domestic capital, foreign reserves, fry constraints, feed constraints, and feed ingredient constraints. On the other hand, the external constraints represent domestic market demand, export market demand, and pollution. The resource constraints together with the external constraints define the feasible set of solutions.

4.3 Results and discussion

This case study is comprised of three scenarios. The scenarios differ with respect to the parameter values for the fuzzy membership functions as well as the weight assigned to the different objectives under consideration. In the first scenario, and for the purpose of practical implementation, we use the results of the pay-off matrix to determine the tolerance intervals for the fuzzy membership functions. Overall, the solution strikes a balance among the competing objectives in which regional availability of protein, employment, foreign exchange earning attains 61%, 86%, and 54% of their ideal value, respectively.

In the second scenario, and to test the flexibility in decision making, different weight distributions are applied to the objectives under consideration. The solution reflects that change in preference in which foreign exchange earnings attain 93% of its ideal value at the expense of the other two objectives.

Since the ideal and anti-ideal numbers represent extreme cases, and may not reflect the preference of the decision maker, to illustrate the flexibility of the approach in accommodating uncertainty, the third scenario represents a case where the tolerance interval is decreased by 25 percent relative to the first scenario. The solution reflects the decision maker preferences by increasing the level of attainment of regional availability of protein at the expense of foreign exchange earning.

5. CONCLUSION

This paper applies fuzzy set theory to multiple criteria decision making in aquaculture planning. In effect, the paper demonstrates how fuzzy set theory can be used to explicitly account for the inherent uncertainty encountered when planning for aquaculture development in a given region. The case study illustrates the use of the proposed fuzzy MCDM framework to aquaculture planning in Northern Egypt.

6. ACKNOWLEDGMENTS

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