Advances in Fuzzy Mathematics.
ISSN 0973-533X Volume 3, Number 1 (2008), pp. 43–50

http://www.ripublication.com/afm.htm

IWRM: Approach of Intuitionistic Fuzzy-Eia for Selection of Best Catchment Area

Srijit Biswas*
Assistant Engineer (PWD), Govt. of Tripura, India
**Corresponding Author E-mail : srijitbiswas@yahoo.com*

Pankaj Kr. Roy
Lecturer, School of Water Resources Engineering,
Jadavpur University, Kolkata-700032, West Bengal, India.
E-mail : pk1roy@yahoo.co.in

Sekhar Datta
Principal, Tripura Institute of Technology,
Agartala-799009, Tripura , India.
E-mail: sekhardatta@yahoo.co.in

Abstract

The approach of Integrated Water resources Management (IWRM) implies that the water should be managed alongside the management of environmental impact of it's co-dependent natural resources, namely soil, forests, air and biota and it should be applied at catchment levels for sustainable ecosystem[4]. The all catchment area of an IWRM are under consideration of several impacts due to environmental as well as non-environmental factors[3,4]. Thus environmental impact assessment (EIA) plays an important role for evaluation of those impacts and enable the IWRM to augment the positive effects of it. For any EIA , statistical analysis via sampling survey is a powerful tool to know the people thought as well as expert's perception. But all the information so obtained from various sources are involve with full of uncertainty & hedges like "high flood area", "poor sanitation", etc. Naturally, every decision-maker hesitates more or less, on every evaluation activity[5]. Because some part of his perception contributes to truth ness and rest part contributes to falseness. So uncertainty is a major factor for such evaluation which could be solved by using a powerful mathematical tool of fuzzy logic. In this paper we present a methodology of intuitionistic fuzzy EIA (IF-EIA) successfully for optimal solution of best catchment area out of n alternatives. To understand the methodology, a hypothetical case study is presented here.

Keywords: criteria value matrix, dominance matrix, intuitionistic fuzzy set, mean fuzzy set.

1. Introduction

An IWRM can enter into a successful stage only when it can able to mitigate all kinds of adverse environmental impact from it's existing eco family areas. Excess use of fertiliser, lack of wild life conservation, deforestation, indiscriminate location of industries, poor sanitation, etc. , are generally the main responsible factors that influence adverse environmental impact in a catchment area [6]. All this factors are involve directly or indirectly to create more or less adverse impact. For a particular factor this impact is more in a particular catchment area but simultaneously for another catchment area this may be less than other factors. This is the common feature for all environmental factors. But there is certainly an integrated impact for all kinds of factors in all catchments area which naturally may vary from one to another. So it is very essential to do the actual comparative study among all catchment area and to see which one has the least adverse environmental impact and which one is the next. In this paper we solve this problem with a very logical treatment. Since "IF EIA or Intuitionistic Fuzzy EIA" [1,2] is a generalization of "Fuzzy EIA" [7], we have used the "IF EIA" with no loss of generality. The scope of work of the paper is to do a ranking among all catchments area under an IWRM-authority for taking fruitful decision about future plan of action for a new development project.

2. Method of "IF Environmental Impact Assessment" [2]

First of all we recollect some definitions from [2].

2.1 Attribute of the Assessment :

The assessment is done by collecting information or values for certain attributes which are called the attributes of the assessment.

For example, consider a project of "SANITARY ASSESSMENT OF A CATCHMENT AREA", for which some relevant attributes could be "high flood area", "poor drainage system", "bad approach road", etc.

2.2 Universe of the Assessment :

Collection of all attributes of the assessment is called the Universe of the Assessment.

2.3 Mean Fuzzy Set of an IFS :

Let E be an universe and X be an IFS of E. The mean fuzzy set of the IFS X is a fuzzy set m of E given by the membership function

$$m(x) = \frac{\mu_A(x) + 1 - \nu_A(x)}{2}$$

2.4 Weighted Average of an IFS :

Let A be an IFS of a universe X, and let μ be the mean fuzzy ser of A. Suppose that to each element $x \in X$, there is an associated weight $W_x \in R+$ (set of all non-negative real numbers).

Then the weighted average of the IFS A is the non-negative number a(A) given by

$$a(A) = \frac{\sum \mu(x) \cdot W_x}{\sum W_x}$$

2.5 Grading of Assessment Output :

Depending upon the value of a (A), the grading of overall output could be temporarily proposed as below:

grade = A, if $.8 < a(A) \le 1$
grade = B, if $.6 < a(A) \le .8$
grade = C, if $.4 < a(A) \le .6$
grade = D, if $.2 < a(A) \le .4$
grade = E, if $0 \le a(A) \le .2$

It is obvious that the best grade is "E" and the worst grade is "A".

In the next part we present the methodology of assessment by a hypothetical case study.

3. Case Study

Consider a project of "SANITARY ASSESSMENT OF A CATCHMENT AREA (Drawback)". To do the assessment let us consider the following attributes (for the sake of simplicity in presenting the method we consider here only ten attributes):-

x_1 = bad approachable road.
x_2 = high flood area
x_3 = poor garbage system
x_4 = unusual number of mosquito breeding
x_5 = unusual number of fly breeding
x_6 = poor drainage system
x_7 = unusual use of pesticides in field
x_8 = crude discharge of industrial effluent
x_9 = thickly populated area
x_{10} = unusual habit of open defecation

Now the job is to assign values to these attributes. This can be done either by direct observation or by collecting views from a good number of Engineers in addition to the information from local people ,local panchayet, local NGO, local Govt.

management authority etc., in general. Let us suppose that the data collected from 100 people for an attribute x_i reveals that more or less 70 people are in support of the truthness of the attribute, 20 are in support of falseness and the rest 10 people are without any comment due to hesitation. We set the following :-

$$\mu_A(x_i) = .7 \quad \text{and} \quad \nu(x_i) = .2 .$$

Suppose that the data (hypothetical) are as shown in a tabular form (table-1). These data leads to an IFS X of the universe E where

$$E = \{ x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} \}.$$

Now calculate the mean fuzzy set M of the IFS X. We find that

$$M = \frac{x_1}{.9}, \frac{x_2}{.75}, \frac{x_3}{.85}, \frac{x_4}{.9}, \frac{x_5}{.45}, \frac{x_6}{.75}, \frac{x_7}{.6}, \frac{x_8}{.8}, \frac{x_9}{.5}, \frac{x_{10}}{.6} .$$

It can be calculated that the weighted average of this fuzzy set is .723 and consequently the grade to be awarded is "B". Thus the assessment reveals that the sanitary condition of the said catchment area is not so good .

Table 1

Attribute name	in support of truthness $\mu(x)$	in support of falseness $\nu(x)$	indeterministic part	weight of the attribute W_x
x_1	.9	.1	0	20
x_2	.7	.2	.1	5
x_3	.8	.1	.1	60
x_4	.8	0	.2	50
x_5	.3	.4	.3	40
x_6	.6	.1	.3	70
x_7	.5	.3	.2	20
x_8	.7	.1	.2	10
x_9	.5	.5	0	25
x_{10}	.4	.2	.4	30

4. Optimality Testing

Here we present our proposed method. Suppose that x be the number of environmental assessments A_1, A_2, ….., A_x conducted in connection with x number of environmental factors F_1, F_2, ….., F_x. Suppose y be the number of other factors which are F_{x+1}, F_{x+2}, …., F_{x+y}.

All these factors are needed to be considered for the judgement of a suitable catchment area having least adverse environmental effects. First of all, each assessment A_i is to be done by the method proposed by us in [2].

Now let us discuss our main optimisation method used for multi-factor based decision making. The m(=x+y) number factors of F_1, F_2, ……, F_m are called criteria, based upon which this decision making problem is to be solved.

Suppose , n nos. catchment area are L_1, L_2, …., L_n. Our aim is to choose the most suitable catchment area having least adverse environmental impact out of these n alternative. We first of all furnish few definitions required for further progress of the paper.

4.1 Criteria Value Matrix

The criteria value matrix (table-2) is a n x m matrix $[C_{ij}]$, where

n = number of catchment area

m = number of criteria under consideration

C_{ij} = criteria value in connection with its catchment area L_i and jth criteria F_j

Table 2

	F_1	F_2	…	…	F_m
L_1	C_{11}	C_{12}	…	…	C_{1m}
L_2	C_{21}	C_{22}	…	…	C_{2m}
.	.	.	…	…	.
.	.	.	…	…	.
.	.	.	…	…	.
L_n	C_{n1}	C_{n2}	…	…	C_{nm}

4.2 Dominance Matrix

It is a n x n square matrix $[d_{ij}]$ to be constructed from the criteria value matrix $[C_{ij}]_{nXm}$ such that each element of $[d_{ij}]$ signifies the number of criteria for which the catchment area L_i dominates (i.e. shows identical or better results than) the catchment area L_j (table-3).

Table 3

	L_1	L_2	…	…	L_n	**Row-Sum**
L_1	d_{11}	d_{12}	…	…	d_{1n}	r_1
L_2	d_{21}	d_{22}	…	…	d_{2n}	r_2
.	.	.	…	…	.	.
.	.	.	…	…	.	.
.	.	.	…	…	.	.
L_n	d_{n1}	d_{n2}	…	…	d_{nn}	r_n
Column-Sum	C_1	C_2	…	…		C_n

Here r_i denotes the row-sum and C_j denotes the column-sum $\forall$ i, j = 1, 2, 3, ……., n.

It is obvious that $d_{ii} = m$ and $d_{ij} \geq m$.

The value r_1 indicates the number of times (on the basis of the nn criteria under consideration) the catchment area L_1 dominates all the catchment area, and the value C_1 indicates the number of times the catchment area L_1 is dominated by all the catchment area.

4.3 Index of Suitability

The index of suitability of catchment area L_i (which have least adverse environmental impact) is S_i given by

$$S_i = r_i - C_i, \qquad i = 1, 2, \ldots, n.$$

The optimal selection of a catchment area will be that catchment area corresponding to which the index of suitability is optimum.

The algorithm could be produced as below :

4.4 Algorithm

1. Compute the criteria value matrix from assessments output for environmental factors and from relevant sources.
2. Compute the dominance matrix
3. Calculate index of suitable S_i for each catchment area L_i
4. Find k for which $S_k = \max S_i$
5. The optimal selection is the catchment area L_k

Let us make a case study with hypothetical data to understand the above algorithm.

5. A Case Study on Optimality Testing

Suppose there are three catchment area L_1, L_2, and L_3. An environmental impact analysis among these three catchment area is to be done to find out which one is least effected and which one is not so as far as various environmental factors as well as non-environmental factors that is to be consider for analysis. For the sake of simplicity here we consider only two environmental factors F_1, F_2 and two other factors F_3, F_4.

Suppose that each factor has been analysed with its co-factor using intuitionistic fuzzy approach and recollected in section here. Finally the criteria value matrix is attained (table-4) and then compute the dominance matrix (table-5)

Clearly,

Index of suitability of Catchment area L_1 is $S_1 = 2$

Index of suitability of Catchment area L_2 is $S_2 = 0$

Index of suitability of Catchment area L_3 is $S_3 = -2$

Thus, the most suitable catchment area is L_1, 2^{nd} best is L_2 and the least suitable is L_3.

Table 4

	F_1	F_2	F_3	F_4
L_1	0.50	0.43	5837	6235
L_2	0.25	0.80	7816	4137
L_3	0.48	0.36	4981	7463

Table 5

	L_1	L_2	L_3	**Row-Sum**
L_1	4	2	3	9
L_2	2	4	2	8
L_3	1	2	4	7
Column-Sum	7	8	9	

6. Conclusion

The paper has explore the concept of EIA with degree of certainty that need to be adequately dealt with to ensure IWRM. Thus EIA has a vast potential to play an important role to tackle and mitigate the adverse environmental impact in a catchment area.

In the present paper we see that fuzzy logic & it's higher order fuzzy logic can suitably be applied for evaluation of environmental impact in any catchment area because uncertainty is the integral part involve in the process and prediction. It may also embrace search & rescue measured as well as evacuation plan for the areas that may be at risk from a recurring hazardous.

Condition of a catchment area can be strengthen by IF-EIA's process but there could be other parameters hidden or not hidden, such as local politics, local constraints, etc which will influence the decision makers

Reference

[1] Atanassov, K.T((1986)., Intuitionistic fuzzy sets, Fuzzy Sets and Systems - 20 ,p 87-97.

[2] Biswas, Srijit (1998)., Environmental Impact Assessment : An Intuitionistic Fuzzy Approach. Proceeding of the Second International Conference on IFS. Sofia , 3-4 Oct., p 23-27. (Published in the international journal NIFS, of Bulgaria)

[3] Global Water Partnership (GWP). (2000). Integrated Water Resources Management. GWP Technical Committee Background Paper 4. Stockholm

[4] ICWE (2004), International Conference on Water and Environment, The Dublin Statement on Water and Sustainable Development., June 22.
[5] Munro, J. (1979), Uncertainty & Fuzzyness in Engineering decision- making , Proc. 1st canod. Sem. On system theory ofer Civil Engineers.
[6] Rao, K.J. (1977), Assessment and Management of Environmental Pollution in Some Developed Countries, Jou. IAEM. 2468-77.
[7] Zadeh. I.A. (1965) Fuzzy sets, Infor: and Control- 8 , 338-353.

Biography

Srijit Biswas obtained his Bachelor in Civil Engineering and Master in Public Health Engineering, both the degrees from Calcutta University, West Bengal. His core research area is Environmental Impact Assessment (EIA) in Integrated Water Resources Management using Fuzzy logic. His research interest deals with the Fuzzy mathematical modelling for assessment of environmental impact in IWRM. He is presently an Assistant Engineer in PWD, Govt. of Tripura, India.

Pankaj Kr. Roy obtained his Ph.D in Water Resources engineering from Jadavpur University , West Bengal. Currently he is Lecturer of School of Water resources Engineering, Jadavpur University. He obtained his Master of Engineering in the field of Water resources Engineering from Jadavpur University, West Bengal, India.

Sekhar Datta obtained his Ph.D in Water Resources engineering from Jadavpur University, West Bengal. Currently he is the Principal of Tripura Institute of Technology, Tripura. He obtained the Master of Engineering in the field of Fluid Mechanics from Jadavpur University, West Bengal, India.