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Implementing and Prioritizing the Strategies of Sustainable Agriculture Using Fuzzy Analytic Hierarchy Process (FAHP); Case Study; Hamadan Province Agriculture Field, Iran

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Abstract: In the present study, sustainable agriculture strategies in Hamadan province have been prioritized by use of Fuzzy Analytical Hierarchy Process (FAHP). Based on the results of the studies, 23 strategies were chosen. The chosen strategies were prioritized based on the opinions of 15 experts through relevant questionnaires. The applied technique was implemented in Visual Basic environment. The relevant data were controlled through sensitivity analysis. Among 23 strategies, 8 were prioritized using FAHP. In this study, the strategy creating balance between grazing and pasture obtained first rank among the strategies. It can be concluded a great concern for experts to focus on this problem as the major challenge of sustainable agriculture in the studied area is needed.

Key words: Agriculture, FAHP, Hamadan province, strategy, sustainable agriculture

INTRODUCTION

The history of agriculture is a history of environmental modification (Briggs and Frank, 1989). Although in recent years, application of modern technologies in agriculture has supplied the food demands of human societies but it has also posed many environmental problems and decreasing in natural resources (Hatfield and Karlen, 1994).

Therefore the process of environmental modification resulting from performing agricultural activities is considered as a permanent process during the history. But what is today the source of concern for specialists and supporters of environment, is the increased speed and intensity of environmental modification that are now occurring. Increase in population and the necessity to provide more and cheaper food has encouraged more efforts for establishment of intensify agricultural systems. On the other side, regarding promoted knowledge and attitude of people, there is a tendency to decrease or eliminate the effects of such systems on the environment (Hatfield and Karlen, 1994).

Hence, regarding the interaction mentioned above, the implementing and prioritizing of strategic objectives in agriculture section even more importance than any other time. In the present study, the strategies of sustainable agriculture in the studied area have been prioritized using Fuzzy Analytical Hierarchy Process (FAHP) technique. Hamadan Province covering 19493 square kilometers is located in west of Iran, 320 km far from Tehran with a population of about 1.6 million. This province is one of the major agricultural centers of Iran. Due to the low investments in industrial activities, the development of the area is built upon the improvement of agriculture (Reyahi *et al*., 2004). In the present study, sustainable agriculture strategies in Hamadan province have been prioritized by use of Fuzzy Analytical Hierarchy Process (FAHP) according to Extent Analysis (EA).

MATERIALS AND METHODS

This research was carried out in Hamadan province, during 2004 to 2005. The method which is used in the study is FAHP. Therefore, it is necessary to introduce FAHP and EA as briefly.

FAHP method: The Analytical Hierarchy Process (AHP) is one of the most famous decision making techniques

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which was presented by Saaty (1980). The structure of AHP consists of a hierarchy of criteria and sub-criteria cascading from the decision objective or goal. Fuzzy theory was presented by Iranian researcher. Then this theory was developed and influenced the management and decision making during the recent years(Azar and Faragi, 2002).

In 1983, two researchers from Holland, Van Laarhoven and Pedrycz, presented a technique which was a combination of fuzzy analytical hierarchy process and fuzzy theory and was called FAHP method or Fuzzy Analytical Hierarchy Process (Laarhoven and Pedrycz, 1983). In a new paradigm, FAHP introduced by Chang and developed by Zhu *et al.* (1999) and Chang (1996). This method was known as Extent Analysis (EA) method. Today, EA method is used widely as an advance method of FAHP in decision making process (Azar and Faragi). The specific steps involved in the development and analysis of FAHP are as follows:

Design the hierarchy structure model based on the numbers of criteria and alternatives: Initially, it is necessary to present the schematic of the method.

Determine the δ value (degree of fuzzyness): The practical result indicates that: $0.5<\delta<1$ is more suitable (Zhu *et al.*, 1999).

Construct a pairwise comparison matrix at different hierarchical levels: The pairwise comparisons are described by values taken from a pre-defined set of ratio scale values as presented in Table 1. The ratio comparison between the relative preference of elements indexed i and j on a criterion (Tang and Beynon, 2005). Then an element of M_{IJ} (i.e., a comparison of the ith Decision Alternatives with the jth Decision Alternatives with respect to a specific criterion) is a fuzzy number defined as $M_{IJ} = (l_{ij}, m_{ij}, u_{ij})$, where l_i, m_{ij} and u_{ij} are the upper, modal and lower values for Mij, respectively.

Table 1: Scale of relative importance based on saaty (Zhu *et al.*, 1999)

Level of importance		
Numerical value	Fuzzy value	Definition
1	1-1-1-	Equally preferred
2	1.33 -2- 3.67	Equally to moderately preferred
3	2.33 -3- 3.67	Moderately preferred
4	3.33 -4- 4.67	Moderately to strongly preferred
5	4.33 -5 -5.67	Strongly preferred
6	5.33 -6- 6.67	Strongly to very strongly preferred
7	6.33 -7- 7.67	Very strongly preferred
8	7.33 -8- 8.67	Very strongly to extremely preferred
9	8.33 -9 -9.67	Extremely preferred
Reciprocals of above nonzero		If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with I.

Determine the fuzzy synthetic extent values (M): As mentioned, in the pair-wise comparison matrix, each elements is considered as a Triangular Fuzzy Number (TFN). Each TFN is shown by three values, l and u are the lower value and upper value respectively and m is the mid-value of TFN. Generally, TFN denoted as (l, m, u) (Zhu *et al.*, 1999). Based on this fact, if M considered as one element of pair-wise comparison matrix, then l, m and u are the values of M. This means that triangular fuzzy number M could be shown as M(l,m,u) (Chang, 1996).

Calculation the weight vectors: In this part, it is necessary to consider of comparison for fuzzy synthetic extent value (Chang, 1996). For example, for tow fuzzy synthetic extent values M_1 and M_2, the degree of possibility of $M_1 \geq M_2$ is obtained. Also, the degree of possibility for a fuzzy synthetic extent value M to be greater than the number of k fuzzy synthetic extent values M_i (i = 1, 2, 3, k) can be given by the use of the operations max and min and can be defined by:

$$V(M \geq M_1, M_2, \ldots M_K) = V[(M_1 \geq M_1) \text{ and } (M_1 \geq M_2) \text{ and} \ldots \text{and } (M_1 \geq M_K)] = \min v(M \geq M_K) \quad (1)$$

Assume that:

$$d' = (A_i) = \min V(M_i \geq M_k) \quad (2)$$

Where K = 1, 2, ...n ; k ≠ I and d′ (A_i) value represents the relative preference of each decision alternatives (Tang and Beynon, 2005).

Then a weight vector related to each matrix is given by :

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_m)) \quad (3)$$

Case study: In this study, first the strategies of sustainable agriculture in Hamadan province have been implemented, then these strategies have been prioritized by use of FAHP according to EA method.

Implementing the strategies and criteria: Based on the results of the studies related to environmental evaluation (Reyahi *et al.*, 2004), as well as the results of Knowledge Attitude and Practice (KAP) study on sustainable agriculture among rural farmers in Hamadan province (Reyahi *et al.*, 2005) and also library studies about Hamadan agricultural fields, 23 strategies were choosen. It were necessary using the viewpoints of experts and specialists. so, this draft were sent in the form of questionnaires to 20 specialists and experts. They was requested to give their opinions regarding each of criteria

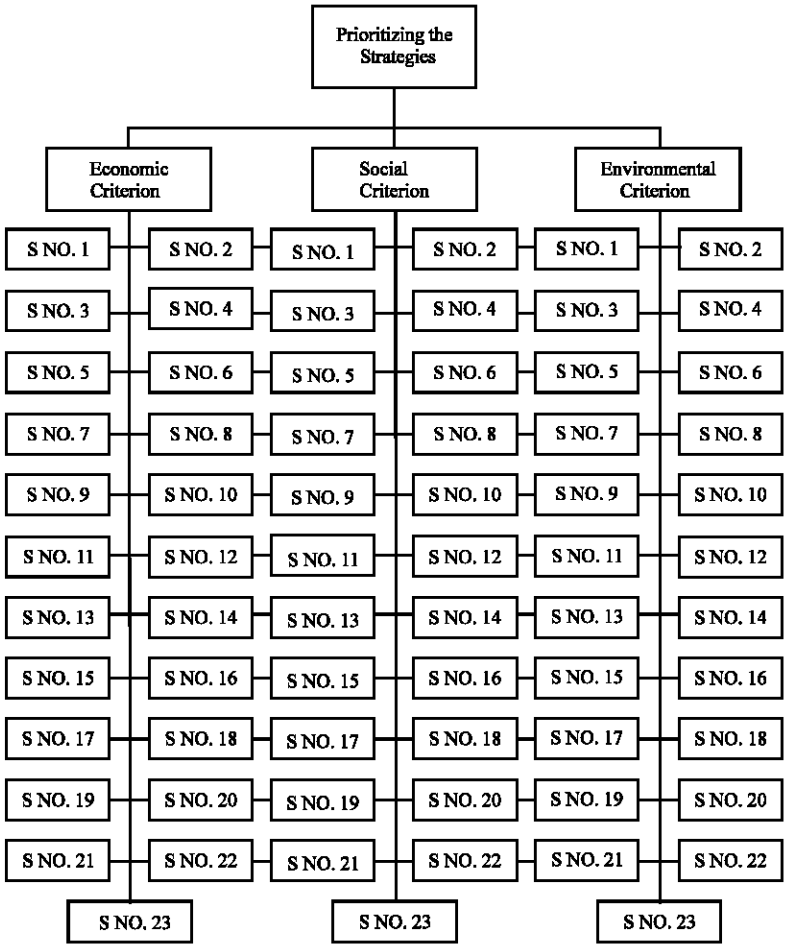

Fig. 1: Hierarchy structure model

and strategies provided in questionnaires. In this way, the questionnaires were sent to them and then amended based on the opinions of experts and specialists and confirmed by them. According the above explanations and based on the fact that the content of research questionnaire were prepared based on the opinions of specialists, therefore, the validity of questionnaire were confirmed.

Prioritizing the strategies and criteria: Strategies have been prioritized in six steps:

Step 1: Design the Hierarchy Structure Model: It has been drawn in order to give a framwork of the research. On the top of this diagram is the most important research objective, i.e., prioritizing the sustainable agriculture strategies, while the criteria that are effective in some way or another in the prioritization process come next. And the 23 strategies of this research come at the end of this chart. The Hierarchy Structure Model is presented in Fig. 1.

Step 2: Determine the δ value: The value of δ select as 0.67 (Zhu *et al*., 1999).

Step 3: Construct a pairwise comparison matrix at different hierarchical levels: The prioritizations have been made by pair-wise comparison matrix. Hence the questionnaire were designed based on the viewpoints of specialists and experts. This questionnaire includes four empty matrixes. The first matrix is used for prioritization of criteria and the other three matrixes for prioritization of strategies based on the criteria of this research. (1-9 scale) has been used to determine the numerical quantity and prioritize one strategy to the other or prioritize one criterion to the other (Saaty, 1980). This means that each of the scales has been shown by one of the linguistic variables and each linguistic variable has been shown by a triangular fuzzy number. The information related to the above-mentioned (1-9 scale) has been shown in Table 1. Questionnaires containing Hierarchy

Structure Model and four matrixes were distributed among 20 specialists. From these specialists 15 responded to the questionnaires.

Step 4: Determine the fuzzy synthetic extent values(M): The matrix information gathered from the questionnaires completed by specialists and experts were transferred to a computer file under Excel spread sheet. Using the facilities of Excel spread sheet, the geometrical mean related to all of the matrices elements were calculated. Finally, 4 matrixes were found for this research. The fuzzy synthetic extent values were determined by use of Eq. 1. for each of which matrix.

Step 5: Calculation the weight vectors: In this research, the number of strategies were very high, So it were seemed that hand calculations would be erroneous. Therefore, in order to prevent committing errors and increasing accuracy of calculations, we tried to implement a part of the methods in Visual Basic programming Environment. Means, an algorithm were defined as step-by-step. After that, using algorithm to build a solution, testing the solution and making enhancements. Then, The weight vector related to each matrix were calculated. Following the weight vector concept shown in Eq. 3.

Step 6: Normalization: The data were normalized by performing all calculations for each of the four matrices as explained above, the obtained information were integrated by weighting mean method, the importance coefficient of each strategy were calculated and then the strategies were prioritized.

Sensitivity analysis: In this study, the Sensitivity analysis were performed in order to verify the obtained results by use of *Triantaphyllou* method (Triantaphyllou and Sanchez, 1997). Because of the sensitivity analysis were too long and great in Triantaphyllou and Sanchez (1997) method, therefore this method were implemented in Visual Basic programming environment. After proving the accuracy of the logic of this program and making necessary controls, this program were used for necessary calculations required for sensitivity analysis.

RESULTS

Findings of this study are presented in two parts as follows:

Implementation of strategies and criteria: As mentioned above, in this research the viewpoints of experts and specialists have been used to implement strategies and criteria. On this basis, the social, economic and environmental criteria were selected. It should also be mentioned that 23 strategies have been implemented are shown in Table 2.

Prioritization of strategies: In the first step for prioritization of strategies, the amounts fuzzy synthetic extent values of each strategy or criterion in the related matrix were calculated. In the next step, the obtained amounts or fuzzy synthetic extent values of each pair-wise comparison matrices were transferred to the provided Visual Basic computering program in four steps. In order to summing up and prioritizing the results of this

Table 2: Implemented Strategies before prioritizing

1	To take necessary actions for permanent and balance incomes of villagers
2	To create the balance between grazing and pasture
3	To observe exploitation of land using with the land capability
4	To execute the agricultural lands integration plan and to prevent piecemeal of agricultural lands
5	To rationalize and clarify governmental subsides in agriculture section
6	Controlling water supply from underground resources (to install countor, to close unauthorized wells, to supervise about water supply from underground according to the license
7	To complete, expedite and provide credits in order to implement watershed management plans including mechanical and biological plans
8	To develop the extension in agriculture section
9	To promote level of literacy among rural farmers
10	To motivate the youth in order to working in agriculture section
11	To grant bank facilities in order to modernizing the farms of province as supervised and based on planned manner
12	To have agricultural lands registered
13	To encourage farmers for establishment the NGOs and other society in agriculture section
14	To promote applied research in agriculture section
15	Planning for recruitment of farm experts by farmers
16	To control quality of agricultural products regarding pathogen, poison, antibiotic and hormone remaining on crops
17	To promote and complete soil and geology studies in the province
18	To promote and expand cultivation of crops with low water need through wet farming
19	To control surface waters in the province through dam building and executing artificial recharge
20	To increase immunity of animal husbandry and poultry, to combat parasites and relevant diseases and to render veterinary services
21	To provide insurance coverage related to agricultural products against pests, flood and drought
22	To promote the agricultural transformation industries
23	To plan production of potager products in hydroponics units and production of strategic products in open farms

Table 3: The primary results of prioritizing the strategies by FAHP methods

	Economic	Social	Environmental	Results				
No.	0.10406	0.07646	0.81948				Total	Ranking
1	0.92666	0.00000	0.00000	0.09643	0.00000	0.00000	0.09643	3
2	0.00000	0.00000	0.54417	0.00000	0.00000	0.44593	0.44593	1
3	0.00000	0.00000	0.45583	0.00000	0.00000	0.37355	0.37355	2
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
8	0.00000	0.13893	0.00000	0.00000	0.01062	0.00000	0.01062	7
9	0.00000	0.32291	0.00000	0.00000	0.02469	0.00000	0.02469	4
10	0.00000	0.27243	0.00000	0.00000	0.02083	0.00000	0.02083	5
11	0.07334	0.00000	0.00000	0.00763	0.00000	0.00000	0.00763	8
12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
13	0.00000	0.26573	0.00000	0.00000	0.02032	0.00000	0.02032	6
14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
15	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
19	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
20	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
21	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
22	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0
23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0

Table 4: Prioritized strategies based on FAHP

No.	Strategy	Ranking
2	To create the balance between grazing and pasture	1
3	To observe exploitation of land using with the land capability	2
1	To take necessary actions for permanent and balance incomes of villagers	3
9	To promote level of literacy among rural farmers	4
10	To motivate the youth in order to working in agriculture section	5
13	To encourage farmers for establishment the NGOs and other society in agriculture section	6
8	To develop the extension in agriculture section	7
11	To grant bank facilities in order to modernizing the farms of province as supervised and based on planned manner	8

Table 5: The prioritizing of the criteria

Characteristic	Social criterion	Economic criterion	Environmental criterion
Before sensitivity analysis	0.07646	0.10406	0.81948
After sensitivity analysis	0.19502	0.26542	0.53956

computering program, The weight vector related to each matrix were calculated and were transferred to Table 3. Based on the calculation, the strategies were prioritized and shown in Table 4.

Sensitivity analysis of weight values related to criteria: The sensitivity analysis related to criteria were performed by use of Triantaphyllou and Sanchez (1997) method. The most amount of sensitivity coefficient were related to the environmental criterin, i.e., 170. Having applied the obtained results and amended the environmental criterion and finally, data obtained were normalized by new results, showed a change of weight criteria but no change were seen in the prioritization of criteria. The results of such changes are presented in Table 5.

Sensitivity analysis of weight values related to strategies: Using the introduced method, the sensitivity analysis were performed while the most amount of sensitivity coefficient were found 87.6 for strategy No. 3. (To observe exploitation of land using with the land capability) related to environmental criterion. Having applied the obtained results and amended the strategy No. 3. and final table were normalized by new results, showed that no change were made in the results of prioritizations. The weight of strategies did not change also.

DISCUSSION

This study showed FAHP method have been frequently used in different cases as: to Capital Investment study (Tang and Beynon, 2005), to select a provider for specific service (Mikhailov and Tsvetinov, 2004), to evaluate success factors of E-commerce (Feng and hongyan, 2005), to prioritize and rank the influencing factors of public work's quality (Yang, 2006), for robot selection (Vikas and Singh, 2005) and any other fields. In general, the frequent use of FAHP show that the mentioned method can be affectively used in evaluation and ranking the alternatives.

Based on the viewpoints of specialists and experts in this research, the environmental criterion is more important than social and economic criteria and this fact is very important and has a base role. This leads us to make a more real prioritization of strategies. The viewpoints presented about prioritization of criteria were so strong and straight forward that performing sensitivity analysis in various stages could not make a change in prioritization of criteria. But the weights of criteria did not go any changes in both FAHP and AHP methods. The results showed that the FAHP method could prioritize only eight strategies out of 23 strategies. This is perhaps because the specialists and experts believe that only these eight strategies are really important and the other strategies are not so important. These results support the finding of the other studies indicating that there is no weight with three decision alternatives out of five decision alternatives (Tang and Beynon, 2005).

According to the findings of this study, the strategy To create the balance between grazing and Pasture obtained the first rank in this prioritization. This may be compared with the written report of the general department of natural resources of Hamadan province (Department of Natural Resources of Hamadan Province, 2005). Based on present study, this province has the first rank regarding the ratio of grazing to pasture. This means that the studied area is the first province of the country regarding its proportion of grazing to pasture and this has attracted attention of many specialists. The results showed that the proposed method can be effectively used for prioritizing the strategies of sustainable agriculture.

The authors sure that FAHP method, with the capability of obtaining information in more systematic and efficient ways, contributes to the effectiveness of managing and prioritizing relevant managerial competence activities and also, closer to the logic of human thought.

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