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Full Length Article

Land Suitability Evaluation for Wheat Cultivation by Fuzzy-AHP, Fuzzy- Simul Theory Approach As Compared With Parametric Method in the Southern Plain Of Urmia

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ABSTRACT
The development of a land suitability classification is a prime requisite for land use planning and development, because it guides decisions on land utilization towards an optimal utilization of land resources. In this study, in order to comparative efficacy of the fuzzy method for land suitability evaluation, AHP and Simul weighting methods for wheat were used in the southern part of Urmia plain and results of the fuzzy method were compared with results of the parametric method. The study area was divided into 16 land map units and seven major land characteristics of wheat production were selected as the evaluation criteria. The correlation (r^2) between land indices obtained from methods and the observed performance in the region, are 0.86, 0.82 the method based on fuzzy-AHP and fuzzy- Simul set theory and are 0.78 the parametric method .RMSE related to the fuzzy-AHP method is 450 , fuzzy-Simul 484 and whereas for parametric method is 670 . The higher correlation between land indices and yield production, and smaller RMSE for the fuzzy method showed this method is more accurate than the parametric method. But the accuracy of results greatly depends on the selection of suitable membership functions, determination of critical points of functions and amounts of assigned weight with Analytical Hierarchy Process for different characteristics of lands.
Key words: Analytical Hierarchy Process, fuzzy- simul, land suitability evaluation, parametric approach, Fuzzy membership functions

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INTRODUCTION

Agriculture is important as a source of food and income, but How, Where and When to cultivate are the main issues that farmers and land managers have to face day to day. Land evaluation is carried out to estimate the suitability of land for a specific use such as arable farming or irrigated agriculture. Land evaluation results from a complex interaction of physical, chemical and bioclimatic processes and evaluation models are reliable enough to predict accurately the behavior of land [1] , [7]. In parametric method, a quantitative classification is allocated to each characteristic of land. If a characteristic of land for a specific product was completely desired and provided optimum conditions for that, maximum degree 100 would belong to that characteristic and if it has limitation, the lower degree will be given to it. Later, allocated ranks will be used in calculation of the land index. In parametric
method, different classes of land suitability are defined as completely separate and discrete groups and are separated from each other by distinguished and consistent range. Thus, land units that have moderate suitability can only choose one of the characteristics of predefined classes of land suitability. Fuzzy sets theory for the first
time defined by Zadeh (1965) in order to quantitative defining and determining of some classes that are expressed vaguely such as "very important" and so on. In fuzzy thinking, determination of specific border is difficult and belonging of various elements to various concepts and issues are relative. The analytical hierarchy process (AHP) developed by Saaty [5] is the multi-criteria evaluation technique used, enhanced with Fuzzy factor standardization. Besides assigning weights to factors through the AHP, control over the level of risk and trade off in the siting process is achieved through a second set of weights, i.e., order

weights, applied to factors in each factor group, on a pixel-by-pixel basis, thus taking into account the local site characteristics. The main purpose of this study is to prepare land suitability evaluation for wheat using Fuzzy methods and compare it with parametric method for the southern plain of Urmia .

MATERIALS AND METHODS

The study area lies in the southern plain of Urmia in the Western Azarbayjan province, Iran. It is located within coordinate of latitude 37°15'00'' and 37°35'00'' North and longitude 45°5'00'' and 45°20'00'' East with the area of 5600 hactor . The studied region has Mesic temperature regimes. Furthermore, the studied area has Zeric moisture regimes. Using GPS device and base map, profiles location defined and profiles excavated and described using presented methods in "Field Book Describing and Sampling Soils"(1998). The studied area was divided into 16 land units and 7 land characteristics that are effective in irrigated wheat selected including soil depth (cm), texture, electrical conductivity (dSm^{-1}), Calcium carbonate content (%), pH , drainage and climate. The irrigated wheat requirements were determined using FAO frame work for land evaluation [8]. In parametric method of land evaluation, the square root was used [8]. In fuzzy method, based on irrigated wheat requirements, the pimf membership functions were used to determine the degree of membership of each land characteristic to land suitability classes (Figures 1) and the results were put in a matrix R (called characteristic matrix). Then, via Analytic Hierarchy Process (AHP) the weight of each effective land characteristic in irrigated wheat yield was calculated and put in weights matrix (W). The AHP technique has the ability to incorporate different types of data and comparing two parameters at the same time by using the pairwise comparisons method, the base requirement for the AHP method [5]. this method, pairwise comparisons are considered as inputs and relative weights are as outputs. The Saaty scale [5] was used for generation of pairwise comparison matrix which relatively rates priorities for two criteria (Table 1). It was supposed that comparison matrix was reverse and reciprocal that means if a criterion A in comparison with criteria B has a double priority, it could be inferred that criteria B has a priority half of criteria A. The criteria priorities are defined according to expert's judgments. After generation of pairwise comparison matrix, the criteria weights are calculated that includes sum of each column of pairwise comparison matrix and division of each component by the result of each relevant column sum. The resulted matrix is knows as normalized pairwise comparison matrix. The average of each row of the pairwise comparison matrix is calculated and these average values indicate relative weights of compared criteria.
Fuzzy-Simul method were based on the method proposed by Van Ranst et al (1996). for determining standard suitability matrix (matrix P) of the product suitability classes were determined based on production potential and reference suitability matrices were established by attributing randomly selected between 1 and 0 (100000 in this study) to each of considered land qualities. Reference suitability matrices were obtained by combining the reference weight matrices with characteristic matrix. By calculating the difference between the proportions of matrix standard reference unit 100 000 matrix fit is obtained, which leads to less weight matrix was the difference as the best weight matrix for selected properties. To determine the final land suitability class in each land unit, a multiple operator (combination) was used. The final matrix of land suitability (E) was calculated after multiplying the characteristic matrix (R) in each land unit by weights matrix (W). The components of E indicate the degree of membership of relevant land unit to land suitability classes. This matrix is calculated as below :
$E = W \circ R$ Where: ° is fuzzy operator created from Triangular norm T (as minimum) and Triangular conorm T* (as maximum) (Ruan, 1990) . $LI = \Sigma\, d\, E_j \times A_j$ Where: LI: land index d: normalized (standardized) value of land suitability matrix (E) A: average of maximum and minimum indices of land suitability classes.

$$f(x;a,b,c,d) = \begin{cases} 0, & x \le a \\ 2\left(\dfrac{x-a}{b-a}\right)^2, & a \le x \le \dfrac{a+b}{2} \\ 1-2\left(\dfrac{x-b}{b-a}\right)^2, & \dfrac{a+b}{2} \le x \le b \\ 1, & b \le x \le c \\ 1-2\left(\dfrac{x-c}{d-c}\right)^2, & c \le x \le \dfrac{c+d}{2} \\ 2\left(\dfrac{x-d}{d-c}\right)^2, & \dfrac{c+d}{2} \le x \le d \\ 0, & x \ge d \end{cases}$$

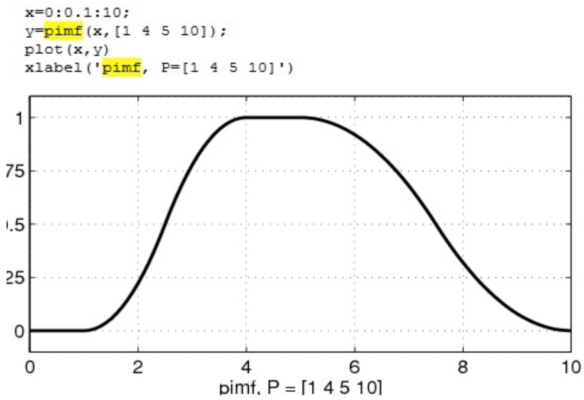

Figure 2. pimf membership function and its equation

Table 1. The Saaty scale [5] was used for generation of pairwise comparison matrix

Intensity of 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 to extremely strong
9	Extreme importance

RESULTS AND DISCUSSION

The irrigated wheat requirements were determined using FAO framework for land evaluation (Sys, 1985). The studied area was divided into 16 land units and 7 land characteristics considered to be relevant to irrigated wheat (table 2) .

Table 2. Selected land characteristics for wheat in religion

Land units Units	deep Effective rooting (cm)	Soil Texture	EC (dS/m-1)	pH	CaCO3 (%)	Dranige	Climate index
1	130	L	0.72	7.76	17.98	good	91.4
2	130	L	0.3	7.9	4.78	moderate	91.4
3	130	CL	0.3	7.9	4.78	poor	91.4
4	130	L	0.3	7.9	4.78	moderate	91.4
5	130	C	0.3	7.9	4.78	Poor but drainable	91.4
6	50	L	0.3	7.9	4.78	Poor and aeric	91.4
7	150	S.L	1.53	7.79	15.86	moderate	91.4
8	140	L	0.81	8.56	24.4	moderate	91.4
9	145	S.L	1.53	7.7	15.86	moderate	91.4
10	145	C	1.53	7.7	15.86	Poor but drainable	91.4
11	150	CL	1.39	7.77	28.8	moderate	91.4
12	150	C	1.39	7.77	28.8	Poor and aeric	91.4
13	150	CL	0.89	7.5	21.66	Poor and aeric	91.4
14	150	C	0.89	7.5	21.66	Poor but drainable	91.4
15	150	C	0.95	7.6	23.5	Poor but drainable	91.4
16	140	SiC	2.4	8.4	21.38	Poor and aeric	91.4

C=Clay, L= Loam, C.L= Clay Loam, S.L= Sandy Loam, S.C.L= Sandy Clay Loam

The results of Pair wise Comparison Matrix in the AHP method for preparation of the weights used for the overly of the Fuzzy maps are given in Table 3. By the determined land characteristic weights in Table4 for wheat, the weight matrix (W) was generated as the matrix below:

$$(w) = [0.26\ \ 0.13\ \ 0.1\ \ 0.17\ \ 0.05\ \ 0.19\ \ 0.1]$$

Table3 : Pair wise comparison matrix for wheat

Criteria	EC	$CaCO_3$	pH	Texture	soil depth	drinage	climate
EC	1	2	3	3	5	2	2
$CaCO_3$	0.5	1	2	0.5	2	0.33	2
pH	0.33	0.5	1	0.5	3	0.5	1
Texture	0.33	2	3	1	5	0.5	2
Soil depth	0.2	0.5	0.33	0.2	1	0.5	0.5
drinage	0.5	3	2	2	2	1	2
climate	0.5	0.5	1	0.5	2	0.5	1
sum	3.36	9.5	12.33	7.7	20	5.33	10.5

Table4. Normalized pairwise comparison matrix with criteria weights for wheat

Criteria	EC	$CaCO_3$	pH	Texture	soil depth	drinage	climate	sum	weight
EC	0.30	0.21	0.24	0.39	0.25	0.38	0.19	1.9	0.26
$CaCO_3$	0.15	0.11	0.16	0.06	0.10	0.06	0.19	0.83	0.13
pH	0.10	0.05	0.08	0.06	0.15	0.09	0.10	0.64	0.1
Texture	0.10	0.21	0.24	0.13	0.25	0.09	0.19	1.22	0.17
Soil depth	0.06	0.05	0.03	0.03	0.05	0.09	0.05	0.36	0.05
drinage	0.15	0.32	0.16	0.26	0.10	0.19	0.19	1.36	0.19
climate	0.15	0.05	0.08	0.06	0.11	0.09	0.14	0.7	0.1

For fuzzy- simul weight , Considering that the product were 16 points for each of them an optimal matrix weights, average weights were obtained as the final weight was used in land evaluation. For, this part of calculated were used of computer languages. Final results of the best matrix of weights (matrix W) are as follows, respectively, indicating that the salt, lime, reactive, soil texture, soil depth, drainage and climate:

(w) = [0.21 0.11 0.12 0.15 0.16 0.11 0.14]

Table 5. Observed wheat yield, land suitability classes and land indices obtained by fuzzy approach and parametric for different land units

unit No.	Observed yield (kg/ha)	Land suitability classes evaluation for irrigated wheat Parametric		Fuzzy-AHP			
		Parametric Land index	Parametric Land class	Fuzzy AHP index	fuzzy AHP class	Fuzzy Simul index	Fuzzy Simul class
1	6000	86	S1	87	S1	87.5	S1
2	5500	81	S1	85	S1	85	S1
3	4500	62	S2	79	S1	81	S1
4	4200	78	S1	82	S1	82	S1
5	4800	45	S3	78	S1	76	S1
6	4000	47	S3	75	S1	74	S2
7	5000	75	S1	83	S1	84	S1
8	4200	86	S1	74	S2	74	S2
9	5500	81	S1	86	S1	88	S1
10	4700	62	S2	78	S1	79	S1
11	5000	78	S1	83	S1	84	S1
12	3500	45	S3	64	S2	63	S2
13	4900	47	S3	82	S1	84	S1
14	4700	75	S1	75	S1	74	S2
15	4000	43	S3	78	S1	77	S1
16	3500	40	S3	77	S1	79	S1

Major limitations to wheat yield were EC and drainage. The correlation (r^2) between land indices obtained from both methods and the observed performance in the region for wheat, is 0.86 for the method based on fuzzy-AHP and 0.82 for the method based on fuzzy-simul and is 0.78 for the parametric method. RMSE related to the fuzzy-AHP , fuzzy- simul method is 450, 484 whereas for parametric method is 673(fig2). A comparison between results of this research and other investigators (Van Ranst et al., 1996; Sanchez, 2007 ; Joss et al., 2008; Keshavarzi and Sarmadian, 2009) indicated that the fuzzy method with higher correlation factor, had more accuracy and capability of predicting yield, since fuzzy set method considered the continual land changes and is more efficient in reflecting spatial variability of soil characteristic rather than Boolean's two-valued logic that overlooks a considerable section of useful information during land evaluation processing. Nonetheless, the accuracy of the results is mainly dependant on the designated weights to different land characteristics. Although in land suitability evaluation, nowadays the emphasis is on quantitative (numerical) methods, because the fuzzy sets theory's problem in land suitability evaluation needs a high volume of calculations. On the other hand, increasing the number of land characteristic, increases the number of pairwise comparisons and decision making on spatial variability of different characteristics in each land unit becomes difficult, because different characteristics has different weights and designation of weight to characteristics needs more experience and criteria precedence. The weakest part of the fuzzy set methodology for land evaluation is the way in which membership functions, class centers, cross-over values and weight values are chosen (Keshavarzi and Sarmadian, 2009). Davidson et al. (1994) also stated that one critical issue in the application of fuzzy set theory to land suitability assessment is the choice of membership functions. This is not a straightforward task since decisions have to be made on membership values according to degree of suitability.

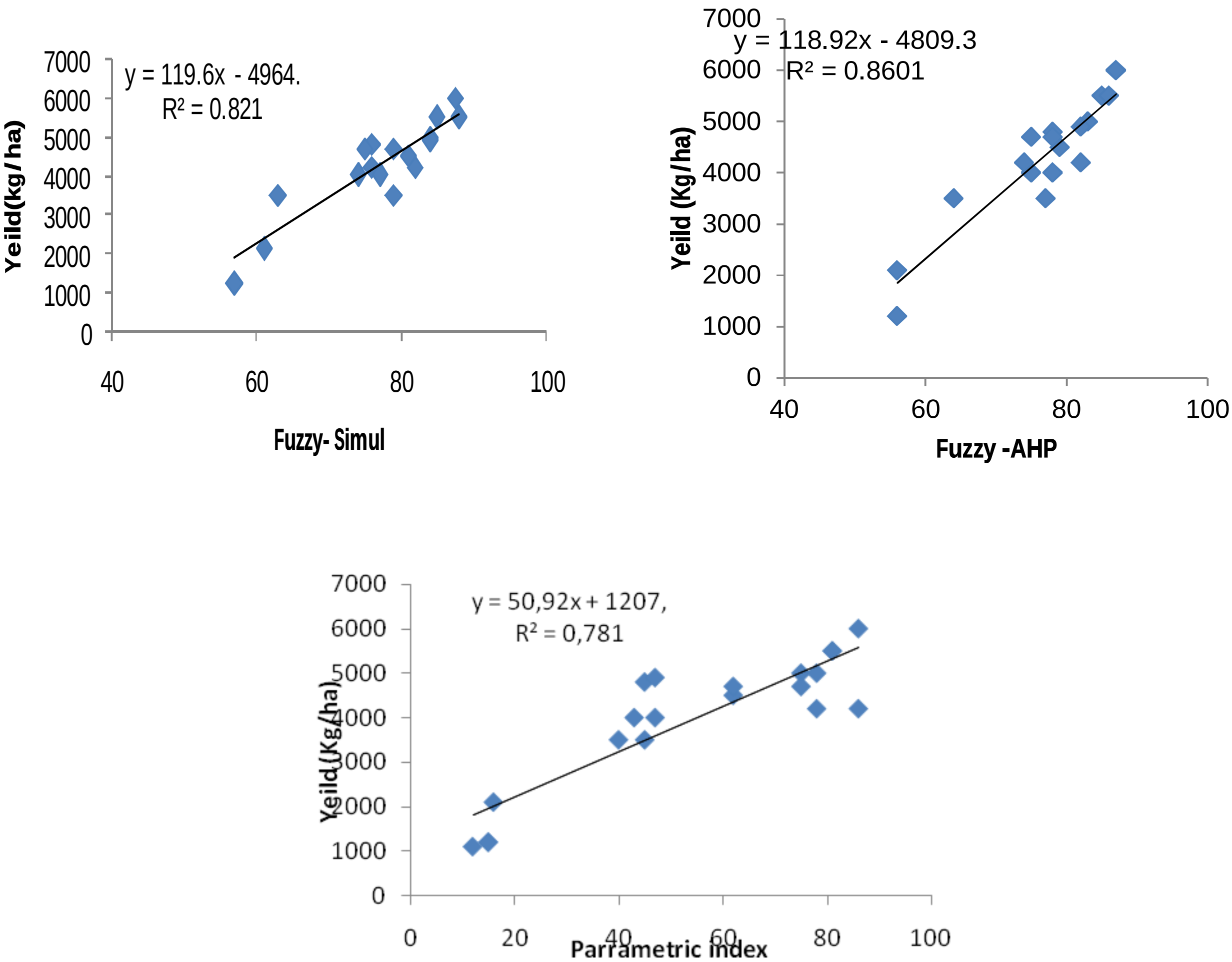

Figure 2. Linear regression between land suitability index and observed irrigated wheat yield in fuzzy-AHP, Fuzzy-simul approach and parametric approach

CONCLUSION

The use of fuzzy technique in this study produced land suitability for irrigated wheat in a continuous scale. Land suitability indices reflect inherent fertility of the soil. The approach in this research is well applicable for applications in which subtle differences in land characteristic is of the major interests. Considering major constraints to the use of fuzzy technique for land suitability evaluation, it results valuable information for identifying major limitations to crops production and strategies for overcoming them. The most important factor that complicates a decision making problem, is domination of uncertainty situation. Decision making under uncertainty situation is complex and difficult, thus achieving a suitable and optimum choice demands compliance with rules, values and different description aspects of decision process. The other advantage is that it allows the environment to be inherently vague and does not try to limit soil continual system to the data measured by soil science researchers.

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