Land Evaluation Techniques Comparing Fuzzy AHP with TOPSIS methods

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ABSTRACT
Increases in populations and in particular in developing countries are placing increased pressure on both natural and agricultural resources. In many cases, especially in semi-arid regions, the pressures are compounded by restricted agricultural lands. Reliable and relevant land evaluation is a requirement for land use policy and decision making to support sustainable rural development. Land evaluation techniques for many developing countries are still needed to develop a model for predicting land suitability for self-sufficiency in agricultural production. Selection an appropriate land evaluation technique in developing courtiers such as Libya is very important for current and future land uses planning. This paper compared two land evaluation techniques for; barley using FuzzyAHP and TOPSIS methods for a test area within Jeffara Plain of Libya. The results of the Fuzzy AHP and TOPSIS models are based on standardizing land characteristics by using different fuzzy models, applying the pairwise comparisons method for criteria weighting and using generalized family of distance metrics functions. Land suitability results for barley from the use the Fuzzy AHP and the TOPSIS methodologies have been derived. Error matrix and analysis of the results are presented using two assessment technologies; an overall accuracy and KAHAT statistic.

Keywords: Land evaluation, Fuzzy AHP , TOPSIS, Pairwise comparisons method ,Overall accuracy and KAHAT statistic.

1. INTRODUCTION
Land resources are gradually becoming scarce as increases in population place pressure on natural resources. The world population grows; an increase of food supply is urgently needed to meet those demands. In addition, Land use policy in developing countries frequently makes little use of technical information and when they do policy makers requires this to be interpreted into brief statements which eliminate technical details (Nwer, 2005). There are many approaches which are widely implemented in land evaluation such as: the USDA land capability classification (1961) and the FAO framework for land evaluation (1976). Some of these techniques have used in developing countries, but the information which used is often not linked to local knowledge and local conditions (Clayton and Dent, 1993). The availability of GIS and Multi-Criteria Decision analysis (MCDM) methods allow combining knowledge derived form different sources to support land use planning and management (Malczewski, 1999). MCDM methods such as Fuzzy AHP method and TOPSIS have been employed with success to the model land evaluation technique (Parkash 2003), but, these methods are still not used in many developing countries such as Libya. This paper compares land evaluation models for barley using Fuzzy AHP and TOPSIS methods in North-Western region of Jeffara Plain of Libya .

2. BACKGROUND OF MULTI-CRITERIA DECISION METHODS

MCDM approaches were developed in 1960s to assist decision-makers to incorporate many options, reflecting the opinions of the actors concerned, into a potential or retrospective framework. They were designed to define the relationship between the data input and the data output. MCDM can be separated into main two main groups of methods; multiobjective and multiattribute (Malczewski, 1999). In this paper, Fuzzy Analytical Hierarchy Process (FAHP) and TOPSIS methods have been selected to compare the model outputs for cash crops in study area. 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 (Saaty, 1977). TOPSIS technique was selected to be used in this paper because it orders a number of alternatives on the base of their separation from the ideal point and it employs a number of the distance metrics equations to produce the best alternatives ((Malczewski, 1999)

3. METHODOLOGY

There are many established techniques are extensively used for generating land-use suitability evaluation. The FAO framework with Fuzzy AHP and TOPSIS methods have been selected for a test area within part of Jeffara Plain in Libya. The main aim from this test is to incorporate local knowledge from different sources in order to the model of land-use suitability analysis. The paper methodology has been divided into four stages. These stages are**:**

3.1FACTORS DETERMINING LAND-USE SUITABILITY FOR BARLEY

According to local experts, the study area is suitable for three cash crops such as barley, wheat and maize. For this paper, land-use suitability model for barley has been developed using Fuzzy AHP and TOPSIS methods. A number of land characteristics affecting barley production were identified after the discussion with the local experts. These are: Soil texture, % soil calcium carbonate (% $caco_3$), rootable depth, Available Water Holding Capacity (AWHC), % Organic Matter (% O.M), cation exchange capacity (CEC), soil salinity (EC), % soil alkalinity (% ESP), soil drainage, and soil reaction (soil pH), stones at surface, infiltration rate, erosion hazard and topographic characteristics.

3.2WEIGHTING FACTORS

Deriving weights for the selected map criteria (i.e. land characteristics map layers) is the base requirement for applying the Fuzzy AHP and TOPSIS methods (Malczewski, 1999). Weighting factors for land- use suitability evaluation for barley in this paper was obtained from local experts, through a pairwise comparisons statistical analysis in Idrisi environment. Local experts in Libya have used their experience to generate weights for land characteristics for barley. Pairwise comparison matrix for barley which derived from discussion with the Libyan local experts is shown in Table 1. The Consistency Ratios (CR) for this pairwise comparison matrix was equal to 0.1 .This shows that the comparisons of land characteristics were perfectly consistent, and the relative weights were appropriate for applying in land-use suitability evaluation models that use Fuzzy AHP and TOPSIS methods.

Land Characteristics	% slop	soil texture	% $CaCO_3$	% O.M	% ESP	AWHC	EC	% Stones	Soil drainage	Soil pH	CEC	Rootable depth	Infiltration rate	Soil erosion	Eigenvalues
% slop	1														0.021
soil texture	3	1													0.16
% $CaCO_3$	3	1/3	1												0.043
% O. M	3	1/3	1/3	1											0.036
% ESP	3	1/3	1/3	1/3	1										0.033
AWHC	3	1/3	3	3	2	1									0.124
EC	3	1/5	3	5	2	1/3	1								0.07
% Stones	3	1/3	3	2	2	1/3	1/3	1							0.046
Soil drainage	3	1/3	3	2	2	1/3	1/2	2	1						0.051
Soil pH	3	1/5	3	2	2	2	2	2	2	1					0.124
CEC	3	1/3	3	2	2	1/3	1/2	2	2	1/3	1				0.062
Rootable depth	3	1/3	3	2	2	1/3	2	2	2	1/3	3	1			0.079
Infiltration rate	3	1/3	3	2	2	1/3	2	2	2	1/3	1/3	1/3	1		0.058
Soil erosion	3	1/3	3	2	2	1/3	2	2	2	1/3	3	3	3	1	0.093

Table 1: Pairwise comparison matrix for barley in the study area

3.3MODEL STRUCTURE

In this paper, the FAO framework for land evaluation with Fuzzy AHP and TOPSIS approaches was employed to develop land-use suitability analysis for barley. Fuzzy AHP and TOPSIS models are given below:

3.3.1LAND-USE SUITABILITY ANALYSIS USING FUZZY AHP METHOD

The Fuzzy AHP procedure is considered one of the most common MCDM methods in resolving land suitability problem (Malczewski, 1999). The Fuzzy AHP approach in this paper has been divided into five stages. These stages are summarized in figure (1).

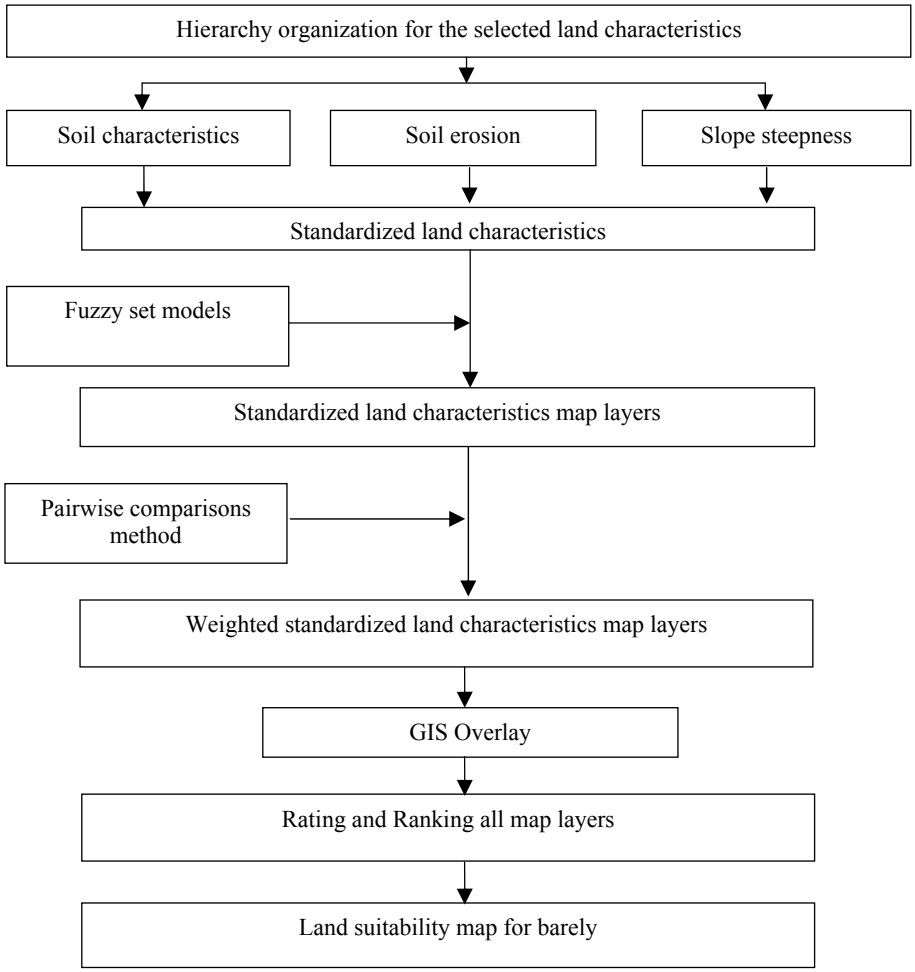

Figure 1: Fuzzy AHP procedure to the model of land-use suitability analysis for barley

3.3.2LAND-USE SUITABILITY ANALYSIS USING TOPSIS METHOD

The Fuzzy AHP procedure which described above has been extended in this paper to another five stages to be TOPSIS land evaluation method. These stages are presented in figure 2.

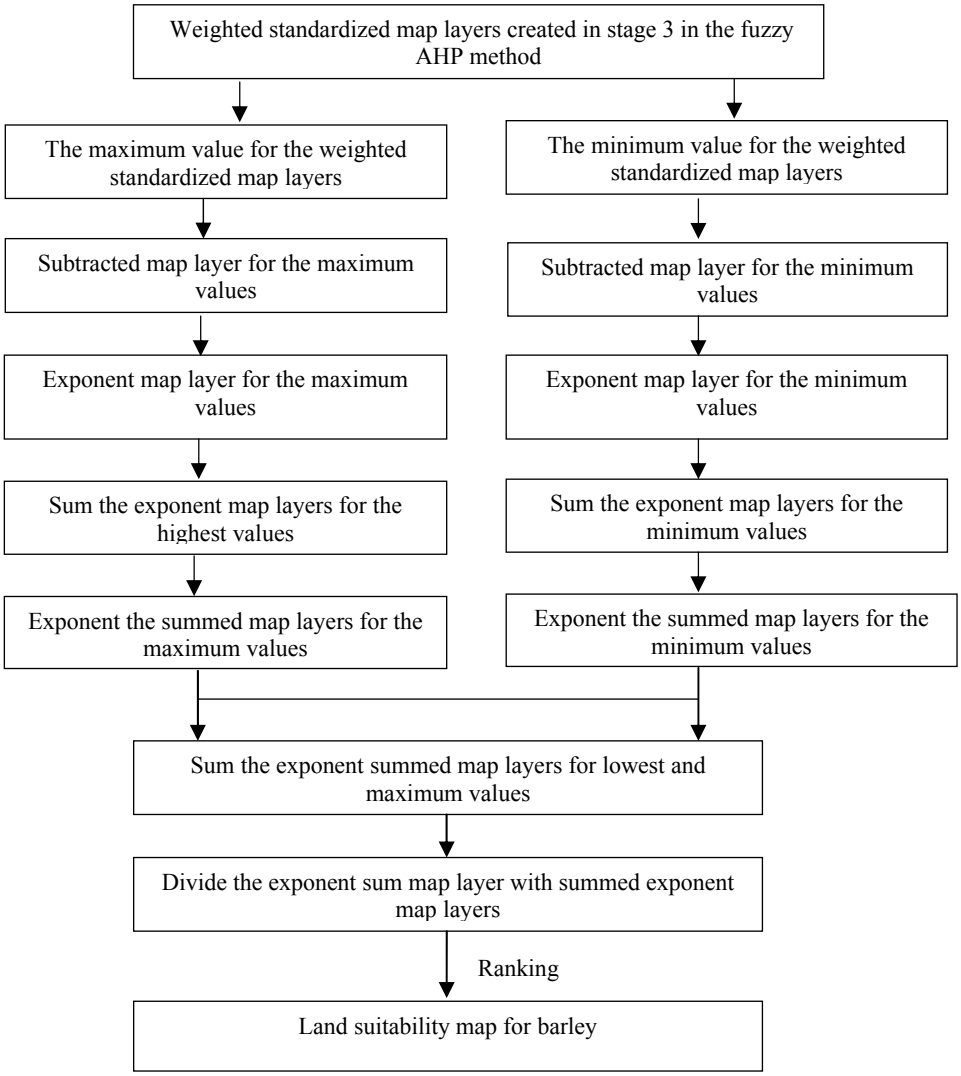

Figure 2: TOPSIS methods to the model of land-use suitability analysis for barley

3.4 MAP COMPARISON

With the Fuzzy AHP and TOPSIS techniques it is possible to obtain high suitable and less or not suitable classes with parcel of lands have the highest and lowest MFs values, respectively. Therefore, parcels of lands with high MFs will be ranked as classes 1 (most suitable classes) and parcels of lands with low MFs will be assigned as classes 4 (less suitable classes or not suitable classes). Ranking land units it is very necessary to compare the models outputs. To determine the correspondence between land suitability maps, the resulting maps from Fuzzy AHP and TOPSIS methods they will be cross- tabulated and then the confusion matrix will be created to estimate the relative performance of the Fuzzy AHP and TOPSIS results. In addition to the confusion matrix, an overall accuracy and the KHAT statistic; represents the agreement between the maps will be generated in this study (Congalton 1991).

4. RESULTS AND SUMMARY

The resulting maps for barley using Fuzzy AHP and TOPSIS methods were obtained. Table 2 summarizes the results of suitability for barley for Fuzzy AHP and TOPSIS methods.

Fuzzy AHP		TOPSIS	
Suitability	%	Suitability	%
0.79 - 0.63	1	0.66 - 0.50	5
0.63 - 0.49	78	0.50 - 0.40	6
0.49 - 0.36	15	0.40 - 0.30	80
0.36 - 0.29	1	0.30 - 0.24	4
No data	5	No data	5

Table 2:Suitability result for barley

The result of the two land evaluation models for barley was compared using cross-tabulation analysis and the overall accuracy and KHAT statistic analysis have used to assess the model outputs (Table 3).

	TOPSIS				
Fuzzy AHP	1	2	3	4	Row Total
1	2614	619	0	0	3233
2	10684	39424	8850	0	58958
3	0	15803	196112	3210	215125
4	0	0	5470	11086	16556
Column Total	13298	55846	210432	14296	293872

Continued Table 3

Weight Type	KHAT Statistic	% KHAT Accuracy	Kappa Interpretation
Liner	0.70	70	Substantial agreement

Classes	Producer's Accuracy (%)	User's Accuracy (%)	(%) Overall Accuracy
1	19.7	80.9	85
2	70.6	66.9	
3	93.2	91.2	
4	77.5	67	

Table 3: Error Matrix for the Fuzzy AHP and TOPSIS classifications for barley

Form this comparison it can summarize that most locations of the study area was mapped as class 2 from the use the Fuzzy AHP classification, while from the use the TOPSIS classification the most part of the study area was mapped as class 3. For all the two land evaluation models, few areas less suitable classes have been found. Using the KHAT accuracy and overall accuracy for assessing the results show that there is good agreement when the comparison between the Fuzzy AHP and TOPSIS classifications has been made.

5. CONCLUSION AND DISCUSSION

Using different GIS functions to the model of land evaluation was one of the main objectives of this paper. Land evaluation model based on using Fuzzy AHP and TOPSIS methods show that the percentages of land units which ranked as highly suitable and less suitable classes for barley are very small. Furthermore, the MFs values which derived from the use the Fuzzy AHP and TOPSIS methods had very little variation. This variation was found because the TOPSIS classification has some biasness towards negative and positive ideal values. Additionally, the results of the Fuzzy AHP method are not completely comparable with that created from TOPSIS method. This was resulted because some functions which employed to the TOPSIS model are not similar with that used to the Fuzzy AHP classification. The high percentages of the KHAT accuracy and an overall accuracy shows that there is a good agreement between the maps.
From this paper a number of conclusions can be drawn. First, land characteristics affecting barley production was very well organized and then assessed to fit into the framework of decision-making. Secondly, the use of decision-making methods to the model of land evaluation has facilitated the incorporation of expert knowledge from different local experts and literature review. Thirdly, weighting of the selected land characteristics was made according to their relative importance with taken the crop requirement for barley under local conditions into accounts. Finally, assessing the results using an overall accuracy and KHAT statistic agreed that good agreement was obtained when the comparison between the Fuzzy AHP and TOPSIS classifications has been made.

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