

OWA Analysis for Ecological Capability Assessment in Watersheds

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ABSTRACT: Fuzzylogic computes a multi-criteria evaluation by means of either a Boolean analysis, Weighted Linear Combination (WLC) and Ordered Weighted Averaging (OWA) of factor images. OWA works with standardized factor images and employs a variant of the WLC. It takes into account the risk associated with the decision and degree of tradeoff associated with the variables in the analysis. In this research, for Ecological Capability Assessment and watersheds management in study area, we have studied 22 biological and physiological factors. For ecological capability evaluation, the method of OWA was deployed. This method involves criterion weights and order weights. The generality of OWA is related to its capability to implement different combination operators by selecting appropriate order weights. By specifying suitable order weights, it is possible to change the form of aggregation from the minimum-type combination through all intermediate types including the conventional weighted linear combination, to the maximum-type combination. The paper focuses on the OWA method as well as an approach for integrating Geographic Information System (GIS) and OWA. OWA has been developed as a generalization of multi-criteria combination. The OWA concept has been extended to the GIS applications as part of a decision support module in GIS. In this study to obtain the criteria weights, comparisons were made by evaluating 22 criteria against each other, therefore we attained comparable data via the technique of Analytical Hierarchy Process (AHP) and five scenarios of OWA method were used. The results of field studies, third scenario for the study area proposed.

Key words: Fuzzy Logic, Ecology, Evaluation, AHP

INTRODUCTION

Geographical Information Systems (GIS) are important tools for spatial planning (Brailand Klosterman, 2001; Spanou *et al.*, 2012; Kim *et al.*, 2012; Basso *et al.*, 2012; Rasouli *et al.*, 2012; Nejadi *et al.*, 2012; Fumagalli and Toccolini, 2012; Mondejar-Jimenez *et al.*, 2012; Vukicevic and Nedovic-Budic, 2012). Spatial planning involves decision-making techniques that are associated with techniques such as Multi Criteria Decision Analysis (MCDA) and Multi Criteria Evaluation (MCE). Combining GIS with MCDA methods creates a powerful tool for spatial planning (Jankowski, 1995; Malczewski, 1999; Shumilov *et al.*, 2011; Najafi and Afrazeh, 2011; Dragicevic *et al.*, 2011; Kanokporn and Iamaram, 2011; Belkhiri *et al.*, 2011; Ahmed and

AbdellaElturabi, 2011; Hayatgheib *et al.*, 2011; Jing and Zhiyuan, 2011; Salehi *et al.*, 2012; Feng *et al.*, 2012; Ashrafi *et al.*, 2012). MCE is perhaps the most fundamental of decision support operations in GIS. Another category of decision making techniques utilized in spatial planning is based on the application of Fuzzy Set theory (Bogardi, *et al.*, 1996; Burrough, *et al.*, 1992; Mays, *et al.*, 1997; Smith, 1992; Wang, *et al.*, 1990; Xiang, *et al.*, 1992). Fuzzy Set theory was introduced by Zadeh (Zadeh, 1965), although the underlying concepts predate this. Nowadays, Fuzzy Set theory is a significant topic and is used in many different fields and technical arenas to address a variety of issues, both mundane and abstract (Badenko and Kurtener, 2004). Combining GIS with the

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application of Fuzzy Set theory presents a relatively new approach to location choice and land suitability assessment.

The combination of GIS with Fuzzy Set theory and deterministic models is known as GIS Fuzzy Modeling (GISFM). During the last few years, several applications of this approach for spatial planning have been attempted. In particular, GISFM was used for the assessment of burned forest areas with the aim of planning land restoration. Common problems of using of Fuzzy algorithms to support spatial planning had been discussed in (Kurtener and Badenko, 2002). GISFM is a useful approach for dealing with uncertainty and imprecision. Quality of GIS database plays an important role in GIS database formation. GIS database is based on various sources of information, which are characterized by different quality. Fuzzy sets can be seen as logical models which use logical rules to establish qualitative relationships among the used variables. Fuzzy sets serve as a smooth interface between the qualitative variables involved in the rules and the numerical data at the inputs and outputs of the model (Dalalah and Bataineh, 2009). For the designer who understands the system, these rules are easy to write where as many rules as necessary can be supplied to describe the system adequately. In Fuzzy logic, unlike standard conditional logic, the truth of any statement is a matter of degree. For example, consider the rule IF (machine is old) THEN (precision is poor), variables, "old" and "poor", map to ranges of values. Fuzzy inference systems rely on membership functions to explain how to calculate the correct values between 0 and 1 (Dalalah and Bataineh, 2009).

GIS can combine very different data types and allows quantitative analysis at the scale of landscapes or entire regions. For example, information on soils, hydrology and vegetation might be combined in analysis of wildlife strategy for restoration of degraded ecosystems. Nowadays, GIS has become an indispensable tool for land and resource managers (Nouri, *et al.*, 2006).

In short, GIS-based multicriteria decision analysis involves the utilization of geographical data, the decision maker's preferences and the combination of the data and preferences according to specified decision rules. Over the last decade or so, a number of multicriteria evaluation methods (decision rules) have been implemented in the GIS environment including weighted linear combination (WLC) (Jankowski, 1995; Eastman, 1997), ideal point methods (Carver, 1991; Pereira and Duckstein, 1993), concordance analysis (Carver, 1991; Jankowski and Richard, 1994), and analytic hierarchy process (Banai, 1993; Jankowski, 1995; Malczewski, 2006). Among these procedures, the

WLC (compensatory decision rules) and Boolean overlay operations (no compensatory decision rules), such as intersection (AND) and union (OR), are considered the most straightforward and the most often employed. They have also traditionally dominated the use of GIS as decision support tools. Recent developments in multicriteria decision analysis suggest the two classes of decision rules can be considered as specific cases of a family of ordered weighted averaging (OWA) (Malczewski, 2006).

OWA has been developed as a generalization of multicriteria combination (Yager, 1988). Over the last decade or so there have been a number of attempts to integrate the OWA concept as a core of GIS-multicriteria decision analysis. The OWA concept has been extended to the GIS applications by Eastman (1997) as a part of decision support module in GIS-IDRISI. Subsequently, Jiang and Eastman (2000) demonstrate the utility of the GIS-OWA for land use/suitability problems. The implementation of the OWA concept in IDRISI15.01 resulted in several applications of OWA to environmental and urban planning problems (Asprothet *et al.*, 1999; Mendes and Motizuki, 2001).

The critical aspect of integrating the GIS and OWA capabilities is the way in which the order weights are obtained. For example, the IDRISI-OWA procedure does not provide a user (decision maker) with a method for obtaining the order weights (Eastman, 1997; Jiang and Eastman, 2000). The procedure assumes that the decision maker can 'intuitively' search and identify the order weights based on the degree of ANDness (or ORness) and trade-off between criteria (Asprothet *et al.*, 1999; Mendes and Motizuki, 2001). To this end, it is important to note that for a given value of ANDness (or ORness) one can obtain a large number of different sets of order weights and associated trade-offs. Also, for a given degree of trade-off one can generate a number of different sets of order weights and associated degrees of ANDness (or ORness) (Yager, 1988). Consequently the methods are based on the principles of maximum dispersion (entropy) or the maximum trade-off. This paper focuses on an implementation of the parameterized-OWA in the GIS environment in the 33, 34 watersheds in Northern IRAN.

In order to introduce Some of the researches that today are to focus on the AHP and OWA of Fuzzy logic, the following cases are raised, i.e., Matkan, *et al.*, (2009), in research with title of Urban Waste Landfill Site Selection by GIS (Case Study: Tabriz City) represents that Ordered Weight Analysis (OWA), by ordered weights, offers this chance to the decision maker to insert more important subjects which have greater role in site selection. Regarding to this ability

the result of site selection by OWA has better resolution.

Sanaee, *et al.*, (2010), in research with title of multi-criteria land evaluation, using WLC and OWA strategies to select suitable site of forage plantation (Case study; Zakherd, Fars) represents that Multi-Criteria Evaluation is a method to compromise relative importance of participating factors and to integrate the factors according to their importance in decision making and two strategies of Weighted Linear Combination (WLC) and Ordered Weighted Averaging (OWA) selected for combining thematic maps. The results indicate WLC is a more conservative method than OWA. However, the overall agreement of the comparing the results, derived from the strategies, is about 95%, the strategy WLC is more conservative than OWA. It allocated more lands in the 2nd and 3rd classes of suitability.

MATERIALS & METHODS

This research is performed at DohezarandSehezar (33, 34) watersheds of Tonekabon city in Mazandaran Province of Iran with area of 35000 ha for evaluation purpose of ecological capability of watersheds (Fig. 1). This area is limited in 36° 19' 22" (north) to 36° 45' 41" (south) of latitude and 50° 31' 43" (west) to 50° 58' 41" (east) longitude. The land use of study area includes natural forest, pasture, agriculture and rural lands that respectively have equivalent surface 32761, 39193 and 5609 ha. This area, due to having capabilities such as rivers and the high density of a tree, it was necessary to assess ecological capability can be done to natural resources should be preserved carefully. In the present research, for achieving general goals of the plan, by studying and assessment of the elements and common techniques of planning and management, GIS tools and planning and management combination model (Grant, 1998) were selected for ecological evaluation. This research method as well as evaluation, determination and selection of appropriate points in concerned area included the following steps presented in Fig. 2. In the present research only those resources applied in modeling were studied. Landform (slopes and DEM), Geology (bed rock and geohydrology), Soil (soil texture, erosion, pH, soil granulation, percent of gravel, soil depth, soil fertility, soil drainage, soil hydrologic groups and soil evolution) and Climate (rainfall, temperature and humidity). Vegetation (density of trees covering, variety value and annual increment), Protected area and Sensitive sites.

The decision problem was formulated based on the guidelines suggested by Malczewski (1999) that can be used to identify priority sites for watersheds

ecological capability evaluation. Due to the problem complexity, and that the goal of this research is to explore the utility of MCE to identify candidate areas for watersheds land use, the focus will be on a subset of realistic criteria available for each objective. Each objective was evaluated separately, before being assessed as a multi-objective evaluation during the analysis procedure (Erensal, *et al.*, 2006). The validity of the MCE outputs was maintained by standardizing all criterion input layers such that their scales of measurement were commensurate. Linear scale transformation and Fuzzy set membership functions are two available standardization methods (Malczewski 1999). They all possessed a level of uncertainty as is inherent in coarse scale marine data. Hence, standardization of the criterion layers as Fuzzy measures was considered to be the most appropriate standardization technique. The Fuzzy set membership function used was a monotonically increasing linear membership model (Fig. 3). Monotonically increasing, linear Fuzzy membership function used to standardize MCE criteria layers. a, b, c, and d represent inflection points where the membership function rises above zero, approaches one, falls below one and approaches zero again, respectively. A monotonically increasing function rises to one and never falls again. Hence b, c, and d all have the same criterion value of 1 (Eastman, 2003).

Once the criterion layers have been standardized, the user assigns weights to them. These weights enable the solution to reflect the importance (as perceived by the user) of the input criteria relative to each other. Similarly, different objectives (which themselves are comprised of multiple, individually weighted criteria) can also be weighted relative to each other (Chou, *et al.*, 2008). Various weighting schemes both within and between objectives were investigated and their details are presented below. Once weights have been specified, the criteria (or objectives) are combined according to a decision rule (Swanson, 2003). The simple additive weighting methods, also known as ordered weighted averaging is the most common type of decision rule used in GIS-based decision-making (Wood and Dragicevic, 2006). This type of rule is implemented by multiplying each criterion layer by its weight and also is considered criterion ordered weights according to the following equation (Eastman, 2003). In order to introduce method of Ordered Weighted Averaging, it is necessary that this method investigated based on trade-off and risk (Fig. 4).

Voogd (1983) presented the application of several multi-criteria evaluation techniques to land planning, where the number of spatial units evaluated was limited. The integration of multi-criteria methods and

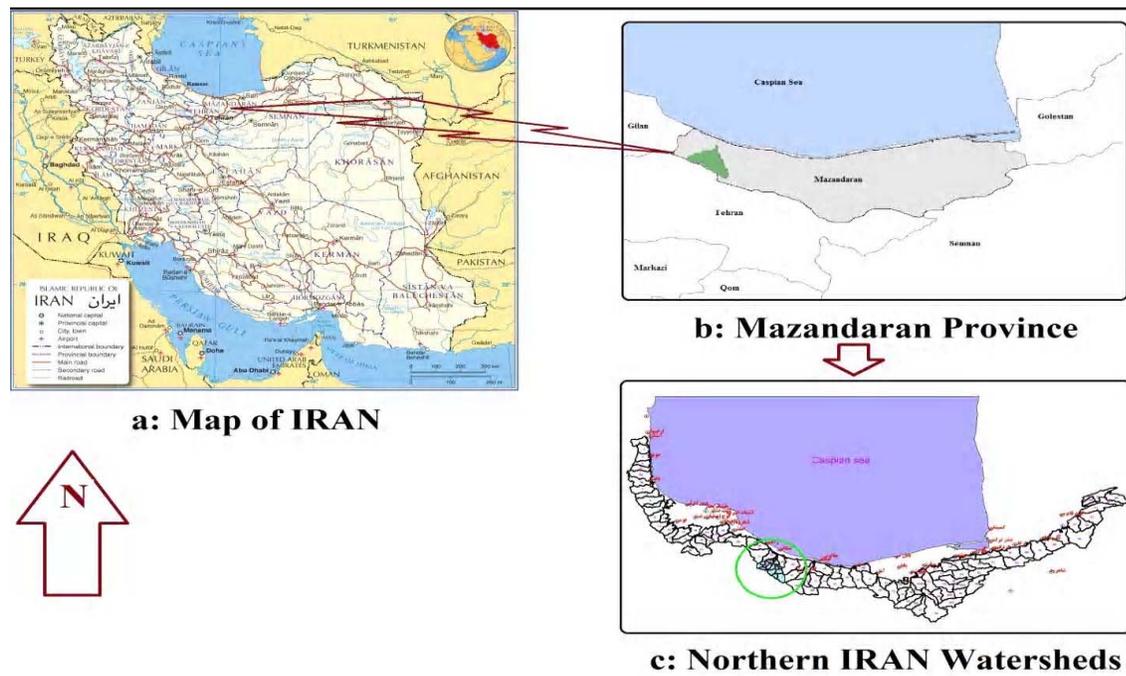


Fig.1. a: map of Iran, b: Mazandaran province, c: Northern Iran watersheds

GIS allows overcoming this limitation and provides a tool with great potential for obtaining land suitability maps or selecting sites for a particular activity (Mendoza, 1997; Eastman *et al.*, 1995; Jun, 2000). While GIS provide an appropriate framework for the application of multi-criteria evaluation methods, which are not capable of managing spatial data, the multi-criteria evaluation procedures add to GIS the means of performing trade-offs on conflicting objectives, while taking into account multiple criteria and the knowledge of the decision maker (Carver, 1991). Multi-criteria evaluation techniques based on the ideal point analysis are the techniques that have been more frequently integrated in a GIS with this aim (i.e., Carver, 1991; Pereira and Duckstein, 1993; Jankowski and Richard, 1994; Malczewski, 1996; Vatalis and Manoliadis, 2002). Another multi-criteria evaluation method frequently integrated into GIS to perform land suitability analyses is the Analytic Hierarchy Process (Banai, 1993; Jun, 2000). The AHP can also be used to generate the weights assigned to the land suitability criteria (Weerakon, 2002) or to the suitability maps to calculate a ‘compound’ suitability score (Mendoza, 1997). The IDRISI15.01 software provides two multi-criteria evaluation tools for obtaining suitability maps; the weighted linear combination (WLC) and the ordered weighted average (OWA) (Eastman, 1995).

Multi-criteria evaluation techniques have also been applied to generate multiple land use scenarios by selecting the optimum use for each land unit. Amongst them, hierarchical optimization (Carver, 1991) involves allocating the maximum area to the highest priority land use, excluding it from the remaining uses, and repeating the process until the total area is allocated (Saaty, 2005). When the hierarchy of the objectives is not known, a compromise solution can be determined by using the ideal point method to assign to each spatial unit the land use for which its suitability is the highest, minimizing the suitability of the remaining uses (Barredo *et al.*, 2004). Eastman *et al.* (1995) developed the Multi Objective Land Allocation method, based on the ideal point concept, and implemented in the MOLA module of IDRISI15.01. Examples of the application of this technique to multiple land use allocation are provided in Van der Merwe (1997) and Chan and Kumar (2007).

The criterion weights have been derived using the pairwise comparison method. This approach required the technical subcommittee to provide its best judgment regarding the trade-offs it was willing to make among the evaluation criteria (Saaty, 1980). After debate and careful analysis of the set of evaluation criteria, the subcommittee made all the pairwise comparisons for the set of the 22 criteria (Amiri, 2009). The criterion weights are calculated the pairwise

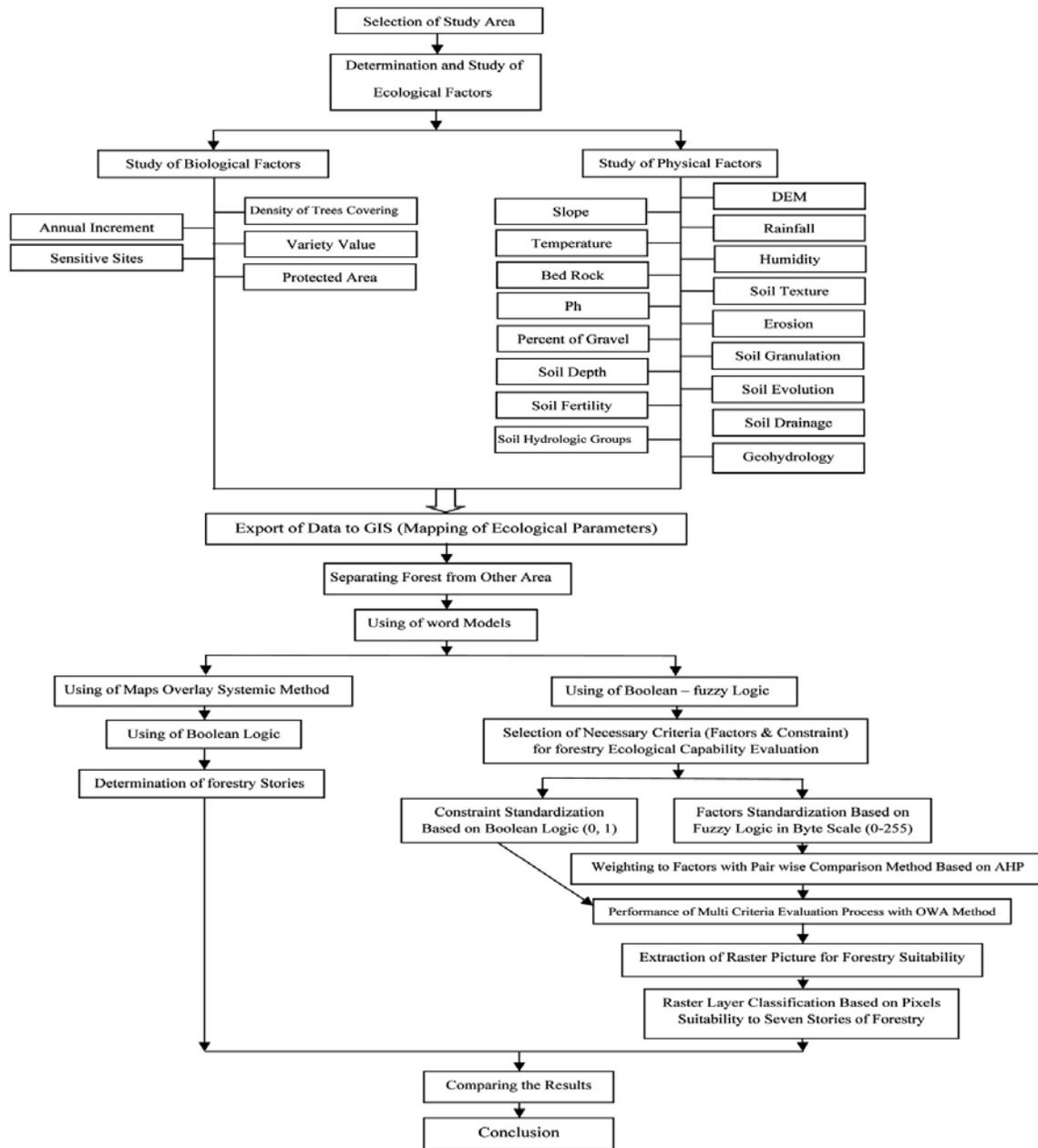


Fig. 2. Stages of implementation of watersheds ecological capability evaluation in study area

comparison matrix is entered in the EXPERT CHOICE9.5 software. Herein, the AHP is used to solve multiple criteria decision problems (Eastman, 2003). By means of a systematic hierarchy structure, complex estimation criteria can be clearly and distinctly presented. Ratio scales are utilized to make reciprocal comparisons for each element and layer (Saaty, 2005). After completing the reciprocal matrix, the comparative weights for each element can be obtained. The AHP is widely used for

tackling multi-criteria decision-making problems in real situations (Hosseini, 2003). In spite of its popularity and simplicity in concept, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-makers perception to crisp values. In the traditional formulation of the AHP, human judgments are represented as crisp values (Saaty, 2005). However, in many practical cases the human preference

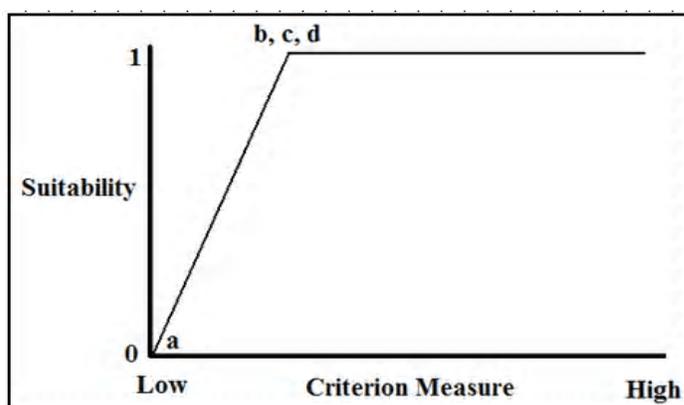


Fig. 3. Monotonically increasing, linear Fuzzy membership function

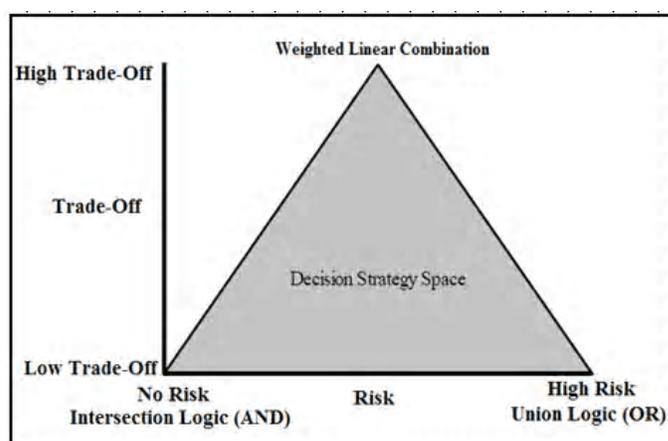


Fig. 4. Decision strategy Space (Eastman, 2006)

model is uncertain and decision makers might be reluctant or unable to assign crisp values to the comparison judgments (Chan and Kumar, 2007). The use of Fuzzy set theory allows the decision-makers to incorporate unquantifiable information, incomplete information, non-obtainable information, and partial facts into the decision model (Chou *et al.*, 2008). Although AHP requires tedious computations, it is capable of capturing a human's appraisal of ambiguity when complex multi-criteria decision-making problems are considered (Erensalet *et al.*, 2006). In addition, this software computes the consistency ratio (CR) associated with the pairwise comparison matrix (Saaty, 1980). After a few iterations and adjustments of the values in the pairwise comparison matrix, the subcommittee was able to achieve a satisfactory level of consistency; that is, CR was less than 0.1. Once a satisfactory level of CR is achieved the EXPERT CHOICE9.5 software calculates the criterion weights based on the pairwise comparison matrix. Table 1 shows the resulting criterion weights.

Standardizing the Factors

Each of the constraints was developed as a Boolean map while the factors were standardized using the module FUZZY so that the results represent Fuzzy membership in the decision set (Eastman, 2003). For example, for the ecological capability evaluation of watersheds, the DEM factor map was standardized using a sigmoidal monotonically decreasing Fuzzy membership function with control points at 1000 and 2700 meters. Thus, areas less than 1000 meters were assigned a set membership of 255 (on a scale from 0-255), those between 1000 and 2700 meters were assigned a value which progressively decreased from 255 to 0 in the manner of an s-shaped curve, and those beyond 2700 meters were assigned a value of 0. Fig. 5 illustrates the standardized results of all five factors and the constraints for the watersheds assessment. For a given set of n criterion (attribute) maps, OWA is defined as a map combination operator that associates with an i th location (object) a set of order weights $v = v_1, v_2, \dots, v_n$ ($v_j \in [0,1], j = 1, 2, \dots, n$, and $\sum_{j=1}^n v_j = 1$)

Table 1. The criterion weights (weight of all physical and biological parameters)

Evaluation criteria										
	Slope	DEM	Bed rock	Geohydrology	Soil texture	Erosion	pH	Soil granulation	Percent of gravel	Annual increment
Criterion weights	0.1253	0.0041	0.0066	0.0100	0.0194	0.1145	0.0553	0.0149	0.0145	0.1292
Evaluation criteria										
	Soil depth	Soil fertility	Soil drainage	Soil hydrologic groups	Soil evolution	Rainfall	Temperature	Humidity	Density of trees covering	Variety value
Criterion weights	0.0132	0.0635	0.0785	0.0110	0.0125	0.0143	0.0135	0.0085	0.0816	0.2096
C.R. = 0.08										

and a set of criterion weights $w = w_1, w_2, \dots, w_n (w_j \in [0, 1], \sum_{j=1}^n w_j = 1)$. Given the attribute values $a_{1i}, a_{2i}, \dots, a_{ni}$ at the i th location, like equation 1:

$$OWA_i = \sum_{j=1}^n u_j z_{ij} u_j = \frac{v_j w_j(z)}{\sum_{j=1}^n v_j w_j(z)} \quad (1)$$

Where $z_{1i} \geq z_{2i} \geq \dots \geq z_{ni}$ is the sequence obtained by reordering the attribute values $a_{1i}, a_{2i}, \dots, a_{ni}$; and $w_j(z)$ is the reordered j th criterion weight, w_j . The criterion weights are reordered according to $z_{1i} \geq z_{2i} \geq \dots \geq z_{ni}$. It is important to note the difference between the two types of weights (the criterion weights and the order weights) (Malczewski, 2003). The criterion weights are assigned to the evaluation criteria to indicate the trade-offs between criteria. All locations on the j th criterion map are assigned the same weight of w_j . The order weights are associated with the criterion values on the location-by-location (object-by-object) basis. They are assigned to the i th location's attribute value in decreasing order without considering from which criterion map the value comes (Malczewski, 2006).

The generality of OWA is related to its capability to implement a wide range of combination operators by selecting appropriate order weights (Yager, 1988). The family of OWA operators includes the most often used GIS-based map combination procedures: the weighted linear combination and Boolean overlay operations, such as intersection (AND) and union (OR) (Yager, 1988; Jiang and Eastman, 2000). The actual type of the OWA operator depends on the form of the order weights. Several methods for determining the weights. Here, we will focus on the maximum entropy approach (Malczewski, 2006). This approach makes use of the measure of ORness and the measure of dispersion. The measure of ORness is defined as equation 2 (Yager, 1988):

$$OR_{ness} = \alpha = \sum_{j=1}^n \frac{n-j}{n-1} v_j \quad (2)$$

The α value ranges from 0 to 1. It measures the degree to which an OWA operator is similar to the logical OR (or the MAX operator) in terms of its combination behavior. The measure can be interpreted in the context of well-established behavioral theory of decision-

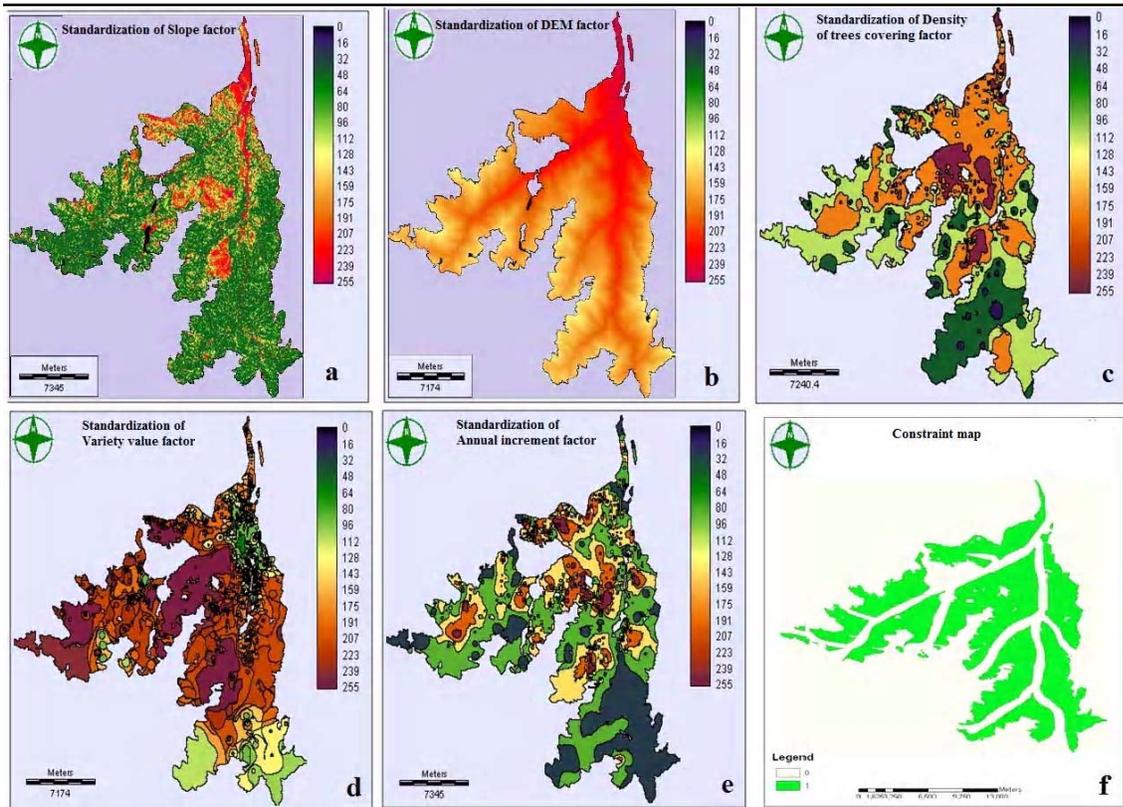


Fig. 5. Standardization of evaluation criteria. For example: a: Slope b: DEM c: Density of trees covering d: Variety value e: Annual increment f: constraints map

making (March and Shapira, 1987). According to the theory, an essential component of any decision-making process is the attitude of the decision maker (individual or organization) towards risk. An individual with low risk-taking propensity will typically weigh negative outcomes more highly and, conversely, an individual with high risk-taking propensity is more likely to weigh positive outcomes more highly. Risk attitudes can be represented on a continuum from risk aversion to risk seeking (Malczewski, 2006). Accordingly, ORness can be recognized as a measure of the degree of the decision-makers optimism (Yager, 1988). The values of ORness in the range from 0.5 to 1 represent optimistic decision strategies, while the values less than 0.5 represent pessimism decision strategies. If ORness = 0.5, then a decision maker is indifferent towards risk or risk neutral. Thus, OWA can accommodate varying degrees of optimism (and pessimism) on the part of the decision maker (Yager, 1988; Jiang and Eastman, 2000). Alternatively, OWA can be characterized by the measure of dispersion. Using the Shannon's measure of entropy, the normalized dispersion is defined as equation 3 (Malczewski, 2006):

$$\omega = -\sum_{j=1}^n \frac{v_j \ln v_j}{\ln n} \quad (3)$$

The values of the measure range from 0.0 to 1.0. The greater the equality among the weights, the greater is the dispersion. The measure can be interpreted as the degree to which the OWA operators use the information contained in the n criterion maps (Malczewski et al, 2003). The more dispersed the order weights, the more information contained in the maps is being used in the process of combining the criterion maps. O'Hagan (1990) suggests that the approach for determining the order weights should be related to the degree of ORness and the measure of dispersion (entropy). Accordingly, the set of order weights is obtained by solving the following nonlinear mathematical programming problem (equations 4 and 5):

Maximize ω ,

$$\text{Subject to: } \sum_{j=1}^n \frac{n-j}{n-1} v_j = \alpha, \sum_{j=1}^n v_j = 1, 0 \leq v_j \leq 1, \text{ for } j=1, 2, \dots, n. \quad (5)$$

A solution to the problems (4)–(5) determines the maximum degree of dispersion (and trade-off) for a given degree of ORness (the α parameter) (Malczewski, 2006).

RESULTS & DISCUSSION

The aim of the OWA combination procedure is to identify and priorities areas in the 33 and 34 watersheds for Ecological Capability Assessment. In this research

implemented five decision strategies. Each strategy is associated with a given value of α and the connection of between tradeoff and Risk (Fig. 4: Decision Strategy Space). OWA will give us control over the position of the MCE along both the risk and tradeoff axes. That is, it will let us control the level of risk we wish to assume in our MCE, and the degree to which factor weights (tradeoff weights) will influence the final suitability map. These scenarios include:

Scenario 1: In this scenario, full weight gives to the last rank-order (the maximum suitability score across all factors for each pixel), results will closely resemble the OR operation in MCE. The order weights that use for OR operation would be the Table 2. In addition, such a weighting would result in no tradeoff and high risk (Fig. 6).

Scenario 2: In this scenario, these order weights specify an operation midway between the extreme of AND and the average risk position of WLC. In addition, these order weights set the level of tradeoff to be midway between the no tradeoff situation of the AND operation and the full tradeoff situation of WLC (Fig. 7).

Scenario 3: In this scenario, level of risk is exactly between AND and OR and level of tradeoff is full, then after the example of Table 2 would specify the following order weights. In here, weight is distributed or dispersed evenly among all factors regardless of their rank-order position from minimum to maximum for any given location. This scenario resembles the WLC method (Fig 8).

Scenario 4: In this scenario, for example, watersheds managers may be interested in a conservative or low-risk solution for identifying suitable areas for watersheds Ecological Capability Assessment. However, they also know that their estimates for how different factors should trade off with each other are also important and should be considered. They will then want to develop a set of order weights that would give them some amount of tradeoff but would maintain a level of low risk in the solution. There are several sets of order weights that could be used to achieve this. For low risk, the weight should be skewed to the minimum end. For some tradeoff, weights should be distributed through all ranks. The set of order weights at Table 2 and the result of this scenario were showed in Fig. 9.

Scenario 5: In this scenario, full weight gives to the first rank-order (the minimum suitability score across all factors for each pixel), results will closely resemble the AND operation in Boolean MCE. In here, the factor with the minimum value gets full weighting. The order weights that use for AND operation would be the following table. In addition, such a weighting would result in no tradeoff and low risk (Fig. 10).

Table 2. The order weights for selected values of parameter α and various scenarios

α	0.0	0.1	0.5	0.9	1.0
Decision Strategy Space	Scenario 1 High level of risk-No tradeoff	Scenario 2 High level of risk-Some tradeoff	Scenario 3 Average level of risk-Full tradeoff	Scenario 4 Low level of risk-Some tradeoff	Scenario 5 Low level of risk-No tradeoff
Order weights					
1st	0	0	0.05	0.30	1
2nd	0	0.001	0.05	0.097	0
3rd	0	0.002	0.05	0.075	0
4th	0	0.005	0.05	0.070	0
5th	0	0.010	0.05	0.065	0
6th	0	0.015	0.05	0.060	0
7th	0	0.020	0.05	0.055	0
8th	0	0.025	0.05	0.050	0
9th	0	0.030	0.05	0.045	0
10th	0	0.035	0.05	0.040	0
11th	0	0.040	0.05	0.035	0
12th	0	0.045	0.05	0.030	0
13th	0	0.050	0.05	0.025	0
14th	0	0.055	0.05	0.020	0
15th	0	0.060	0.05	0.015	0
16th	0	0.065	0.05	0.010	0
17th	0	0.070	0.05	0.005	0
18th	0	0.075	0.05	0.002	0
19th	0	0.097	0.05	0.001	0
20th	1	0.30	0.05	0	0
Σ	1.0	1.0	1.0	1.0	1.0

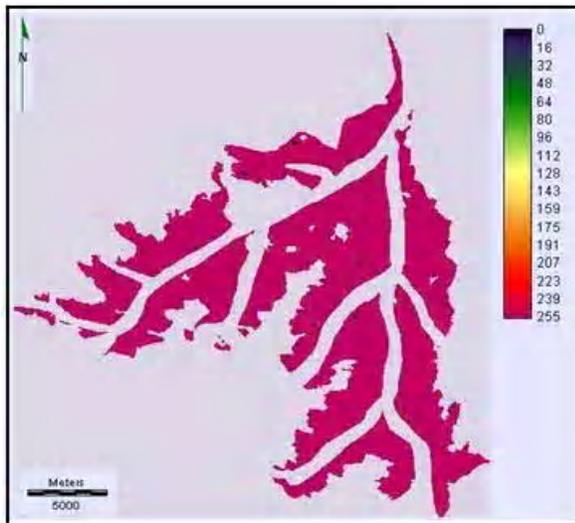


Fig. 6. The map of implementation of the scenario 1

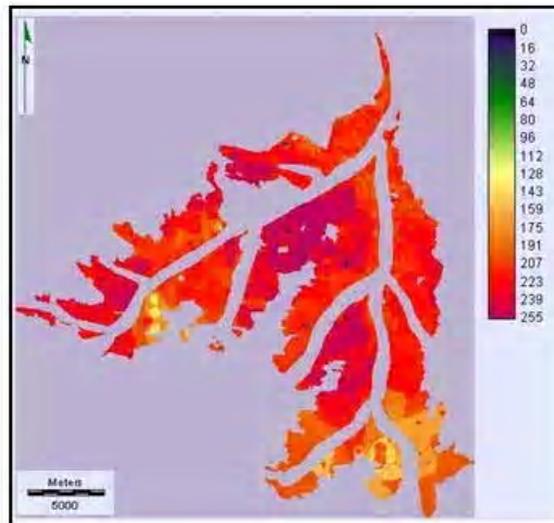


Fig. 7. The map of implementation of the scenario 2

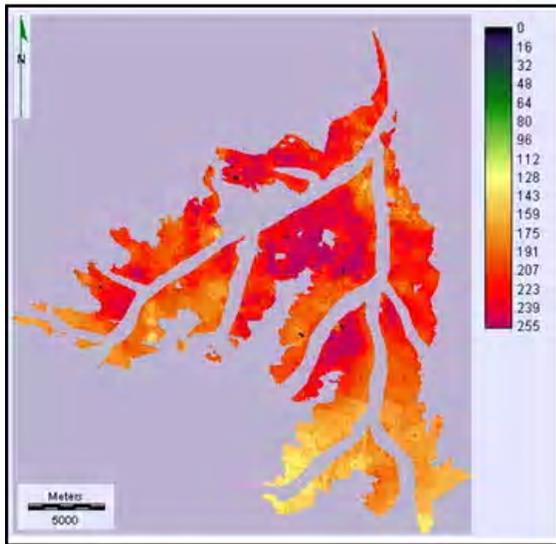


Fig. 8. The map of implementation of the scenario 3

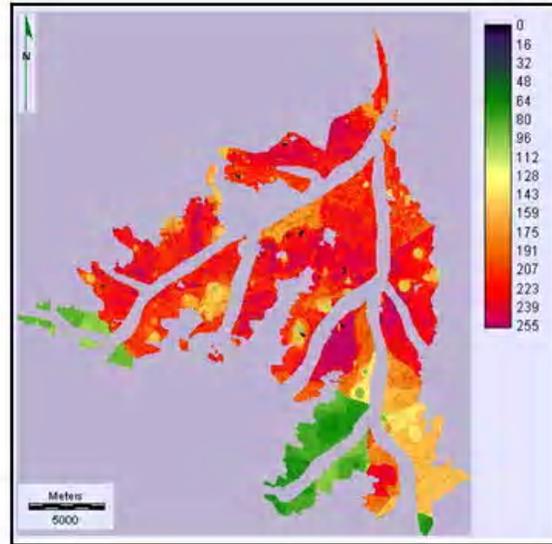


Fig. 9. The map of implementation of the scenario 4

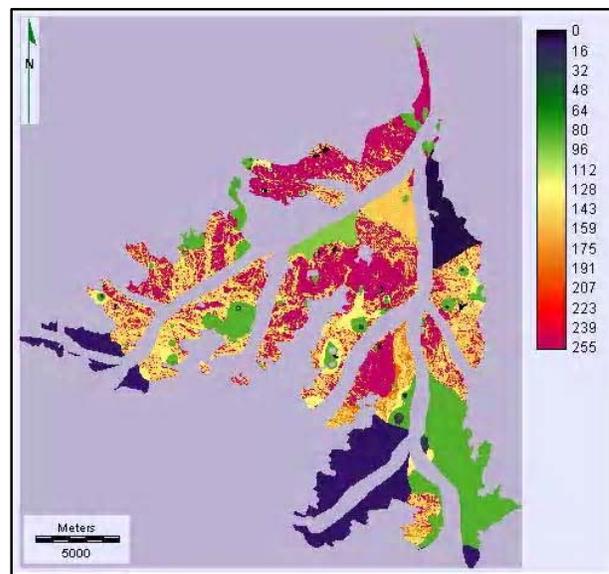


Fig. 10. The map of implementation of the scenario 5

CONCLUSION

GIS Fuzzy Modeling (GISFM) is a new approach based on interfacing Fuzzy and crisp modeling with GIS. It is an appropriate methodology to support location choice and land suitability assessment. The result has demonstrated the advantages of GISFM. Thus by use of Fuzzy models, it possible to describe both subjective (knowledge-driven) and deterministic (data-driven) information. Also GISFM is an effective tool for evaluation of the quality of attribute database. This paper focused on an implementation of the parameterized-OWA approach as a platform for

integrating multicriteria decision analysis and GIS. The approach has been implemented as a core of GIS-MCDA support system in the ArcGIS9.3 and IDRISI15.01 environment. In MCE and GIS was used to combine physical and biological factors for land evaluation and multicriteria evaluation. The system has a range of multicriteria evaluation capabilities including criterion standardization, criterion weighting and the OWA procedures. It has been shown that the OWA concept is an extension and generalization of the conventional GIS operations such as the weighted linear combination and the Boolean overlay analysis. In

this research, for assessing the ecological capability of watershed, after the implementation of mentioned five scenarios in the study area and so prepared of slightly maps and surveyed of field, these findings can emphasize the third scenario is more consistent with nature. Therefore, this scenario was proposed as a better scenario.

The parameterized-OWA approach allows decision makers to explore different decision strategies based on their attitudes between risk and trade-off. The analysis of the methods has allowed us to draw several conclusions for the implementation of an ecological capability evaluation of watersheds in:

1. The watersheds land evaluation method must consider all the ecological parameters.
2. The watersheds land evaluation system should comprise not only the analysis of physical factors but also the biological factors.
3. Multi-criteria evaluation techniques also provide continuous land suitability maps and allow the consideration of socioeconomic factors.
4. The multi-criteria evaluation integrated in GIS has been successfully applied in many situations for optimal land use allocation and it is easily implemented, the application of integer linear programming models is less common and computing time demanding.
5. The flexibility of spatial simulation models and expert systems allows them to be applied to diverse conditions and problems, but complex development is demanded for them to be adapted to a specific region where there are not any previous experiences in this type of models, like 33 and 34 watersheds.

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