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Ecological Capability Evaluation to Determine Suitable Areas for Agriculture Using Fuzzy Logic and AHP Technique in GIS (Case study, Divandarreh city)

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ABSTRACT

Research and study about the possibility of human activity that science of land use is associated with providence development of human society, in currently condition less or more considered in the land use planning's of various countries and to all aspects of human activity in space gives shape till get rid of deadly consequences of unrestrainedly. Environmental ecological capability evaluation is an intermediate step of land use process or planning of environment. In fact evaluation capability provide basic data for second phase of land use, which includes selecting the most appropriate use of land and management system. This study have conducted to assess the environmental capability to determine of agricultural land use. The method used in this study, is one of the latest methods of capability evaluation that consist the following steps: 1-Identify the sources 2-analyzing and calculating 3-evaluation of environmental capability. Identified resources for capability evaluation consist physical (in here climate, soil, elevation, aspect, slope,) and biological (in here vegetation) resources that collectively constitute ecological resources. Then become fuzzy the reclassified maps of soil, climate and vegetation with raster maps of elevation, slope and aspect. Next, according to experts opinion, all parameters were weighting in Expert Choice software that incompatibility rate was 0.09 which is desirable. Then, by multiplying the values each parameter which obtained from AHP in there fuzzy layers resulting layers (maps) are weighted. Then Using overlapping layers using three operations AND, OR and GAMMA show different final results. And this is through their different applications that in fuzzy AND minimum membership is considered that in fact gives the subscription different levels of fuzzy. In OR logic consider the maximum amount fuzzy membership between different layers, that see fit about 90% of the region for the specified land use which is illogical. And GAMMA function depending on the gamma factor (Which in one of the maps is 0.1 and another is 0.9) gives us the different amount. The comparison of overlays shows that Fuzzy AND more appropriate composition is presented for evaluation the potential capability for agriculture in this study. Also survey of another studies and field survey in region show that the result of AND logic is logical quickly. Thus, in this study, been sought a model of ecological agriculture with attitude to all ecological factor in the Divandarreh city as the unit of planning and evaluation of capability. In this regard, study and preparation physical and biological factors was performed. Then using of GIS and FAHP method the evaluation of ecological capability for study area was implemented. As regards, Iran agricultural model change according to areas for evaluation, thus parameters used were calibrated according to the study area, and the results showed that all areas of the Divandarreh city cannot be used for agriculture and even in some places which haven't power for agriculture or have very weak power, unfortunately it is currently used for agriculture.

KEY WORDS
Fuzzy, AHP, capability evaluation, agriculture, Divandarreh

INTRODUCTION

Research and study about the possibility of human activity that science of land use is associated with providence development of human society, in currently condition less or more considered in the land use planning's of various countries and to all aspects of human activity in space gives shape till get rid of deadly consequences of unrestrainedly [27]. Environmental ecological capability evaluation is an intermediate step of land use process or planning of environment. In fact evaluation capability provide basic data for second phase of land use, which includes selecting the most appropriate use of land and management system [23]. Agricultural means ways and manner for optimal utilization of resources soil, water, energy and intellectual and physical power human for arrive to basic and essential needs to effective and maker interaction with nature [29]. Already is going more than three decades of international attention to environmental protection and about two decades of issues surrounding sustainable development. Before this time, in all development projects was considered purely economic view and create revenue and economic efficiency. But in 1970 A.D decade develop and propose this perception in the minds of policy makers and planners that these economic growth lead to environmental degradation, social inequality, and resource depletion and... , and remedy of this problem lead to enormous economic losses in the long term [29]. Agriculture is the oldest active in the world, yet more than half the people world live in the fields. Because food production and distribution change the environment and as well as because these activities, environmental effects of agriculture is inevitable that these effects can be positive and negative [34]. On the other hand, today awareness and knowledge underpin almost all of the foundations of daily life; so that mankind activities as an essential element human action effect on the health and quality of his daily life and is driving force of global change, is strongly influenced by the knowledge [35]. Determine the capability potential and allocation land use proportional to the capability, is a method that can between natural capability, communities need and land use of human activities in space create a logical connection and a stable consistency. There is no doubt that achieving sustainable development, requires the implementation of development plans and exploitation of natural resources based on potential resources and tolerable capacity. Ecological capability evaluation is the intermediate step process of land use planning and the most time-consuming and the most difficult stage of land use preparation [3]. In this regard, Geographic Information System (GIS) as an efficient tool in environmental planning; done store, manage, and analyze spatial data and non-space [8]. In the other hand, the weighting system is strong quantitative and qualitative decision criteria [31,9] which is very useful in land assessment [1].

On the environmental assessment for agriculture, a few studies are available that a number of them are include: In a study titled "Modeling the ecological agriculture and range management from the land use perspective using Fuzzy AHP in GIS" is done for the city Marvdasht in Shiraz. This research aims to better implementation of the ecological model Dr. makhdoum in which to the parameters is given relative weights and importance based on fuzzy analytic hierarchy process (Fuzzy AHP) in GIS information system. And in this way, prone areas to agricultural activities within the scope of the township study and their agriculture utility has identified that has shown each of the seven categories of agricultural model are in the region [24]. In another study that for agriculture and entitled "Assessment of the ecological capability to determine suitable areas for agriculture using GIS (central zone of kyar township)" is performed. To peruse and assessment capability environment for agriculture potential is conducted. Which used from systematical analyze method and identify sources, analyze, zoning, and environment capability evaluation be carried out in several stages. Which ultimately with derive environmental unit and assessment them with ecological model, the suitable areas for agriculture has been found [26]. In another study entitled "evaluation of land ecological proportion through ecological capability model in Ardebil province with aims land use planning has been performed", have attempted a comparison between existing land use and ecological be done which land use maps derived from satellite imagery and ecological assessment be done through the Makhduom model using GIS, the obtained results show that in dry land farming areas, the current account is in conflict with the ecological capability [12]. In another research which to capability evaluation and land use planning with title "comprehensive land use planning in urban watershed catchment using GIS - case study Mahidasht- " is discussed, primarily with use of GIS the maps overlay until providing units assessment capability and management land use, then for this environmental units or small ecosystems also capability evaluation for land use agriculture, grazing, forestry, aquaculture, tourism, urban development and the protection done. In the end check the land use planning and priorities between land uses by qualitative analogy between ecological capability, was produced the map of land use planning of Mahidasht watershed catchment [4]. In another article, entitled "Multi-criteria assessment of land suitability for agriculture using GIS, case study in Qazvin" assessment of ecological capability for agriculture land in the rural of Qazvin city has been done with Makhdoom ecological model using GIS. Then this results, were compared with the results from the evaluation with combined technique process analytic hierarchy process (AHP) and geographic information system (GIS). That AHP method combines the process of ecological and socio-economic characteristics that hasn't succeed in ecological assessment and the two model show many different to evaluate the agriculture [13]. In research entitled "Environmental Assessment for

agriculture with GIS" was conducted in 2005 for Hamedan province the first Makhdoom model was introduced, then from the point of view of the agriculture to characteristics and capabilities of land for agriculture and pasture were examined, capabilities are divided into nine classes according to the results, the amount of agricultural land is wet, dry farmland and pastures were identified. Evaluations showed that the study area is limited potential for agriculture [30]. Land should be according to the general agricultural productivity without damage in the long time is classified. In this study in Indonesia titled "assessment of the land for agricultural use in the upstream catchment Jeneberang" land capability classification system using the USDA done that basin is classified into 8 classes, ultimately classes 1 through 4 is suitable for each land use with condition of good management and classes 5, 6 and 7 for pasture, native coverage and native tree planting is appropriate. It should be noted that each class have limited [32].

MATERIALS AND METHODS

2.1 Study area:

Divandarreh city is located between circuit 35° 34´ and 36° 31´ east, and, 46° 31´ to 47° 29´ north in zone 38S in the Kurdistan province of Iran country. Which is boarder from view political division from south to sanandaj city, from north to Tekab city, from east with Bijar city, from west to Marivan city and from northwest to Saqqez city. The minimum height of sea level is 1646 meters and the maximum is 3160 meters, that have several different climate which average rainfall in thirty years ago about have been 400 millimeter and the average temperature have been about 7.7 ° C with 135 days of frost in the year. This city is about 100 km away from the province center (Sanandaj city), and with area about 4203 square kilometers about cover 15% of the province area, and is one of the main poles of agriculture in province, for this reason, the main occupation of people is depend on agriculture and livestock grazing. (Statistical Center of Iran, 2012) (Figure 1)
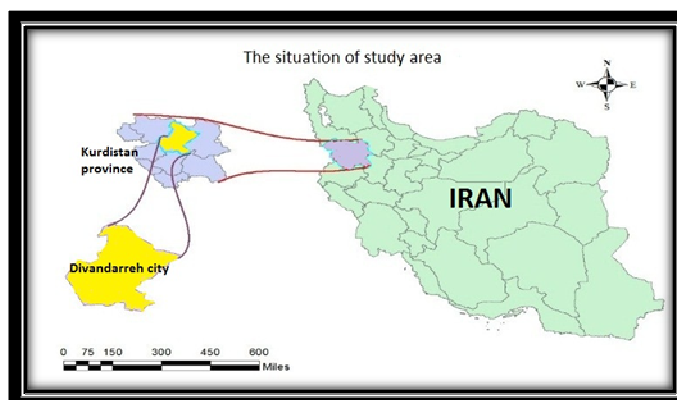

Fig. 1: the study area

2.2 Method:

Undoubtedly for capability evaluation and calculate its suitability for different types of land uses, there are various methods. The first and simplest method is holistic and status. Another scientific method more accurate, is the analysis of one or more operating parameters [36]. The method used in this study, is one of the latest methods of capability evaluation that consist the following steps: 1-Identify the sources 2-analyzing and calculating 3-evaluation of environmental capability

Identify the resources for capability evaluation consist of physical and ecological resources that collectively constitute ecological resources. Parameters of each of the resources depending on the phase and scale maps used may be vary. To evaluate the agricultural potential which is based on model of agriculture and range management, the following factors are considered: the soil, land units (elevation, aspect, slope), Land cover (vegetation), climate and wildlife [21] (diagram 1) that for this research the map all of these parameters were analyzed except wildlife (because it do have map at all).
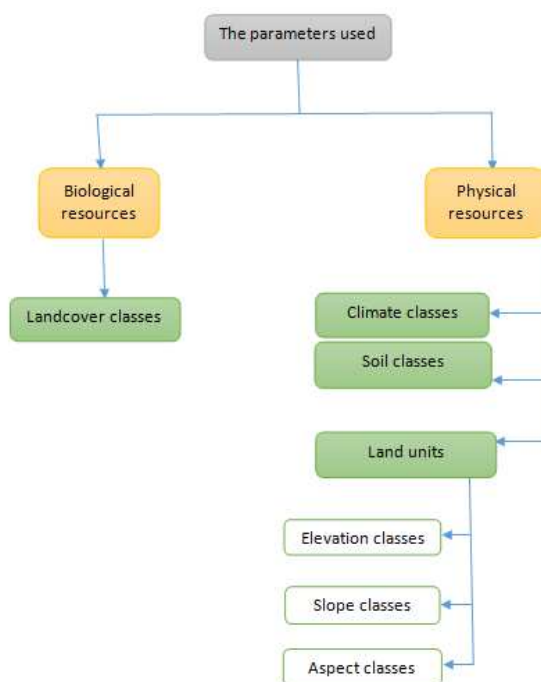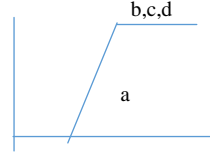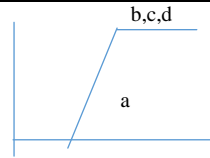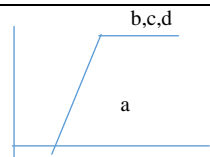
The parameters used in this study (diagram 1):

Diagram 1: parameters used in this study

2.2.1. Map standardizing with fuzzy logic:

Fuzzy logic is capable many of meanings, values and systems that are imprecise and ambiguous given mathematical formulation and provide grounds for argument, control and decision making under uncertainty [28]. In fuzzy logic, each region according to the value that desired criteria earn, get membership that represent the degree of acceptance of that area. This means that each area, with a membership value upper is higher desirable. In fuzzy logic, there is no certainty in Boolean logic and each layer is graded on a scale from zero till one [20]. And since the land capability for any particular land use especially for agriculture is vary at each location and follow a certain range. Therefore, can show these changes with function fuzzy better than any other function. So here use of fuzzy logic to determine the land use capability which include value between zero and one. Then, according to need the map of soil, climate and vegetation standardized (be Reclassify) and then be fuzzy, but the elevation map, aspect and slope due to the continuous raster without the need for standardization be fuzzy (be Reclassify). From functions fuzzy can named functions: Linear, Sigmoidal and etc. In addition to these functions, the user can according to their needs, defining the new function [17]. Here according to the requirement the fuzzy function for each parameter come in the table below (Table1).

Table 1: fuzzy function for each parameter

Function shape	Function formula	Fuzzy function type	Parameters
a,b,c d	$\alpha=(x\text{-point c})/(\text{point d} - \text{point c})*pi/2$	Linear decrease	Elevation
a,b,c d	$\alpha=(x\text{-point c})/(\text{point d} - \text{point c})*pi/2$	Linear decrease	Aspect
a,b,c d	$\alpha=(x\text{-point c})/(\text{point d} - \text{point c})*pi/2$	Linear decrease	Slope

b,c,d a	α=(1-(x-point a)/(point b – point a))*pi/2	Linear increase	Climate
b,c,d a	α=(1-(x-point a)/(point b – point a))*pi/2	Linear increase	Soil
b,c,d a	α=(1-(x-point a)/(point b – point a))*pi/2	Linear increase	Land cover

2.2.2. Fuzzy modeling approach:

Fuzzy set theory is the body of concepts and techniques that are a systematic framework for dealing with ambiguity and inherent imprecision in the process use of thoughts and knowledge of mankind [11]. In this method, all factors are combined in a single step and targeted pattern of modulation maps can be used. The idea of fuzzy logic, spatial objects on the map consider as members of a group. Membership in the fuzzy set theory can take any value between 0 and 1 which reflects a certain degree of membership and there is no practical limit in the choice of the fuzzy membership values [14]. In the fuzzy functions with values 0 and 1, the value of 0.5 is considered as the midpoint or inflection point; each value higher than it have this mean that more likely belongs to fuzzy set and lower value than it have means less likely belongs to of fuzzy sets [16].
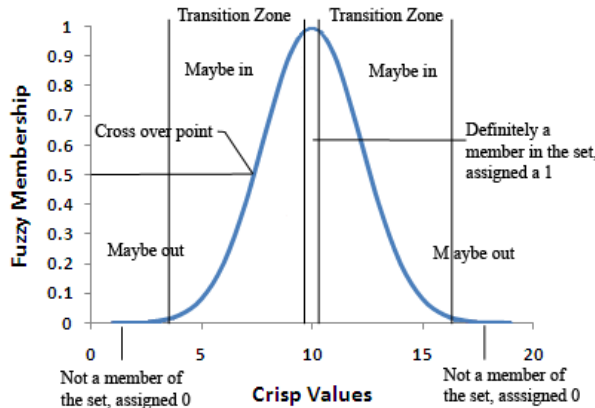

Diagram. 2: Fuzzy membership function diagram(Dombi, 1990)

Fuzzy operators used in this research that for overlay and combine data in ArcGIS used; include: Fuzzy AND, OR and GAMMA that as follows:

1. Subscribe fuzzy operator (Fuzzy AND): The effect of this operation is that map output by the smallest value of fuzzy membership at every position that occur, controlled.

2. Collection fuzzy operator (Fuzzy OR): influence of this operator it is that output maps by the highest fuzzy membership values at each position occur, shows.

3. Gamma fuzzy operator (Fuzzy GAMMA): This function combines algebraic sum and product [6].

These functions are listed in the table below with their formula (Table 2):

Table 2: fuzzy function and its furmula

Function	formula
AND	μcombination =MIN (μA ,μB ,...)
OR	μcombination =MAX(μA ,μB ,...)
GAMMA	μcombination =(FuzzySum)$^\gamma$ ×(FuzzyProduct) $^{1-\gamma}$ γÎ[0,1]

(Refrence: Malczewski, 1999)

2.2.3. AHP method:

The Analytic Hierarchy Process (AHP) who built by Thomas saaty, is one of the most comprehensive systems for designing and decision making with multiple criteria, because it possible to formulate the problem to hierarchical manner, and have possible considering the criteria of quantitative and qualitative in the problem and various options in decision-making, and it is possible analysis sensitivity on criteria and sub criteria [10]. AHP (Analytical Hierarchy Process) is the same hierarchical analysis process that in it one simple method of calculation based on main operations of matrix which by creation suitable hierarchy and processing step to step and making and manufacturing adaptive matrix in different levels of hierarchy, compute special amount and in final weight vector of coefficients, given the relative importance of each item to the top goal of the hierarchy determined. And as one of the most popular techniques decision-making multiple for complex situations where have multiple and conflicting measures, is the flexible and yet powerful tool for decision-making [25]. This process that is based on paired comparisons can intervene various option in the decision-making and also possible analysis on criteria and sub criteria. The advantage of this method is to calculate the rate of consistency and in consistency [10]. After determining the relative importance of each criteria, shouldn't consistency rate be (Consistency ratio; CR) more than 0/1 [10]. At this stage, give value to each of the parameters according to experts view of natural resource, later this value locate in software Expert Choice that the value of each parameter come in down table. In addition, the coefficient inconsistency is 0.09 that show accuracy of the work (diagram 2).
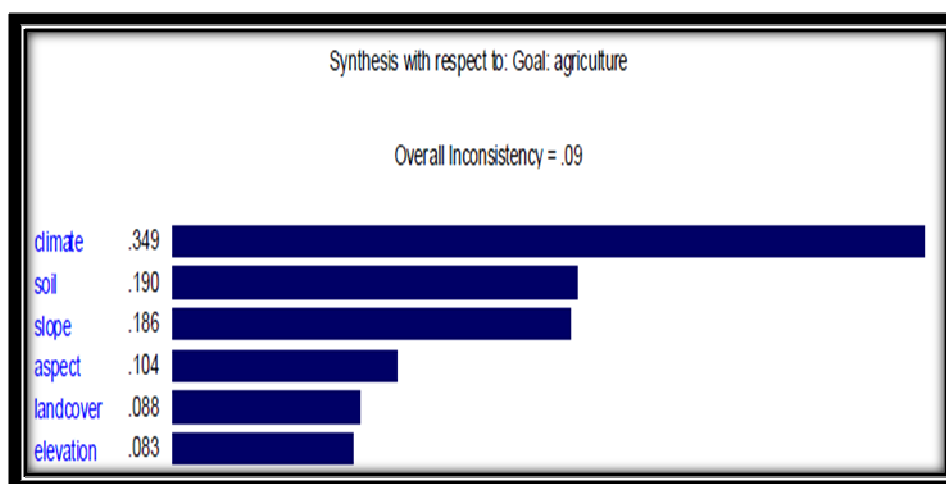

Diagram 2: Parameters value in Expert Choice software by AHP

2.2.4. Fuzzy AHP (FAHP) method:

Uncertainty in preference judgments, increases uncertainty in alternatives prioritize and equally, makes difficult determination priorities (logical stability) agreement [19]. FAHP to avoid of this hazard function was developed until solve problems in hierarchical equivocal [11]. Some research insist on the use of fuzzy logic in AHP to more accordance with the fact [15]. The theory of fuzzy sets, is a designed mathematical theory for model ambiguities processes related to human knowledge [20]. Decision maker can freely select the range of desired values. Expert uncertain judgment can be expressed by fuzzy number [34]. Therefore, FAHP uses range of values for the expression of uncertainty of decision-makers [18]. With combining methods of AHP and Fuzzy addition to considering the advantages of both methods, such as provide a structure, understandable, multi criteria decision or a set of quantitative and qualitative data, existence hierarchical structure and Intelligible can resolve disadvantages [33]. As well to overcome these problems, researchers have used for integration of theory Fuzzy and AHP to improve the uncertainty [23].

In this phase of the work for weighted down fuzzy layer each of the parameters, each of these layers was multiplied in their special amount using Arcgis 9.3 which their amount had obtained from AHP method. Finally obtain maps layer were weighted, which this weighted map come in down (fig 2-7):
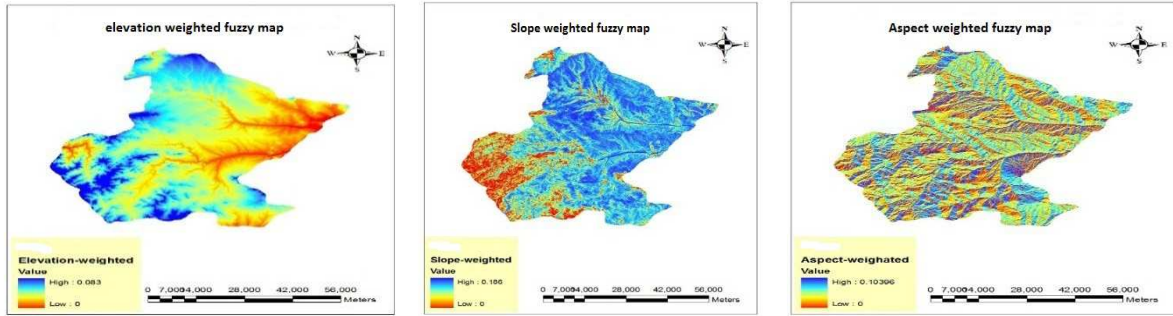
Fig. 2: Elevation weighted fuzzy map **Fig 3:** Slope weighted fuzzy map   **Fig. 4:** Aspect weighted fuzzy map
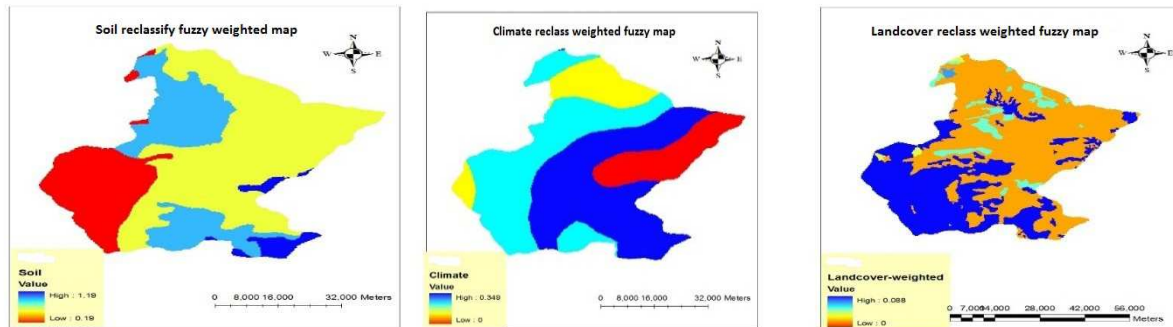

Fig. 5: Soil reclassify fuzzy weighted map **Fig. 6:** Climate reclassify fuzzy **Fig. 7:** land cover reclassify fuzzy
weighted map   weighted map

Results:

In here Geographic Information System (GIS) provides possible the use of geographic information for assist to policy-makers and decision-makers for solving problems, although this system is not an automated decision making system, but is the tool for the search, offering analysis and production map [5].

Then in here using this system (mean GIS) and using three logic AND, OR and GAMMA map overlay that it results come in four maps in below:
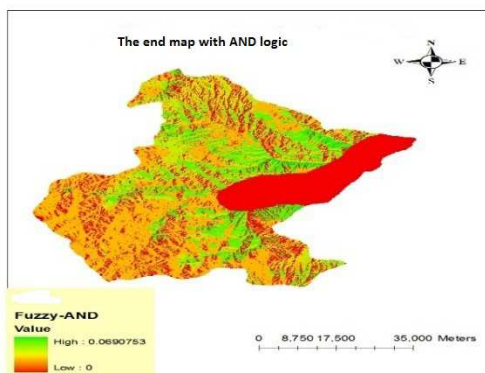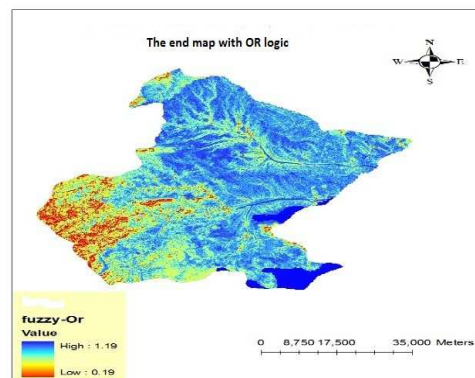

Fig. 8: The end map with AND logics   **Fig. 9:** The end map with OR logics
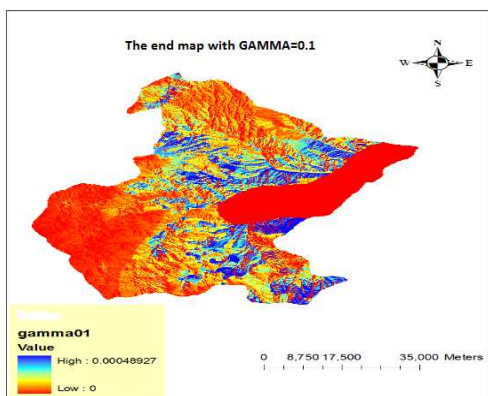

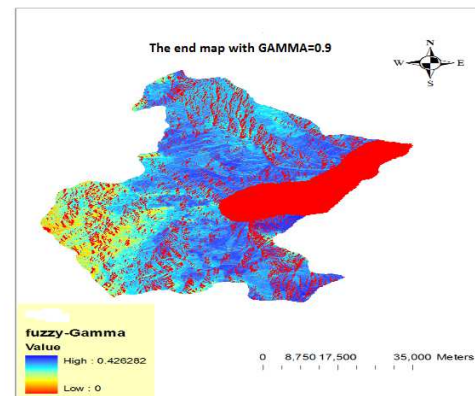**Fig. 10:** The end map with GAMMA=0.1   **Fig. 11:** The end map with GAMMA=0.9

Discussion:

The earth basically have different abilities to support from a particular land use. It is necessary to determine the ability of a region the land capability and ability classification should done. Land capability classification, valuation of land with regular components and packing group into categories based on the nature that potential and limitations of use from it is a stable and appropriate [2].

Evaluation of land ecological capability, is the intermediate step process of land use planning. This stage, is the most important stage of identifying the most appropriate practices in area the land. Efficient and accurate use from available capability evaluation techniques in the world, especially with the Semi-automatic software ArcGis and with weighting parameters used is not cover for anybody and in all cases of capability evaluation can be used. In this research, ecological capability evaluation for agriculture land use with a holistic approach to all important and effective parameters biophysical (biological and physical) within the scope of management as the unit of planning and management of land be performed. Then were investigated to processing and combining data from three different fuzzy logic AND, OR and GAMMA. Then maps of weighted fuzzy; elevation, slope, aspect, soil, climate and land cover (vegetation) using the three fuzzy function were overlaid, that overlay of these layers using three fuzzy operators AND, OR and GAMMA show different results. And this is because their different applications, that in fuzzy AND (fig8) minimum membership is considered that in fact gives the subscription different levels of fuzzy. In OR (fig9) logic consider the maximum amount fuzzy membership between different layers, that see fit about 90% of the region for the specified land use which is illogical. And GAMMA function depending on the gamma factor (Which in one of the maps is 0.1(fig10) and another is 0.9 (fig11)) gives us the different amount. The comparison of overlays shows that Fuzzy AND more appropriate composition is presented for evaluation the potential capability for agriculture in this study. Also survey of another studies and field survey in region show that the result of AND logic is logical quickly. As can be seen in the eastern part of the study area due to the dry climate have the minimum value for agricultural. Another factor that reduces the power required for use in the western region is the abundance slope. It should be noted that the greatest potential for agriculture is almost in the middle part of the study area.

Conclusion:

Achieve to development especially for agricultural sustainable development requires knowledge of environmental resources and the environmental capability evaluation and detailed planning and implementation is essential. Divandarreh city is as one of the important cities of the Kurdistan province in agriculture and range management (and subsequent it livestock) which requires to environmental capability evaluation for agricultural and range management; so we decided to do this work for this city. Since proper planning and management principles in natural resources, based on the recognition of talent and ecological capability the natural ecosystems. Awareness of these resources and determination of potential mentioned resources can prevent crises dependent on agriculture. Which in this status we encounter with a continuous production of agricultural products and sustainable economy. And also will prevent from soil erosion, destruction of resources and another activities which is dependent on agriculture. Thus, in this study, been sought a model of ecological agriculture with attitude to all ecological factor in the Divandarreh city as the unit of planning and evaluation of capability. In this regard, study and preparation physical and biological factors was performed. Then using of GIS and FAHP method the evaluation of ecological capability for study area was implemented. As regards, Iran agricultural model change according to areas for evaluation, thus parameters used were calibrated according to the study area, and the results showed that all areas of the Divandarreh city cannot be used for agriculture and even in some places which haven't power for agriculture or have very weak power, unfortunately it is currently used for agriculture.

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