Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252023v36n119rc

A New Spatial Model for Ecological Suitability Assessment of Irrigated Farming in Jahrom County, Iran

Um novo modelo espacial para avaliação de adequação ecológica da agricultura irrigada no condado de Jahrom, Irã

Parviz Jokar[1], Masoud Masoudi[1]* Biswajeet Pradhan[2]

[1]Department of Natural Resources and Environmental Engineering, School of Agriculture, Shiraz University, Shiraz, Iran. [2]Centre for Advanced Modelling and Geospatial Information Systems, School of Civil and Environmental Engineering, University of Technology Sydney, Sydney, Australia.

ABSTRACT - Agricultural suitability assessment is a process that requires spatial data, geo-information tools, and the expertise of a computer scientist to analyze the information. The main objective of this paper is to propose a new model (based on Iranian ecological model and Food and Agriculture Organization (FAO) model) for ecological suitability evaluation with geometric mean evaluation and calibration methods for better planning management of irrigated lands. Next, to verify and compare the proposed method with other well-known existing, methods such as, Boolean logic and MCE (WLC) models were used. For testing these models, normalized difference vegetation index (NDVI) was used. Findings of this research showed that the proposed model by geo-mean and calibration (kappa=0.79) is the best among used methods. On the contrary, arithmetic mean method showed the lowest accuracy (kappa=0). So, these methods (geometric mean evaluation and calibration) have high flexibility in locating agricultural lands. Overall, this study can be used as a basic framework to evaluate ecological suitability for other regions with similar conditions because of its simplicity and high precision.

Keywords: Evaluation. Agriculture. Boolean. Geo-mean. GIS.

RESUMO - A avaliação da adequação agrícola é um processo que requer dados espaciais, ferramentas de geo informação e a expertise de um cientista da computação para analisar as informações. O principal objetivo deste artigo é propor um novo modelo (baseado no modelo ecológico iraniano e no modelo da Organização das Nações Unidas para Agricultura e Alimentação (FAO)) para avaliação da adequação ecológica com métodos geométricos de avaliação média e calibração para uma melhor gestão do planejamento das terras irrigadas. Em seguida, para verificar e comparar o método proposto com outros métodos já conhecidos existentes, foram utilizados métodos como, lógica booleana e modelos MCE (WLC). Para o teste desses modelos, foi utilizado o índice de vegetação de diferença normalizada (NDVI). Os achados desta pesquisa mostraram que o modelo proposto por geo-média e calibração (kappa=0,79) é o melhor entre os métodos utilizados. Pelo contrário, o método médio aritmético mostrou a menor precisão (kappa=0). Assim, esses métodos (avaliação e calibração média geométrica) têm alta flexibilidade na localização de terras agrícolas. No geral, este estudo pode ser utilizado como um quadro básico para avaliar a adequação ecológica para outras regiões com condições semelhantes devido à sua simplicidade e alta precisão.

Palavras-Chave: Avaliação. Agricultura. Booleano. Geo-média. GIS.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

Received for publication in: May 26, 2022.
Accepted in: October 6, 2022.

***Corresponding author:**
<masoudi@shirazu.ac.ir>

INTRODUCTION

From the beginning of the civilization, human beings have used land resources to satisfy their needs. So, agriculture is the first occupation of the civilized man. Nowadays agriculture has become one of the good professions which has given the name as commercial agriculture, precision agriculture, etc. and sustainable agriculture as being the part of it (FAO, 1976; ALAVI PANAH et al., 2001).

Iran is often located in arid and semi-arid regions and this issue exacerbates land vulnerability. Achieving the optimal level of food and food security requires the use of optimal methods and spatial analysis that can accurately assess the capabilities and potential of the environment for food production now and in the future (MASOUDI, 2014; MASOUDI; ZARE, 2019; SAFARIPOUR; NASERI, 2019).

Therefore, the concept of land suitability evaluation was evolved, because it is very essential to understand land capacity to support appropriate vegetable cultivation (FAO, 1983; PRAKASH, 2003; MU, 2006; PAN; PAN, 2012; FROJA, 2013; MASOUDI; JOKAR, 2015).

The concept of sustainable agriculture involves producing quality products in an environmentally safe, socially acceptable, and economically efficient way, i.e., optimum utilization of the available natural resources for efficient agricultural production (ZONNEVELD, 1989; ROSSITER, 1996; PRAKASH, 2003; NWER, 2006; LEE; YEH, 2009; MARTIN; SAHA, 2009; SONNEVELD et al., 2010; ELSHEIK et al., 2010; KESHAVARZI, et al., 2010; HE et al., 2011; FAO, 2011).

Prerequisite for land use planning is land suitability assessment. Because land suitability assessment is a complex process, multi-criteria assessment (MCE) is one of the spatial analysis methods that can help assess land suitability (LIAO; WU, 2013; SAFARIPOUR; NASERI, 2019; JAHANTIGH; MASOUDI; JOKAR, 2019; MASOUDI et al., 2020). McHarg (1969) showed that land suitability evaluation is an important practice in land use planning. Therefore, choice of proper method of evaluation for planning is very important (O'NEILL, 1989).

Hataminejad et al. (2013) investigated land suitability through an ecological model in Ardabil province with the aim of land use planning. The results obtained in this study showed that in the fields of rainfed and irrigated agriculture, the use of the current situation is contrary to ecological potential, and the continuation of the current trend will have devastating results.

Feng, Zhu and Sun (2014) used the AHP FUZZY method to land suitability analysis of China's coastal recovery. In this research, FUZZY method was used to solve the problem that exists in multi-criteria evaluation and complex design. Results showed that this method had high flexibility in land suitability analysis.

Masel Ullah (2014) investigated urban land-use planning using Geographical Information System (GIS) and Analytical Hierarchy Process (AHP) in the Dhaka city. The research result shows that highly suitable area (13%) should be used for urban residential zone; moderately suitable area (35%) should be designated as mixed-use zone; low suitable iv area (42%) should be reserved for agricultural use and open spaces; and not suitable area (10%) should be protected from any types of activities except agriculture. The research approached an urban land-use planning at a regional scale. The research results were also validated with Detail Area Plan of Dhaka Metropolitan Development Plan package in some order. Such validation concludes that GIS based AHP can be applied successfully for preparing urban land-use planning at the regional level.

Ayalew (2015) conducted a study on land suitability to peanuts and sweet potatoes based on GIS in east Amhara, Ethiopia. The results of this study showed that the largest part of the region is unsuitable for peanut and sweet potato crops. Radan et al. (2017) investigated comparison ability between FAO and Iran ecological models to estimate of capability ecological land for using pasture. Results of this study showed that based on FAO model 5 units have been recognized suitable for pasture from 8-unit land, and remainder is unsuitable. Based on Makhdoom model 238 unit has been in third floor and 71 units have been in fourth floor of pasture.

Nazari Viand et al. (2019) utilized land suitability assessment for agriculture using analytical hierarchy process in Northern Parts of Khalkhal County, Iran. Final potential map classified in 4 potential classes using natural break classification method. Classes with potential category from 1 to 2 (65% of area) were allocated to agriculture class and category from 3 to 4 (35% of area) were allocated to non-agricultural activities. Also, conformity map between current land use map and potential map showed that in 61.8% of area there is a conformity between current land use map and potential categories map for agriculture activity.

Also, nowadays technological advancements in geo-spatial domain have brought ease for decision-makers to utilize land resources (CARVER, 1991; TAYLOR; WOOD; THOMAS, 1997; MAPEDZA; WRIGHT; FAWCETT, 2003; MASOUDI; JOKAR; SADEGHI, 2017). Mitra and Ilangovan (2004) have reported that Geographical Information Systems (GIS) has a very significant role to find the best site. GIS is typically used to store and analyze extensive information in a map-based format (AMARSAIKHAN et al., 2004). Fallah et al. (2009) investigated agricultural suitability in Kasilian watershed by GIS. Their results showed that approximately 30% of lands are appropriate for agriculture. In another paper, Pourkhabbaz, Javanmardi and Faraji Sabokbar (2014) have done suitability assessment of agriculture by using multi-criteria evaluation (MCE) methods such as analytic hierarchical process (AHP) and Serbian name: VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and Simple Additive Weighting (SAW) in Takestan -Qazvin Plain. Their results indicated that the application of MCE could be useful in agricultural evaluation.

As a result, and in contrast to above methodologies, Iranian ecological model (MAKHDOUM, 2006), Boolean logic and geometric mean models have been popularly utilized for agricultural suitability assessment with ecological perspective (ASADIFARD et al., 2019). Although Boolean logic is a simple method, it can be qualitative and strict enough to locate suitable regions for each land-use (JOKAR; MASOUDI, 2016). Geometric mean model as a proposed new method also focused on quantitative and easy evaluation approach because the MCE methods (e.g., AHP, Genetic Algorithm and etc.) are usually difficult to perform by users (ASADIFARD et al., 2019; JOKAR; MASOUDI; KARIMI, 2021). The main goal of this paper was carried out to develop a new proposed method in comparison to Boolean logic, average-based methods (like MCE). This proposed method may have the potential to assess the irrigated land suitability in a simple and systematic way.

MATERIALS AND METHODS

Study Area

Jahrom Township (Figure 1) is situated in southern Iran. It has an area of 5436 km^2 and is located at latitude 28° 19' to 29° 10' N and longitude 52° 45' to 54° and 4' E. The average height is about 1050 m mean seal level. The climate is arid to semi-arid and in mountainous regions is often moderate. The climate of Jahrom city is hot and dry and the average rainfall is about 285 mm per year. The average temperature in this city is about 20 degrees Celsius. The regional crops cultivated in this area are mostly horticultural. For that reason, the proposed methodology is designed based on this particular land-use.

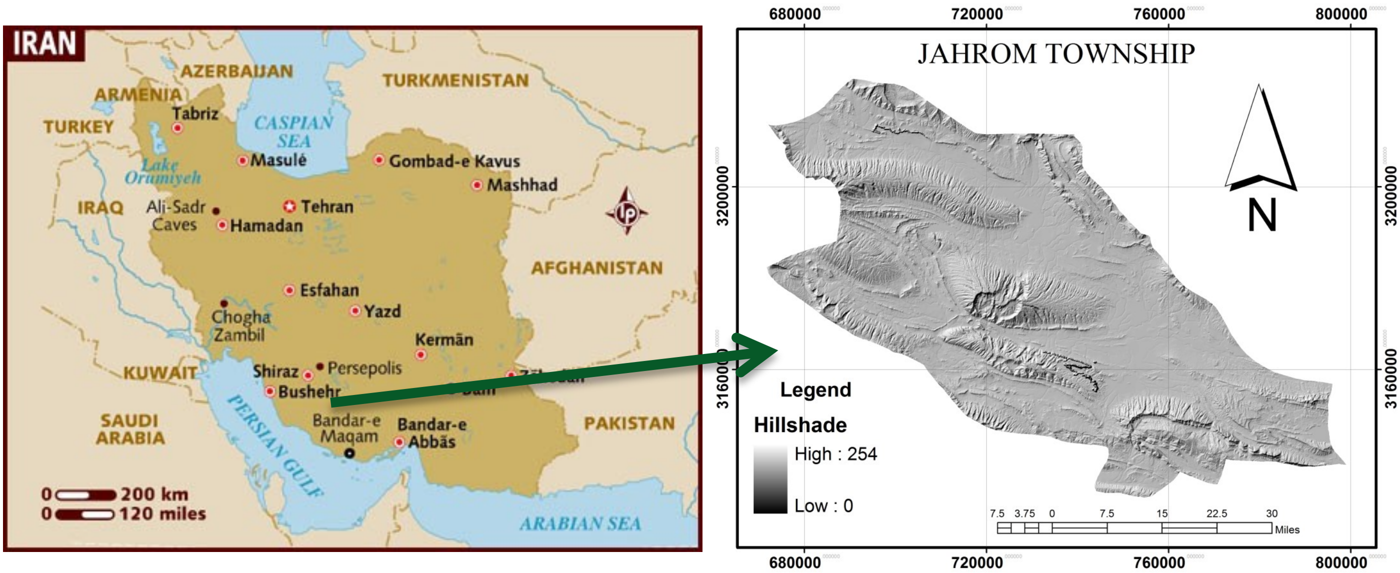

Figure 1. Study area map.

Data

Two types of data were obtained: 1) numerical data, and 2) thematic data, mainly in map format with spatial reference of UTM Zone 39N projection. All data were processed in GIS (Table 1). Land type parameter was extracted from land unit map and slope parameter was derived from the digital elevation model (DEM) map. Current state of climate and drought parameters were extracted from climatology stations of study area. Current state of climate was established based on De Martonne model and drought was produced based on SPI index. Soil map was directly used. Also, the boundaries of maps were modified by global positioning system (GPS) tools based on the field data. Water related data (quantity, decline and salinity) were extracted from regional water organization. It should be noted that NDVI images (from USGS website) and current land-use were used for validation of different suitability maps.

Methodology

The overall methodology comprises of two parts. A) Models description and reclassification of parameters; and B) evaluation and formulating of proposed model based on Boolean logic, MCE (WLC) and geometric mean**.** Figure 2 shows the methodological flowchart of the designed model.

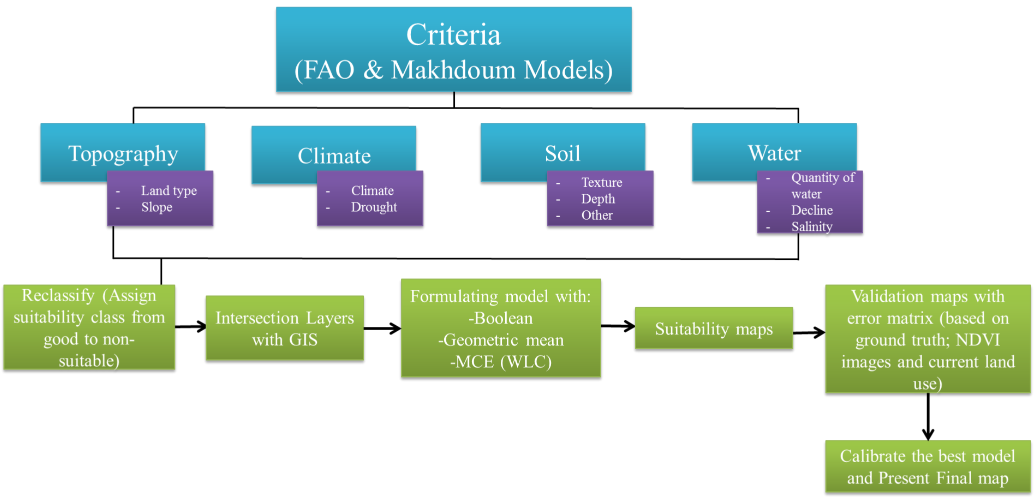

Figure 2. Flowchart showing the methodology adopted for ecological suitability evaluation in this study.

Models description and reclassification of parameters

Iranian evaluation model of ecological suitability for agricultural use (MAKHDOUM, 2006), consists of seven (7) classes. Food and Agriculture Organization (FAO) ecological model (6 classes) is also a classic model. In this research, the above two models were used to propose a new model. Subsequently, model parameters were reclassified to four new classes including suitable (good), moderate, poor and non-suitable (Table 1).

Table 1. Suitability classes of agriculture use in different model.

Iranian ecological model classes	Suitability description	FAO classes	Suitability description	Proposed model (reclassified)	Suitability description
1	Highly Suitable	1	Highly Suitable	1	Suitable
2	Suitable	2	Suitable		
3	Moderate	3	Moderate	2	Moderate
4	Moderate	4	Poor		
5	Poor	5	Poor	3	Poor
6	Poor	6	Non- suitable	4	Non- suitable
7	Non-suitable				

It should be noted that the parameters included in the revised proposed model used both Iranian ecological model and FAO, and is based on geographical and environmental condition of the study area (such as drought, degradation of water resources). Another reason for using two models was based on the choice of suitable order in the parameters and range of classes. Therefore, the proposed models were adjusted based on integration of Iranian ecological model and FAO models (Table 2).

Table 2. The parameters classes for ecological suitability assessment of irrigated farming.

Criteria	Indicators	Class limits and their ratings score			
		Highly suitable (3)	Moderately suitable (2)	Poorly suitable (1)	Not suitable (0)
Topography	Land type	Plain	-	Hill	Mountain
	Slope (%)	0-8	8-15	15-30	>30
Climate	Current state of climate	Semi-arid to wet	Arid	Super arid	-
	Drought	Slight	Moderate	Severe and very severe	-
Soil	Texture	Heavy, moderate, light	Coarse	very coarse	-
	pH	6.1-8.5	4.2-6,8.5-9	9-9.5	>9.5
	Depth	Deep	Semi deep	Shallow	Very shallow to None
	Gravel percent	0-35	35-75	>75	-
	Drainage	Good to moderate	poor	-	-
	Erosion	None, slight	Moderate	Severe	very severe
	Granulating	Fine to Moderate	Coarse	-	-
	Evolution	Perfect	Moderate	Low	None
	Salinity	<8	8-16	16-32	>32
	ESP	<15	15-30	30-50	>50
	Fertility	Good	Moderate	Low to very low	-
Water	Quantity of water (m^3/year/ha)	>3000	1500-3000	<1500	None
	Lowering of water table (cm/year)	None, 0-20	20-30	>30	-
	EC (μmhos/cm)	0-750	750-2250	>2250	-
	SAR	0-18	18-26	>26	-

Evaluation and formulating based on Boolean logic, MCE (WLC) and proposed model of geometric mean

Boolean algebra: Based on intersection (and) and union (or) rules (MCHARG, 1969; MALCZEWSKI, 2004).

Geometric mean: According to the criteria listed in Table 2, each parameter is given the weight from 0 to 3 (0 shows ecological condition of non-suitable and 3 states the ecological condition of suitable for irrigated use. Next, all parameters are combined with intersection function in Arcmap (Geoprocessing part). Next, based on Equation 1 parameters of each criterion (such as slope and landform parameters in topography criteria) are multiplied to obtain related criteria (such as topography criteria).

$$criteria\_x = (layer1 \times layer2 \times \ldots \times layern)^{1/n} \quad (1)$$

Where, criteria-x is a parameter of each criterion (such as slope and landform parameters in topography criteria), "n" is the number of parameters.

Finally, all criteria are multiplied to obtain a final score of land suitability for irrigated agriculture (Equation 2).

$$\text{final score of land suitability for irrigated agriculture} = (Topography \ x \ Climate \ x \ Soil \ x \ Water)^{1/4} \quad (2)$$

where, final score helps us to prepare final map based on Table 3. Finally, suitability classes of quantitative are assigned for irrigated planning in GIS (Table 3).

Table 3. Suitability classes for irrigated planning based on their scores.

Suitability classes	Good (1)	Moderate (2)	Poor (3)	Non-suitable (4)
Scores	> 2.5	1.5 - 2.5	0.5 - 1.5	< 0.5

Arithmetic mean: In the arithmetic mean method, scores related to parameters were averaged.

MCE (WLC) method: In this paper, MCE is used to evaluate the irrigated agriculture. Accordingly, 45 questionnaires were given to experts in the field of irrigated planning for weighting the criteria and factors. Then calculation of weightings was done based on Table 4 show the weight of criteria and factors with Consistency Ratio or CR<0.1. Then WLC (weighted linear combination) method used for the weighted overlay of the input data layers. With the weighted linear combination, factors are combined by first applying a weight to each factor and criteria, followed by a summation of the results to yield a suitability map (Equations 3 and 4). Finally, constraint factors (C_i) were multiplied in map (FALLAH SHAMSI, 2004; GHADIMI et al., 2011).

$$criteria\_x = [(\mathrm{W1} \times \mathrm{factor1}) + (\mathrm{W2} \times \mathrm{factor\ 2}) \ldots + (\mathrm{Wn} \times \mathrm{factor})] \times \mathrm{Ci} \quad (3)$$

$$Final\ criteria\_x = [(\mathrm{W1} \times \mathrm{Criteria1}) + (\mathrm{W2} \times \mathrm{Criteria2}) \ldots + (\mathrm{Wn} \times \mathrm{Criteria})] \times \mathrm{Ci} \quad (4)$$

Table 4. Weight of criteria and indicators by AHP.

Criteria	Criteria Weight	Factor	Factor Weight
Topography	0.23	Slope (%)	0.55
		Land Form	0.45
Climate	0.24	Drought	0.52
		Current state of climate	0.48
SOIL	0.26	Texture	0.14
		Depth	0.14
		Drainage	0.14
		Erosion	0.14
		EC	0.15
		ESP	0.14
		Fertility	0.15
Water	0.27	Quantity of water	0.27
		Lowering of water table	0.25
		EC	0.25
		SAR	0.23

Calibration and Validation

In order to evaluate accuracy of obtained map quantitatively, the results were compared pixel by pixel with ground reality (MAKHDOUM et al., 2009). First, the maximum production was calculated using normalized difference vegetation index (NDVI) images for the year 2014 (HOLBEN, 1986). Then, the average and standard deviation of production in current irrigated lands were calculated by $NDVI_{max}$ images. Next, samples of irrigated lands (Table 5) and non- irrigated lands were gathered by “Create Fishnet” algorithm in ArcGIS 9.3 environment, systematic randomly (FALLAH SHAMSI, 1997). Then, these points were overlaid on the land suitability maps. The obtained result is observed in a table namely, “Error Matrix” or agreement matrix (Table 5) and quantitative indices like “Overall Accuracy, Kappa Coefficient and Inclass index” were calculated (CONGALTON, 1991). Inclass coefficient is a validation index used in order to estimate suitable classes for every use, such as agri-lands with high production (FALLAH SHAMSI, 1997).

Table 5. Error matrix for irrigated use in the study area.

Model		Ground reality		
Classify	Class	Agricultural land with production more than or equal to the average (NDVI value ≥ μNDVI)	Agricultural lands with poor production (NDVI value < μ_{NDVI} - SD_{NDVI}), Natural resources in hill	Natural resources in mountain, Desert lands
	1.2	*		
	3		*	
	4			*
Number of points		364	217	378

In order to calibrate the model, omission and commission error and maps of parameters were used to increase accuracy amount. Hence, according to omission and commission error and maps of parameters in geometric mean method, quantitative ranges of suitability classes (Table 3) were changed repeatedly to reach to the best model with highest accuracy. In this research, the range of class 3 (Table 3) was changed from 0.5-1.5 to 0.5-1.73 for calibration of the model with highest accuracy (KOSMAS; POESEN; BRIASSOULI, 1999; SEPEHR et al., 2007). This kind of calibration was done in other classification like Mediterranean Desertification and Land Use (MEDALUS) Method (ZAKERINEJAD; MASOUDI, 2019).

RESULTS AND DISCUSSION

The ecological potential model of irrigated agriculture was based on physiographic, climate, soil and water criteria and according to different potential assessment methods. The suitability maps are shown in Figure 3.

The maps include methods of Iranian ecological model (MAKHDOUM, 2006), reclassified model with Boolean algebra (max limit), MCE (WLC) and geometric mean and calibration of geometric mean. In the maximum limit method, most of the area was under the unsuitable class with about 67%. Also, the study area did not have a suitable capability class. In the arithmetic mean method, most of the region was under the moderate class with about 87%. Unsuitable capability class was not observed in this method. In the geometric mean method, most of the region with about 67% was under the class of inappropriate capability, the moderate (29%), suitable (4%) and poor (0.32%) were in the next order. In the MCE method (WLC) the percentage of each class was almost similar to the geometric mean method. In the calibration method, most of the area was in the unsuitable class with about 67%. The moderate classes (19%), the poor (10%) and the suitable classes (4%) were in the next order. It is worth mentioning that in the ecological model of Iran or Dr. Makhdoom's model (MAKHDOUM, 2006), 66% of the area was in the 7th or inappropriate class, 30% in both of the 5th and 6th classes or weak classes and the moderate classes of 3 and 4 covered 4% of the study area. Also, no 1st or 2nd classes or suitable were observed.

In order to test the mentioned models, the accuracy of the different irrigated agriculture models was assessed based on the agreement matrix approach and according to the effective accuracy indicators in the Table 6.

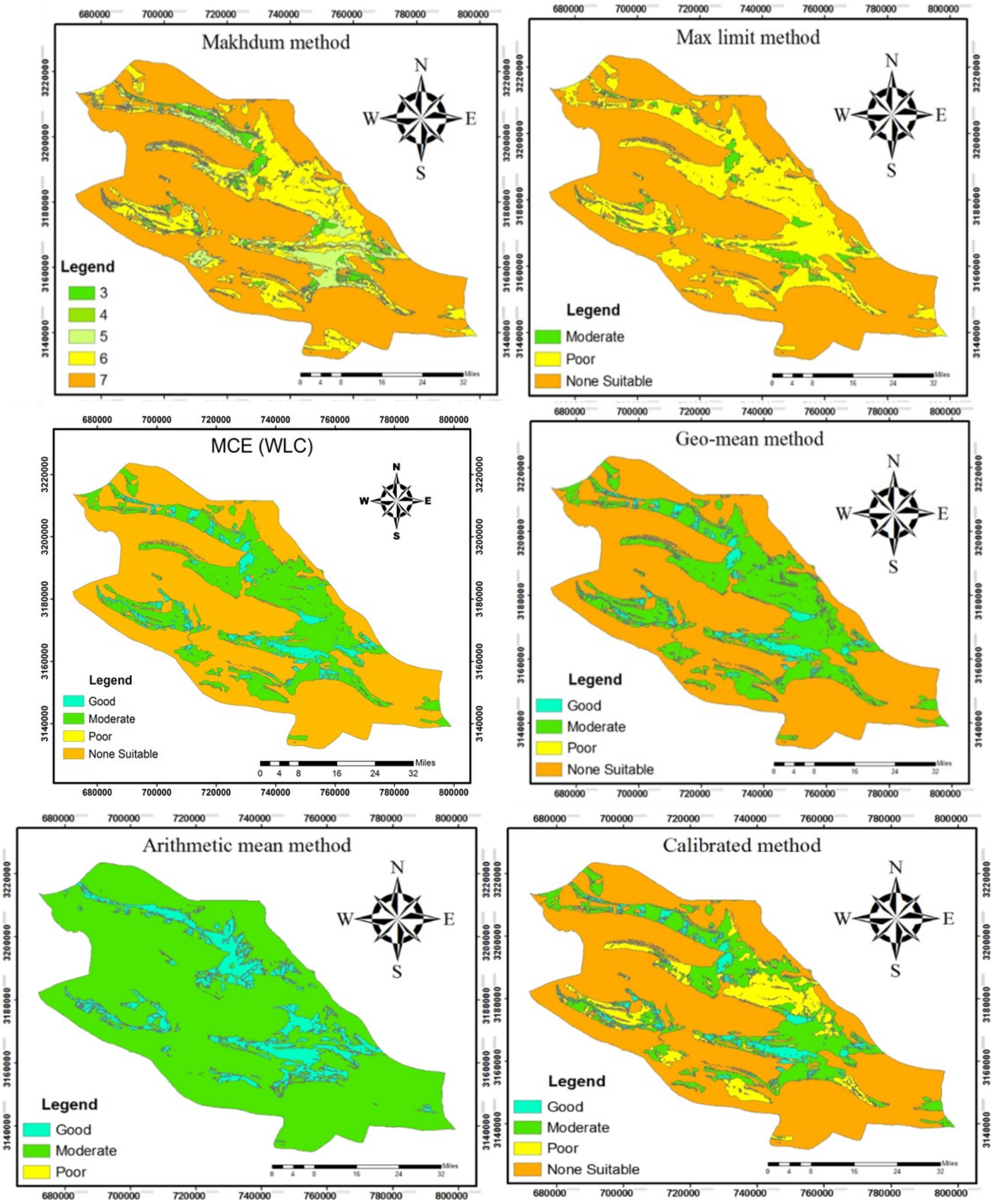

Figure 3. Maps of ecological suitability by different methods.

Table 6. Amounts of overall accuracy, Kappa and Inclass coefficients in the used models.

Accuracy indicators	Iranian ecological model	Revised method (4 classes)				
		Boolean logic	Average based			
			Arithmetic mean	MCE (WLC)	Geo_ mean	Calibration of Geo_ mean
Overall accuracy (%)	70	68	38	72	73	87
Kappa coefficient	0.56	0.52	0	0.53	0.55	0.79
Inclass	0.85	0.43	0.61	1.36	1.43	3.8

The results in Table 6 showed that in the method of maximum limit or modified ecological model of Iran due to the addition of indicators of drought and degradation of water resources with almost unsuitable conditions in the region and also the method of evaluation based on Boolean logic, the accuracy of evaluation was decreased slightly. Then, by changing the evaluation method based on geometric mean and calibration, the model reached to its highest accuracy. Results showed that proposed method (4 classes) by geo-mean is better than Iranian ecological method and even than MCE (WLC). At the same time, the calibrated proposed method (4 classes) by geo-mean model is the best among different used models (Table 6). It should be noted that arithmetic mean has the lowest accuracy. Figure 4 shows that Boolean methods tend to provide non-suitable classes, and geometric mean and calibration methods place among other mentioned methods. This indicates geometric mean and calibrated revised method (4 classes) can be a useful model for finding potential area for agriculture. For a range of 0 to 1 (grade of fuzzy members), output of methods such as Boolean-based tends to 0 or non-suitable classes. So, this method has high sensitivity for finding suitable lands. The proposed method is placed from 0 to 1. So, this method has a high flexibility in differentiating classes and locating them compared to the above views. It should be noted that Geo-mean model with higher accuracy is simpler than MCE. Because it does not need weighting process.

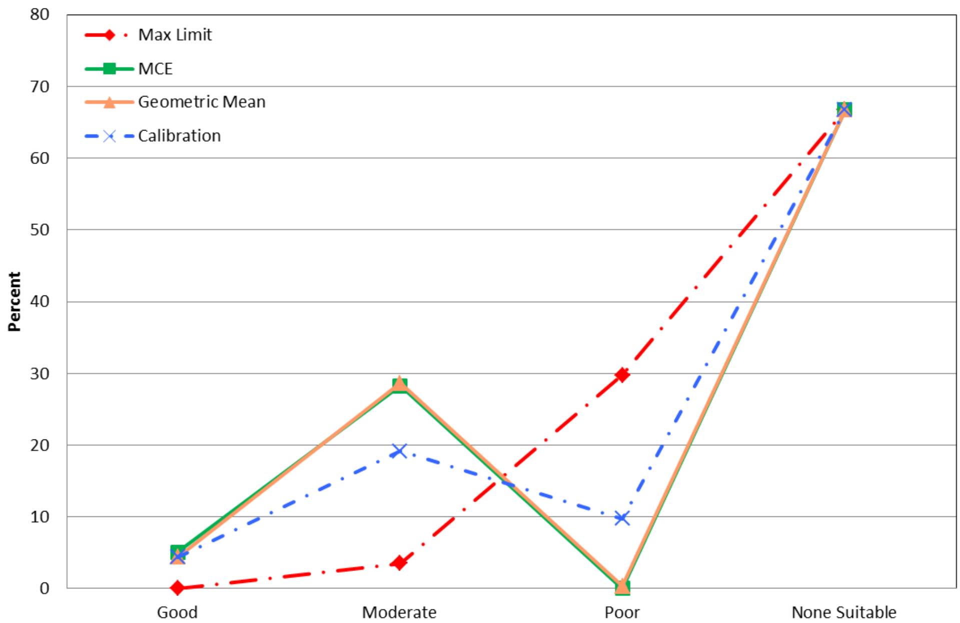

Figure 4. Percent of different suitability classes in different models.

The land use models presented by Makhdoom (MAKHDOUM, 2006) and FAO should be changed based on the areas under evaluation, so it is necessary that these models to be calibrated for different climatic conditions. In this study, first the ecological potential models of land uses were studied using different methods (Boolean and mean logics) and with a comprehensive view of the environmental characteristics of Jahrom Township. In this study, each land use model was evaluated by the criteria that affect it, which is based on the following:

Based on the results obtained in the different approaches of irrigated agricultural use model with effective criteria, it was determined that by considering important indicators such as drought and degradation of groundwater resources, especially in arid and semi-arid regions, which have unsuitable conditions in terms of these parameters, model accuracies were improved. In a study conducted by Sepehr et al. (2007) to evaluate desertification in arid and semi-arid regions based on the MEDALUS model, they concluded that since the MEDALUS model is set for the Mediterranean region, so to recast it in arid and semi-arid areas, groundwater situations should be seriously considered.

The results obtained from Table 6 showed that for assessing ecological potential based on model calibration and without considering these conditions for irrigated agricultural use (with taking into consideration of the drought index and water resources degradation), the geometric mean method for uncalibrated conditions and the calibration method for calibrated conditions have the highest accuracy, respectively.

It is worth noting that the calibration range intended for irrigated agricultural use is often done by changing the quantitative range of the weak classes from 0.5-1.5 to 0.5-1.73. Therefore, it can be said that the upper calibration limit of the desired classes of land uses in Jahrom Township with a dry and semi-arid climate is 1.73. Considering this range and considering regional conditions, the model has the highest accuracy compared to other methods.

Additionally, in the proposed geo-mean method, the average of ecological situations has been considered and socioeconomic conditions have been considered, indirectly, because agricultural use related to socioeconomic conditions. The proposed geometry method is a simple system of ecological-socioeconomic conditions which considers limitations and real potential of land, together.

In the Boolean methods (e.g. FAO, 1976) the classification process is quite strict. But the proposed model is more flexible than Boolean model. This critique of the Boolean method can also be seen in the research of Elaalem, Comber and Fisher (2010) and Jokar and Masoudi (2016). Also, Amiri et al. (2010) used two models to evaluate the ecological suitability of forestry in Mazandaran Province: Boolean and AHP-Fuzzy (Analytic hierarchy process and Fuzzy) methods. Their findings emphasized the improvement of AHP-Fuzzy methodology against the conventional Boolean for assessment of the ecological suitability of forests in the northern part of Iran. The output from this research corroborates similar findings.

In addition, other advantage of the new proposed model method is reducing the higher effect of some factors such as soil criteria with many indicators against topography criteria with only two parameters. Also, there are regions with ecological characteristics of non-suitable (e.g. very severe salinity). Defining these regions as the zero number in Equations 1 and 2 make these regions to be considered as non -suitable. So, whole criterion or other parts of study area do not return to 0. Also 0 number is used in WLC method as constrain factor, meaning only one parameter is not suitable make that polygon or pixel as not suitable although other ecological parameters are suitable or semi-suitable.

CONCLUSIONS

Land management should be done with an integrated approach of development and nature protection. Achieving this important goal in the direction of sustainable development is possible with the approach of assessing capacity and land management. Different criteria are involved in the land assessment process. The main goal of this paper was to develop a new method for land suitability evaluation using the integration of FAO model with Iranian ecological model in GIS. This study investigated a modeling with Boolean logic, Arithmetic mean, Geometric mean and MCE (WLC) models by Geographic Information System (GIS). Next, the land suitability maps for irrigated farming were produced. Among the mentioned models, the results showed that Arithmetic mean had the lowest accuracy (Table 6). Next, the evaluation methods were changed by averaging methods (MCE, geomean and its calibration). Results (Table 6) showed that these methods had a higher accuracy compared than Boolean logic and Arithmetic mean. Geometric mean method had a higher accuracy and simplicity than MCE method, because the method is simpler than MCE and does not require weighting process. Also, its calibration was the most optimal method for agriculture planning.

Overall, the results of this study clearly showed that in any research and field study, it cannot be said which method is the best method to assess the suitability of land and land use planning, but in this case the assessor must consider the environmental, ecological, economic and social attention of each region in the process of assessing ecological potential. The results of this research made a very important achievement in the land use planning process and will be considered as a starting point and a turning point for future studies and evaluations. However, due to the fact that land suitability assessment issues are multi-criteria and with one-objective, in future studies, it is suggested to design this proposed model for every use and finally all uses combined with land use planning methods like MOLA (multi-objective land allocation).

ACKNOWLEDGMENTS

This work would not have been possible without the financial support of Shiraz University (Grant number: 93GRD1M75441; Grant recipient: Dr. Masoud Masoudi). We are also grateful to all of National offices and organizations for providing the data for monitoring the work.

REFERENCES

ALAVI PANAH, S. K. et al. The use of TM thermal band for land cover/land use mapping in two different environmental conditions of Iran. **Journal of Agricultural Science and Technology**, 3: 27–36, 2001.

AMIRI, M. J. et al. Comparison of maps overlay systemic method and boolean-fuzzy logic in the ecological capability evaluation of no. 33 and 34 watershed forests in northern iran. **Environmental Sciences**, 7: 109-124, 2010.

AMARSAIKHAN, D. et al. An integrated approach of optical and SAR image for forest change study. **Asian Journal of Geoinformatics**, 4: 27-32, 2004.

ASADIFARD, E. et al. Evaluating the ecological potential for rangeland use by various land-use planning methods in Firozabad County. **Rangeland**, 13: 14-25, 2019.

AYALEW, G. A Geographic information system based physical land suitability evaluation to groundnut and sweet potato in east Amhara, Highlands of Ethiopia. **Journal of Biology, Agriculture and Healthcare**, 5: 33-38, 2015.

CARVER, S. J. Integrating multi-criteria evaluation with geographic information systems. **International Journal of Geographical Information Science**, 5: 321-339, 1991.

CONGALTON, R. G. A Review of assessing the accuracy of classifications of remotely sensed data. **Remote Sensing Environment**, 37: 35-46, 1991.

ELAALEM, M.; COMBER, A.; FISHER, P. Land Suitability Analysis comparing Boolean logic with fuzzy analytic hierarchy process: In: Accuracy 2010 Symposium, 2010, Leicester, **Proccedings…** Leicester: ISARA, 2010. p. 245-247.

ELSHEIK, A. R. et al. An Agricultural Investment Map Based On Geographic Information System and Multi-Criteria Method. **Journal of Applied Sciences**, 10: 1596–1602, 2010.

FALLAH, M. S. H. et al. Zoning Ecological Capability Evaluation of Kasilian Watershed for Agricultural Utilization Using GIS. **Journal of Geography and Environmental Studies**, 34: 115-126, 2009.

FALLAH SHAMSI, S. R. **Accuracy Assessment of Satellite Based Maps Using Sampling**. MSc Dissertation, Faculty of Natural Resources, University of Tehran, Iran, 1997.

FALLAH SHAMSI, S. R. **Economic Evaluation of Different Land uses in Kalibar-chai Forest-covered Watershed, Using Linear Programming and Geographical Information Systems.** PhD Thesis Report, Natural Resource Faculty, Tehran University, Karaj, Iran, 2004.

FAO - Food and Agriculture Organization of the United Nations. **Guidelines: Land Evaluation for Rained Agriculture.** Soils Bulletin 52. Rome, 1983. 237 p.

FAO - Food and Agriculture Organization of the United Nations. **A framework for land evaluation. Soils Bulletin 32.** Soil resources development and conservation service land and water development division, Rome, 1976, 87 p.

FAO - Food and Agriculture Organization of the United Nations. **Food Security in Libya.** An Overview, World Food Programme, 36, 2011.

FENG, L.; ZHU, X.; SUN, X. Assessing coastal reclamation suitability based on a fuzzy-AHP comprehensive evaluation framework: A case study of Lianyungang, China. **Marine Pollution Bulletin**, 89: 102-111, 2014.

FROJA. N. **Fuzzy-GIS Development of Land Evaluation System for Agricultural Production in North West Libya.** PhD Thesis, Heriot-Watt University, School of the Built Environment. 2013.

GHADIMI, M. et al. Protection Modeling of Manesht and Ghalarang Protected Areas Using Fuzzy logic. **Environmental Sciences**, 8: 85-106, 2011.

HATAMINEJAD, H. et al. The Evaluating of Land Use Suitability by the Method of Ecological Potential in the Ardebil Province toward Land use Planning. **Town and Country Planning**, 5: 5-26, 2013.

HE, Y. et al. Regional Land Suitability Assessment for Tree Crops Using Remote Sensing and GIS: In: CONFERENCE OF COMPUTER DISTRIBUTED CONTROL AND INTELLIGENT ENVIRONMENTAL MONITORING (CDCIEM), 2011, Changsha. **Proccedings…** Changsha: IEEE, 2011. p. 354-363.

HOLBEN, B. N. Characteristics of Maximum Value Composite Images from Temporal AVHRR Data. **International Journal of Remote Sensing**, 7: 1417-1434, 1986.

JAHANTIGH, H. R.; MASOUDI, M.; JOKAR, P. A quantitative approach to land use planning using GIS – A case study of Chabahar County, Iran. **European Journal of Environmental Sciences**, 9: 12–20, 2019.

JOKAR, P.; MASOUDI, M. Land Suitability for Urban and Industrial Development by a Proposal Model, Case Study: Jahrom Township, Iran. **Journal of Environmental Studies**, 42: 135-149, 2016.

JOKAR, P.; MASOUDI, M.; KARIMI, F. An MCE-based innovative approach to evaluating ecotourism suitability using GIS. **Cuadernos de Investigación Geográfica**, 47: 545-556, 2021.

KESHAVARZI, A. et al. Land suitability evaluation using fuzzy continuous classification (A case study: Ziaran region). **Modern Applied Science**, 4: 72-81, 2010.

KOSMAS, C.; POESEN, J.; BRIASSOULI, H. **Key Indicators of Desertification at the Environmentally Sensitive Areas (ESA) Scale, the Medalus Project: Mediterranean Desertification and Land Use**. Manual on Key Indicators of Desertification and Mapping Environmentally Sensitive Areas to Desertifica-tion. Project report. European Commissio, 88 p, 1999.

LEE, T. M.; YEH, H. C. Applying Remote Sensing Techniques to Monitor Shifting Wetland Vegetation: A Case Study of Danshui River Estuary Mangrove Communities. Taiwan. **Ecological engineering**, 35: 487–496, 2009.

LIAO, H. L.; WU, Q. H. Multi objective optimition by learning outomata. **Journal of Global Optimization**, 55: 459 -487, 2013.

MAKHDOUM, M. **Principles of Land Use Planning**. University of Tehran, Iran, 2006, 289 p.

MAKHDUOM, M. et al. **Environmental Evaluation and Planning by Geographic Information System.** University of Tehran, Iran, 2009, 304 p.

MALCZEWSKI, J. GIS-Based Land-Use Suitability Analysis: A Critical Overview. **Progress in Planning**, 62: 3–65, 2004.

MAPEDZA, E.; WRIGHT, J.; FAWCETT, R. An Investigation of Land Cover Change in Mafungautsi Forest, Zimbabwe, Using GIS and Participatory Mapping. **Applied Geography**, 23: 1-21, 2003.

MASOUDI, M. Risk Assessment of Vegetation Degradation Using GIS. **Journal of Agricultural Science and Technology**, 16: 1711-1722, 2014.

MASOUDI, M., JOKAR, P. Land-use planning using a quantitative model and geographic information system (GIS) in Shiraz Township, Iran. **Ecopersia**, 3: 959–974, 2015.

MASOUDI, M. et al. A GIS-based quantitative model for land use planning in Larestan County, Iran. **EQA-International Journal of Environmental Quality**, 40: 19-30, 2020.

MASOUDI, M.; JOKAR, P.; SADEGHI, M. Land use planning using a quantitative model and geographic information system (GIS) in Darab County, Iran. **Journal of Materials and Environmental Sciences**, 8: 2975–2985, 2017.

MASOUDI, M.; ZARE, R. Different Irrigation Methods and Their Comparisons Based on the Parametric Evaluation Method in Khosouyeh Dam Subbasin, Iran. **Journal of Resources and Ecology**, 10: 504-510, 2019.

MARTIN, D.; SAHA, S. K. Land Evaluation by Integrating Remote Sensing and GIS for Cropping System Analysis in a Watershed. **Current Science**, 96: 569-575, 2009.

MCHARG, I. L. **Design with Nature**. Wiley, New York, 1969, 208 p.

MITRA, D.; ILANGOVAN, D. Site Selection for Harbour Facilities in the Gulf of Cambay, India Using Geographic Information System. **Asian Journal of Geoinformatic**, 4: 81-86, 2004.

MU, Y. **Developing a Suitability Index for Residential Land Use: A Case Study in Dianchi Drainage Area**. MSc thesis in Environmental Studies in Geography, Waterloo, Ontario, Canada. 2006.

MASEL ULLAH, K. **Urban land-use planning using Geographical Information System and Analytical Hierarchy Process: Case study Dhaka city**. Master degree thesis, 30 credits in Master in Geographical Information Sciences (GIS) Department of Physical Geography and Ecosystems Science, Lund University. 2014.

NAZARI VIAND, F. et al. Land Suitability Assessment for Agriculture Using Analytical Hierarchy Process in Northern Parts of Khalkhal County (Case Study: Mikaeel Abad catchment). **Agriculture Science and Sustainable Production**, 30: 225-239, 2019.

NWER, B. **The Application of Land Evaluation Technique in the North-East of Libya**. PhD Thesis, Faculty of Environment, Cranfield University, Silsoe. Cranfield University at Silsoe, 2006.

O'NEILL, R. V. Perspectives in Hierarchy and Scale. In: ROUGHARDEN, J.; MAY, R. M.; LEVIN, S. A. (Eds.). **Perspectives in Ecological Theory**. Princeton University Press. Paul, 1989, p. 140–156.

PAN, G.; PAN, J. Research in Crop Land Suitability Analysis Based on GIS. **Computer and Computing Technologies in Agriculture**, 5: 314–325, 2012.

POURKHABBAZ, H. R.; JAVANMARDI, S.; FARAJI SABOKBAR, H. A. Suitability Analysis for Determining Potential Agricultural Land Use by the Multi-Criteria Decision Making Models SAW and VIKOR-AHP (Case study: Takestan-Qazvin Plain). **Journal of Agricultural Science and Technology**, 16: 1005-1016, 2014.

PRAKASH, T. N. **Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach**. MSc thesis in Science in Geoinformatics, ITC, Netherlands, 2003.

RADAN, Z. et al. Comparison Ability between FAO and Iran Ecological Models to Estimate of Capability Ecological land for Using Pasture. **Journal of Environmental Science and Technology**, 18: 89-103, 2017.

ROSSITER, D. G. A Theoretical Framework for Land Evaluation. **Geoderma**, 72: 165–190, 1996.

SAFARIPOUR, M.; NASERI, D. Ecological Land Capability Evaluation for Agriculture and Range Management Using WLC Method (Case study: Onarchay watershed, Ardabil province). **Journal of Environmental Science and Technology**, 21: 113-123, 2019.

SEPEHR, A. et al. Quantitative assessment of desertification in south of Iran using MEDALUS method. **Environmental Monitoring and Assessment**, 134: 243-254, 2007.

SONNEVELD, M. P. W. et al. Thirty Years of Systematic Land Evaluation in the Netherlands. **Geoderma**, 156: 84–92, 2010.

TAYLOR, J. C.; WOOD, J. A.; THOMAS, G. Mapping Yield Potential with Remote Sensing: In: FIRST EUROPEAN CONFERENCE ON PRECISION AGRICULTURE, 1997, London. **Proccedings…** London: Warwick University, 1997. p. 713-720.

ZAKERINEJAD, R., MASOUDI, M. Quantitative mapping of desertification risk using the modified MEDALUS model: a case study in the Mazayejan Plain, Southwest Iran. **Auc**

Geographica, 54: 232-239, 2019.

ZONNEVELD, I. S. The Land Unit – A Fundamental Concept in Landscape Ecology, and Its Applications. **Landscape Ecology**, 3: 67–86, 1989.