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Ecological potential assessment of soil in agricultural lands in Hamedan Province, Iran, using geographic information system

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Original Article

Abstract

The main purpose of the present study was to assess the ecological potential of agricultural soils using geographic information system (GIS). This research was conducted during 2014 in Hamedan Province, Iran. A cross-sectional study was conducted mapping the 10 factors of soil characteristics (texture, depth, erosion, and aggregation, percentage of slope, direction of slope, height, soil salinity, pH, and fertility) that affect ecological potential. The maps were overlaid in ArcGIS software. The weighting of factors was performed using the analytical hierarchy process (AHP) technique in Expert Choice Software. Preference for the options (layers) was specified and an ecological potential map of agricultural lands in the province was created. Among the factors studied, the pH of the soil weighing 0.313 was the most important factor and soil salinity with 0.228 was the second most important factor influencing ecological potential. In general, growth-oriented agricultural development policies and improper management of farms in recent years has reduced the ecological potential of agricultural lands. The results showed that the highest and lowest ecological potential of soil in agricultural lands in the area was 6.2% and 0.07%, respectively. Development of sustainable agriculture practices, such as low tillage and no-tillage practices, reduction in the use of chemical pesticides, and use of green fertilizers to maintain and enhance the ecological potential of agricultural lands and resources, are recommended. In the policy-making process, sustainability and resource management must become a dominant notion and planning priority for policy makers and managers.

KEYWORDS: Agriculture, Ecological Potential Assessment, Geographical Information Systems, Iran, Soil

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Introduction

In Iran, agriculture is an important sector of the economy and plays a crucial role in achieving sustainable agricultural development. With regard to this sector, missions for self-sufficiency in food production and its contribution to export can encounter problems related to population growth and reduced rural migration. Agriculture involves the use of scientific principles and methods to identify environmental capacity and capability of each region.[1] Ecological potential assessment (EPA) is a process that attempts to regulate human relationships with nature and develop an appropriate and harmonious relationship. EPA is an assessment of uniform and homogeneous land pieces for different types of uses. In fact, this assessment is an effective step toward designing an administrative program for sustainable development of a region. Through identification and assessment of the ecological characteristics of each region, program development can be planned in harmony with nature so that nature can ascertain the land's capabilities for development.

In recent years, external inputs have been particularly emphasized in agricultural activities; chemicals, fertilizers, pesticides, and

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machinery have increased agricultural activity, and therefore, caused an overexploitation of land and natural resources. This approach, in addition to having impact on the environment, has reduced the ecological capability of agricultural lands. According to statistics provided by the Food and Agriculture Organization of the United Nations (FAO),[2] the lack of appropriate management and the unplanned use of agricultural inputs in Iran are far greater than other countries.

In recent decades, several models have been proposed to evaluate ecological capability globally. Most important of these have been land assessment, geomorphology, and overlay models.[3] In contrast to the aforementioned models that only deal with one aspect of ecological resources (biological or physical), the combined model proposed by Makhdom can assess ecological capability. This model has 28 parameters which are classified into 7 classes.[4] This model is more comprehensive than other models. Therefore, Makhdom's model was used in this investigation due to its abovementioned advantages. In the last few decades and especially since the debate concerning EPA, numerous studies have been conducted in this field worldwide. Veríssimo et al., in their research, compared ecological capability in a catchment basin in Portugal.[5] Using characteristics such as salinity, erosion, pH, and texture, they attempted to assess the ecological capability of agricultural land in the catchment using 3 methods of land use planning, geomorphology, and overlaying in a geographic information system (GIS) environment. After comparing the obtained results, the best method for assessing the ecological capability of lands in Portugal were offered. The results of this study illustrated that the overlay method in GIS has higher accuracy than the other 2 methods due to occurrence of fewer errors and its consideration of the percentage of each soil characteristic.[5]

Among the features selected for soil, salinity and pH have the greatest impact on ecological potential of agricultural land. Borja and Elliott studied the ecological potential of land in European countries.[6] They investigated factors such as texture, depth, elevation, slope, salinity, and organic matter to assess the ecological potential of agricultural land in European Union countries. The findings of the overlay method indicated that factors such as texture, salinity, and pH have the greatest impact on ecological potential of agricultural land in various parts of Europe. Among EU member states, Germany, UK, and Lithuania had the highest rates of ecological potential of agricultural land which indicated the best soil for agriculture.[6] However, research has shown that appropriate soil management in agricultural development in European countries has had a great impact on reducing or increasing ecological potential. Countries such as Germany and Britain, with appropriate management, could increase the ecological potential of their agricultural lands.[6] Ceia et al. assessed the ecological potential of agricultural land and soil quality in a catchment in southern Europe using factors such as tissue, salinity, erosion, pH, altitude, and fertility.[7] This study used the 2 methods of geomorphology and overlay method in GIS to assess the ecological potential of agricultural lands.[7]

The results showed soil fertility and ecological potential had the greatest impact on agricultural ecology. However, factors such as high humidity, reduced rainfall, and excessive use of inputs, such as fertilizers and pesticides, have caused a decrease in ecological potential of agricultural lands in the catchment basin in recent years.[7] Chainho et al. examined the effect of soil characteristics (salinity, organic matter, and pH) on the water quality in Portugal. In this study, the use of agricultural inputs (fertilizers, pesticides, and machinery), and ecological potential of the soil and its changes in agricultural land ecology were studied.[8] The research results revealed that between 2005 and 2010, the water quality of agricultural waste was reduced by nearly 12% due to excessive use of chemical pesticides.[8]

The analytical hierarchy process (AHP) is based on paired comparisons; therefore, it can examine various issues.[9] There are many reports on applying AHP for weighting factors. The map overlaying procedure for assessing ecological potential is one of the most important applications of GIS today.[7] The overlaying procedure is a very comprehensive method. In Iran, there have been several studies on the ecological potential assessment for the classification of ecological zones within a catchment and or identifying fertile lands for urban development or agricultural development.[10-15] However, there have been no studies, until today, in the field of ecological potential assessment of agricultural land using factors affecting ecological potential. In general, studies on ecological potential can be classified into 2 categories: ecological zoning,[16-19] and diagnosing an area's potential for agricultural development.[20-24] Unlike previous studies, which used one or a small number of factors, this study focuses on the method and technique of using GIS layers. Thus, 10 factors (salinity, pH, erosion, grain size, texture, depth, elevation, and percentage of slope, direction of slope, and soil fertility) were investigated to determine the ecological potential of agricultural land in the province of Hamedan, Iran, using Makhdom's model. Moreover, the weighting of factors was performed using the AHP technique.

Materials and Methods

Hamedan Province, located in Western Iran, has a cold semi-arid climate with an annual rainfall of 340 mm. It is situated in the middle of Zagros Mountains of Iran. The study area lies between latitudes 33° 59´ and 35° 48´ N, and longitudes 47° 34´ and 49° 36´ E Greenwich meridian. The province consists of 8 cities (Figure 1). The province has an area of about 20,000 km^2, of which approximately 10,252 m^2 (about 6.52% of the province's land area) consists of plains, 5416 km^2 (27.8%) is covered by plateaus and hills, and about 3826 km^2 (19.6%) of the area comprises of mountain slopes with 40 to 100 degrees of inclination.

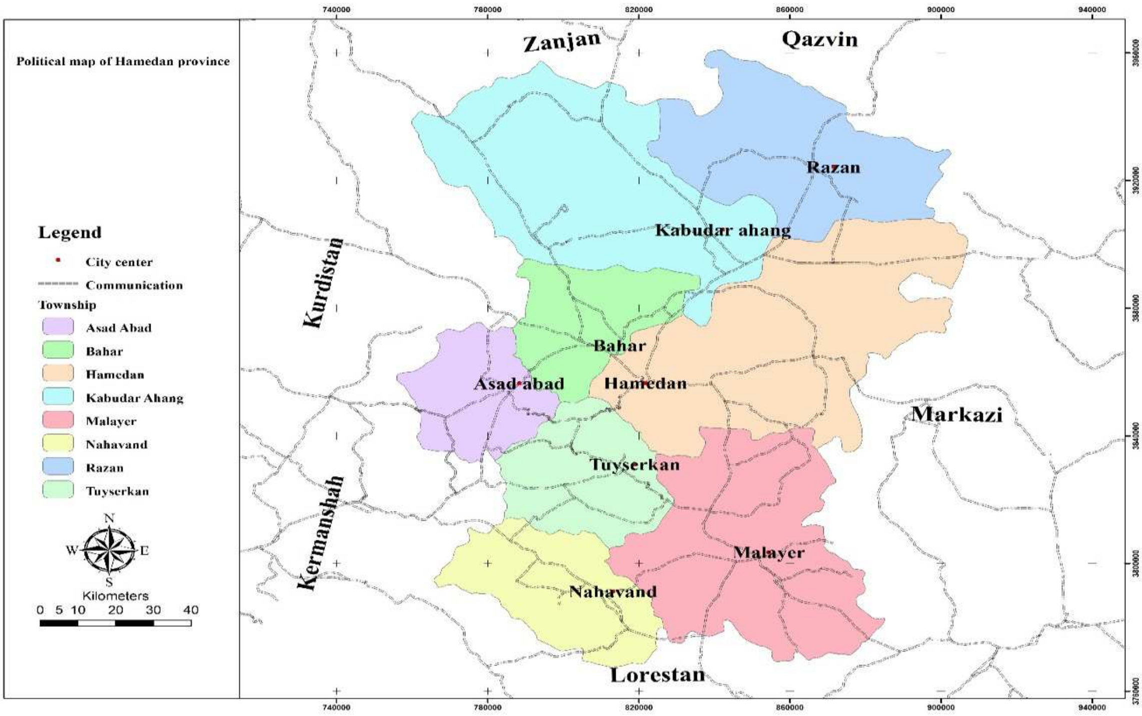

Figure 1. Location of Hamedan province in Iran

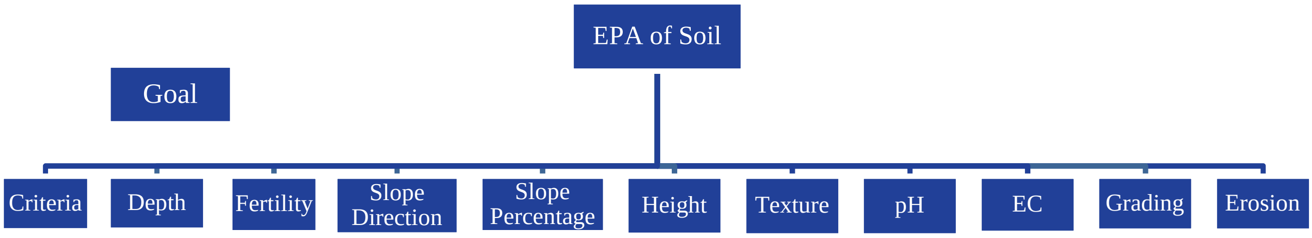

Figure 2. The structure of a hierarchical process
EC: Electrical conductivity; EPA: Ecological potential assessment

This was a cross-sectional study in which the map of 10 factors of soil characteristics (texture, depth, erosion, aggregation, percentage of slope, direction of slope, height, soil salinity, pH, and fertility) affecting ecological potential were provided. Then, the maps were overlaid in GIS medium using ArcGIS software (Version 9.3; Esri, Redlands, CA, USA). The factors were weighed and compared using AHP method (Figure 2). For this purpose, the Delphi method was applied. The judgment of 50 specialists in the fields of agriculture, environmental science, and geography were considered and pairwise comparisons were used to specify the level of importance and priority of each of the factors with respect to each other. Expert Choice Software (Expert Choice Inc., Pittsburgh, PA, USA) was used to form a matrix of rows and columns with the same number of factors. Finally, data was assessed according to the EPA model proposed by Makhdom as follows:[4]

$$Y = ax + \sum_{n=1}^{10} [(a_1 * x_1) + (a_2 * x_1) + \; \ldots \ldots (a_{10} * x_1)]$$

where a is each parameter affecting zoning, x is effective coefficient of each parameter based on Expert Choice Software and, Y is land use levels based on soil ecological capacity depending on the type of cultivation.

Results and Discussion

The pairwise comparison was conducted for the 10 abovementioned factors using Expert Choice Software. Figure 3 presents the pairwise comparisons between those 10 factors. According to the classification presented by Makhdom's model, soil erosion, soil salinity, acidity, fertility, soil texture, slope, height, and slope and soil grading were prepared separately (Figure 4).

Using AHP, relative weight and final weight of each factor was calculated (Table 1). Based on the results, the relative weight of factors are as follows: soil pH (4.53), soil salinity (3.30), soil aggregation (1.42), soil texture (1.23), slope percentage (1.22), soil depth (0.82), fertility (0.71), soil erosion (0.64), height above sea level (0.39) and slope direction (0.22).

	Soil texture	Soil gradin	Slope	Height	Erosion	Fertility	Slope direc	Soil depth	PH	Ec
Soil texture		3.0	5.0	7.0	5.0	1.0	7.0	1.0	7.0	7.0
Soil grading			5.0	8.0	1.0	1.0	7.0	1.0	5.0	5.0
Slope				3.0	9.0	7.0	5.0	5.0	5.0	5.0
Height					1.0	3.0	4.0	3.0	6.0	6.0
Erosion						2.0	4.0	3.0	6.0	8.0
Fertility							6.0	1.0	4.0	9.0
Slope direction								4.0	6.0	8.0
Soil depth									1.0	6.0
PH										1.0
Ec	Incon: 0.24									

Figure 3. Pairwise comparisons between the 10 factors
EC: Electrical conductivity

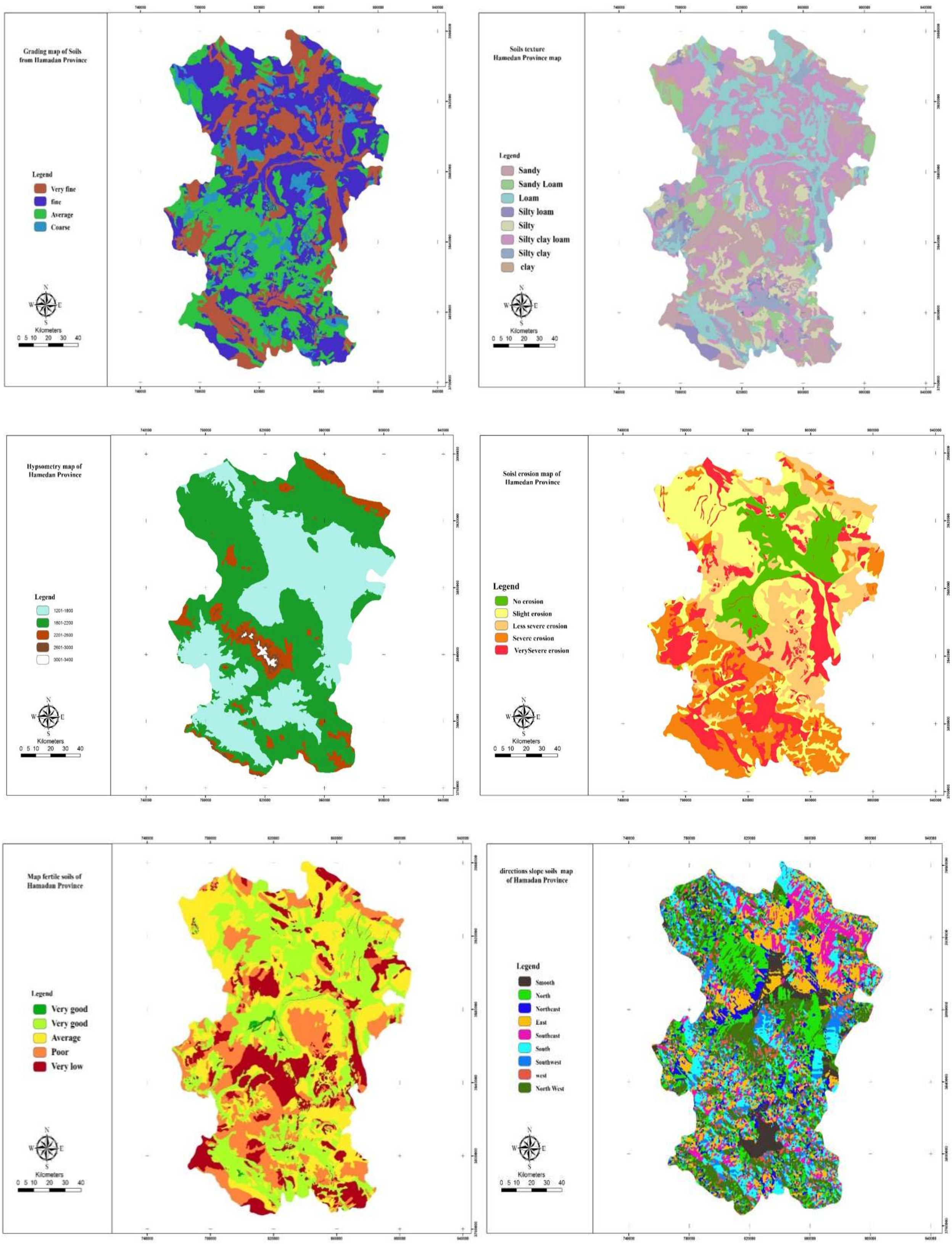

Figure 4. Maps of the possible ecological factors

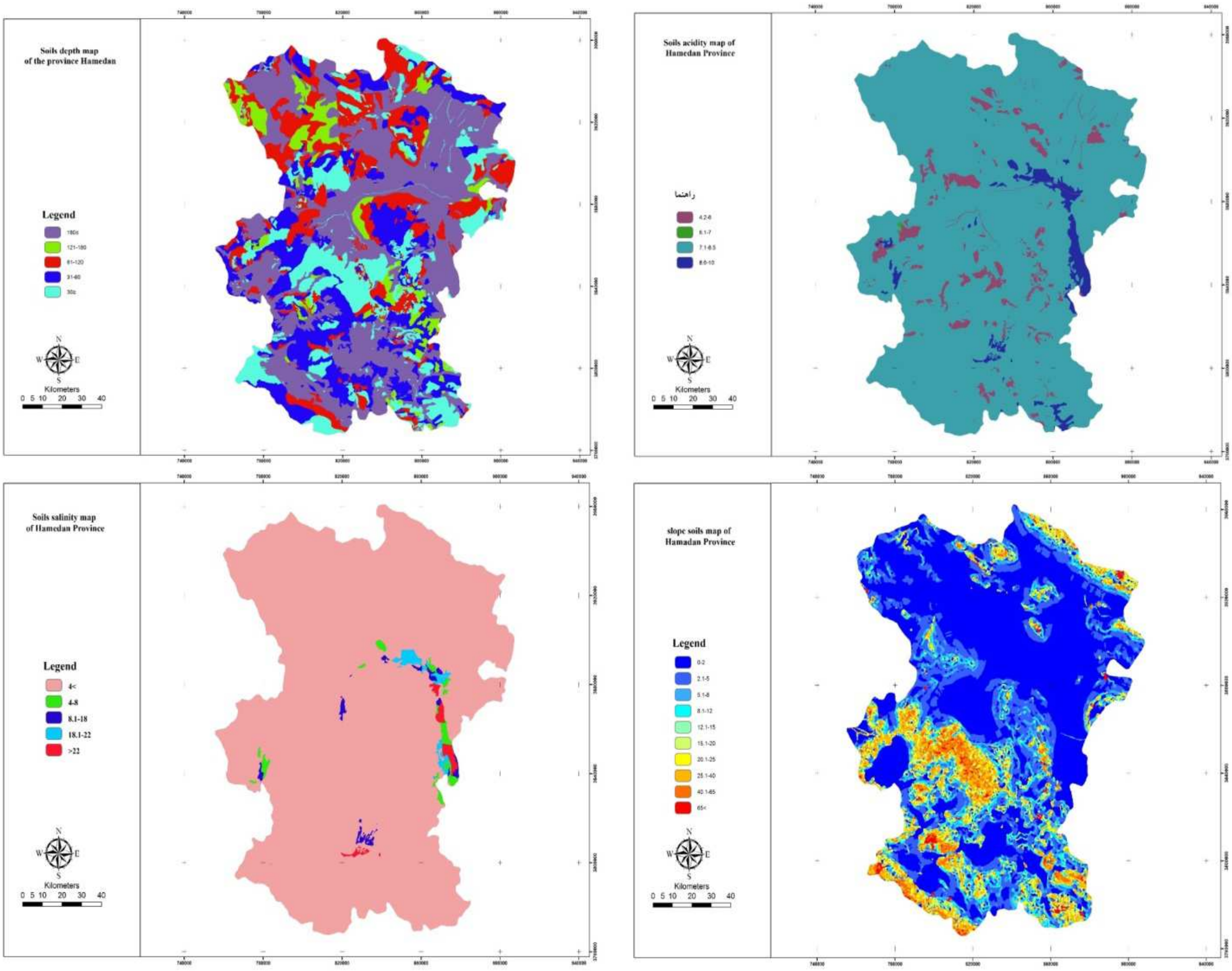

Figure 4. Maps of the possible ecological factors (Continue)

The final weights of the effective factors on ecological potential were derived from a combination of the relative weights. Based on the obtained results, among the considered factors, the pH of the soil with the final weight of 0.313 is the most effective factor and salinity is the second most effective factor impacting ecological potential of agricultural land in the province of Hamedan. The results regarding both factors are consistent with the study by Veríssimo et al.[5] and the salinity factor result is consistent with the findings from Ceia et al.[7] and Borja and Elliott.[6] However, soil fertility is ranked seventh, and thus, is not consistent with the findings of Ceia et al.[7] and Borja and Elliott.[6] Several reasons can cause these differences. Physical differences, different policies about agricultural development, and cultural, religious, and socio-economic differences in each area can influence an area of land and cause dissimilarities. Therefore, clearly this area of Iran cannot be compared with other parts of the world and cannot even be equated to other areas inside Iran. Depending on the region's natural and geographical, economic, and social features the ecological characteristics of agricultural lands can be affected in different ways.

Factors affecting agricultural lands and their weights were determined correctly and with acceptable accuracy (below 0.1) through a review of the literature along with the views of experts and in the form of pairwise comparisons and AHP.[6,19,25] This review highlights the effectiveness of resources and specialized expertise in the form of AHP for the weight of the factors in such research. The zoning map of ecological potential of lands was produced using overlaying method of layers in a GIS (Figure 5). In this method, all the layers are superimposed on one another based on the percentage of each factor and a final map of ecological zoning of agricultural land is produced. Salinity and pH factors were the most important factors. It seems that the main reason for this was the mismanagement of inputs such as fertilizers and chemical pesticides.

Table 1. Final weight of the factors studied

Factors	Relative weight	Final weight	Ranking
PH	4.53	0.33	1
EC	3.30	0.228	2
Soil grading	1.42	0.098	3
Soil texture	1.23	0.085	4
Slope	1.22	0.084	5
Soil depth	0.82	0.075	6
Fertility	0.71	0.049	7
Erosion	0.64	0.044	8
Height	0.39	0.027	9
Slope direction	0.22	0.015	10

EC: Electrical conductivity

In fact, these 2 factors can also have positive or negative effects on other factors. The present study confirms the results of previous studies.[6,7,14] Furthermore, the use of AHP method, combining the weight of factors, and mapping and overlaying layers to achieve the ecological potential map in agricultural lands has been confirmed.[8,16,20,21,24] Among other notable issues in this method, accuracy, simplicity, speed, and repetitiveness, especially in ecological potential assessment of agricultural lands with high standards, are also involved in the assessment. In similar studies only a few specific factors were evaluated in terms of ecological potential of agricultural lands.[5,18,23] The 10 most important factors in terms of impact on ecological potential of agricultural lands were selected based on the recommendations of scholars including Ceia et al.,[7] Veríssimo et al.[5], Chainho et al.,[8] and Veríssimo et al.[26] On the basis of aforementioned factors, the assessment model is more comprehensive than all of the possible ecological potential of agricultural lands in the province of Hamedan.[5,7,8,26].

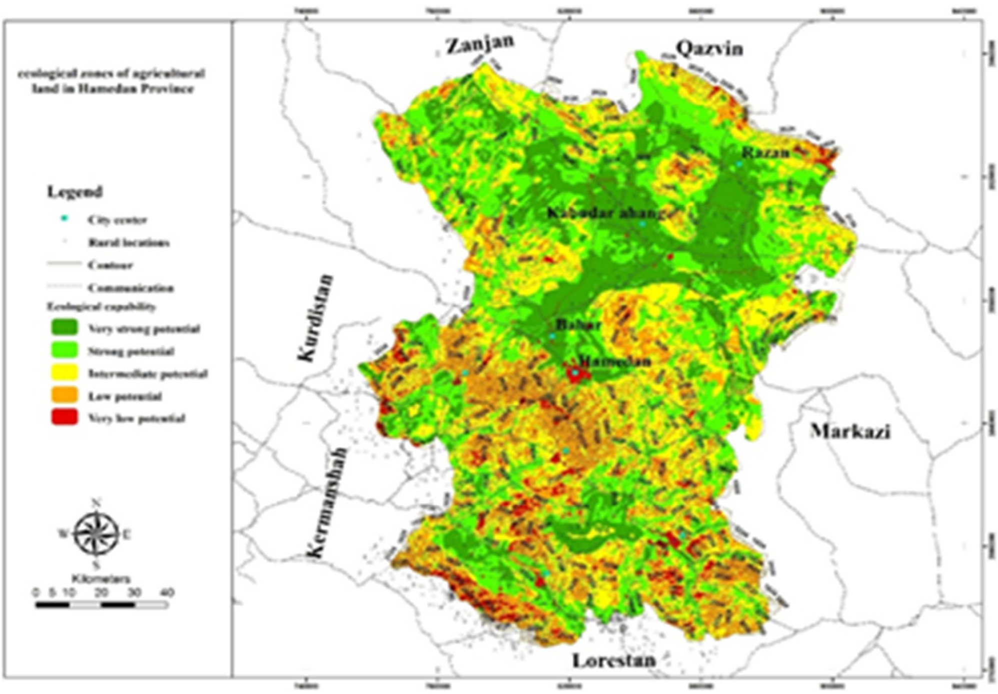

Figure 5. Ranking the ecological zones of agricultural land in the province of Hamedan

The results related to the classification of agricultural land in the province of Hamedan (Table 2) showed that the total area of 1,939,583.78 hectares of the province has immense ecological potential; 979592.33 hectares (32.51%) have very high and high capability, 549050.41 hectares (28.31%) have average capability, and 410941.04 hectares (21.19%) have low and very low ecological potential.

Table 2. Classification of areas based on ecological potential

Categories	Area (ha)	Percentage
Very high potential	393318	2.28
High potential	586274	30.23
Average potential	549050	28.31
Low potential	339381	17.50
Very low potential	71559	3.69
Total	1,939,583	100

In addition, more than 30% of agricultural land is of high ecological potential. The assessment shows the ecological status of soil in agricultural land in the province. However, if water and climate factors are considered in the province, based on the researcher's observation in the cities of Kabudarahang and Razan, Iran, more than 20% of the wells are almost dry and the depth of groundwater is also much lower than in the past. It can be argued that the ecological potential of agricultural land in the province is much lower than that presented in the classification. According to the results of "the map terrain for all types of cultivations" (Figure 6), an area of 282747.052.2 hectares of land is suitable for the cultivation of irrigated wheat. Areas suitable for irrigated wheat cultivation and other uses have also been identified in the province (Table 3).

The results showed that less than 40% of land is suitable for irrigated crops and orchards (Table 3). However, this assessment was based on soil ecological factors. If water and climate factors are also assessed, this ratio will evidently be lower.

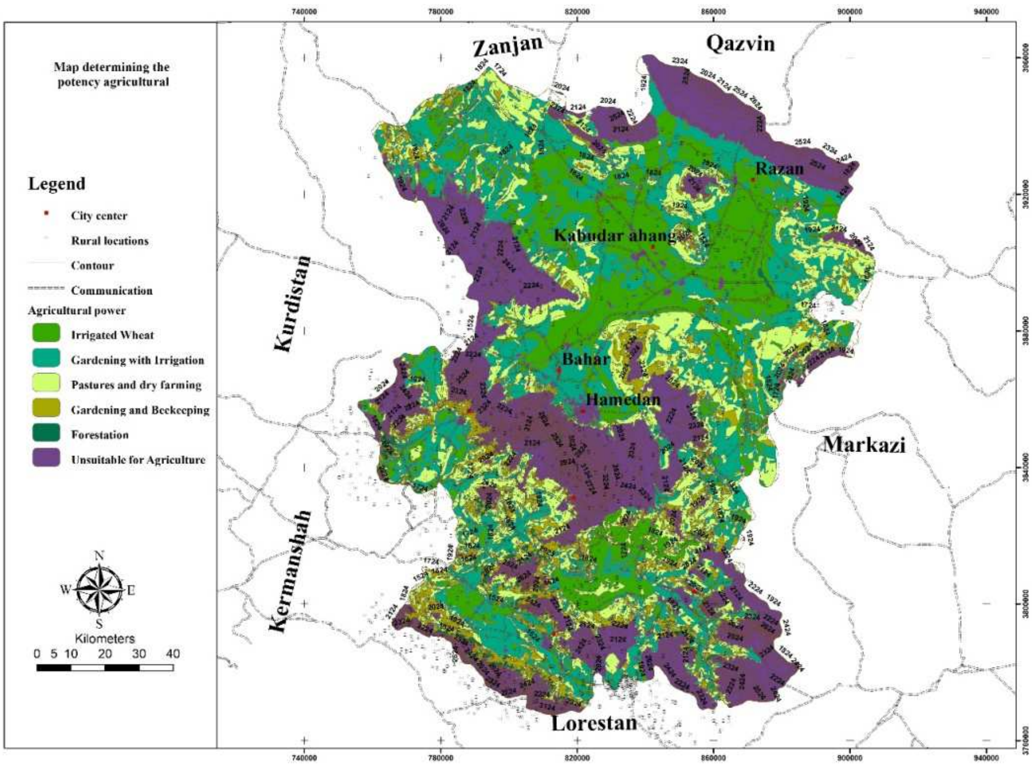

Figure 6. Map of different levels of agriculture applications

Table 3. Area of lands for various agricultural applications

Type of cultivation	Area (ha)	Percentage
Irrigated wheat	282747.052	14.58
Irrigated orchard	432876.606	22.23
Rainfed cultivation and pasture land	450034.169	23.20
Husbandry and pasture	248503.931	12.80
Forest	76599.718	3.95
Unsuitable for agriculture	448822.3011	23.14
Total	1,939,583.778	100

Conclusion

In this study, 10 factors, including soil erosion, salinity, fertility, depth, texture, slope, height, and soil grading, which affect the ecological potential of agricultural land in the province of Hamedan, were investigated. The ecological potential map of agricultural lands in the province of Hamedan was prepared according to the classification in the proposed model by Makhdom. It was found that pH, salinity, and acidity factors have the greatest impact on the ecological potential of agricultural land in the province. Mismanagement of inputs, such as fertilizers and chemical pesticides, to produce more crops and gain higher profits can account for low ecological potential. In fact, these 2 factors can also have positive or negative effects on other factors. In general, it can be said that unsuitable management of farms in recent years and wrong agricultural development policies in Iran to increase production without consideration of detrimental environmental effects has led to severe reduction of ecological potential of agricultural lands in the production of strategic crops, such as wheat, especially in the studied area.

In regards to agricultural issues, taking advantage of saline and alkaline soils is associated with a failure to absorb water and nutrients by the roots of plants and unfavorable ratio between the ion of impaired growth and yield of the plant. Since alkaline soil has very low permeability, irrigation, and drainage, these soils are particularly problematic. Furthermore, although the results show that more than 30% of agricultural lands in the province are of high ecological potential, and nearly 40% of land is suitable for irrigated corps and orchards, the fact is that this assessment has been based on ecological potential of the soil. If water and climate factors were considered, this ratio would be much lower than the estimated amount. The reason for this issue was the exploitation of the soil and water resources for the purpose of achieving more profits in a short time. Thus, conventional management of agricultural lands has led to reduced ecological potential of the soil and water.

Therefore, in order to improve and preserve the ecological potential of agricultural land, it is recommended that agricultural development policies be directed towards producing products that use less water. It is also recommended that agricultural water use efficiency be promoted through the use of sprinklers and drip systems. In addition, it is suggested that agricultural policies be directed towards the following directions: the use of green manures, reduction of the use of chemical pesticides, the use of protective tills (low-till and no-till), and promotion of ways which have the least impact on erosion, and maintain moisture and fertile agricultural lands. Thereby, ecological potential can be protected and agricultural sustainability of agricultural land resources can be increased to an acceptable level. In this regards, a comprehensive and detailed plan on administrative and technical aspects is need to achieve sustainable development in agriculture on the basis of ecological potential of lands. In this proposed plan, an optimizing scheme for the better use of land, water, pesticides, and fertilizers, increasing performance, and safeguarding the environment through the use of sound technologies (organic-based, ecologically sound manure system, and internal input) will be necessary to maintain soil productivity and potential for the future.

For future research, the comprehensive assessment of the ecological potential of agricultural lands and the climate factor (water and weather) is recommended.

Conflict of Interests

Authors have no conflict of interests.

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References

1. Barzegar A. Salt affected soils (identification and exploitation). Khuzestan, Ahvaz: Shahid Chamran University Press; 2002. [In Persian].
2. Food and Agriculture Organization of the United Nations. Fao-food and agriculture. [Online]. [cited 2009]; Available from: URL: http://www.fao.org/home/en/
3. .McHarg IL. Design with nature. Hoboken, NJ: John Wiley & Sons; 1995.
4. Reyahi Khoram M, Shariat M, Azar A, Mahjub H, Moharamnejad N. Environmental evaluation for agricultural activity by GIS; a case study. Sarhad J Agrci 2007; 23(2): 339-44.
5. Veríssimo H, Lane M, Patrício J, Gamito S, Carlos Marques J. Trends in water quality and subtidal benthic communities in a temperate estuary: Is the response to restoration efforts hidden by climate variability and the Estuarine Quality Paradox? Ecological Indicators 2013; 24: 56-67.
6. Borja A, Elliott M. What does 'good ecological potential' mean, within the European Water Framework Directive? Mar Pollut Bull 2007; 54(10): 1559-64.
7. Ceia FR, Patrício J, Franco J, Pinto R, Fernández-Boo S, Losi V, et al. Assessment of estuarine macrobenthic assemblages and ecological quality status at a dredging site in a southern Europe estuary. Ocean & Coastal Management 2013; 72: 80-92.
8. Chainho P, Silva G, Lane MF, Costa J, Pereira T, Azeda C, et al. Long-term trends in intertidal and subtidal benthic communities in response to water quality improvement measures. Estuaries and Coasts 2010; 33(6): 1314-26.
9. Saaty TL. The analytic hierarchy process: planning, priority setting, resource allocation. New York, NY: McGraw-Hill, 1980. p. 437.
10. Dashti S, Monavari M, Sabzghabaei GH. Rehahabilitations to received the rural sustainable development using environmental potential evaluation Zakherd watershed. Environmental Sciences 2009; 6(2): 77-86. [In Persian].
11. Parvaresh H, Dehghani M, Nohegar A. The comparison of physical per ECA ration (geomorphology), and methods for assessing the ecological capability of watershed land in the province of Hormozgan. The Journal of Land Assessment 2010; 2(2): 27-50. [In Persian].
12. Movahed A, Zadeh Dabagh N. Ecological potential evaluation of Dez river confine (Tanzimi sluice than Ghire sluice) for ecotourism. Journal of Environmental Studies 2010; 36(55): 4-6.
13. Norouzi Avargani A, Nouri SH, Kiani Selmi S. Evaluation of environmental capacities for agricultural development? (Case study: Choghakhor rural district, Borujen Township). Journal of Rural Research 2010; 1(2): 9-116. [In Persian].
14. Moradzadeh F, Babaei-Kafaki S, Mataji A. Assessment of ecological competence of surface expansion through GIS (case study: Dadabad District in Lorestan Province). Renewable Natural Resources Research 2011; 2(4): 11-23. [In Persian].
15. Gharakhlou M, Pourkhabbaz HR, Amiri MJ, Faraji HA. Ecological capability evaluation of Gazvin region for determining urban development potential points using geographic information system. Urban a Regional Studies and Research 2009; 1(2): 51-68. [In Persian].
16. Ashrafi A, Mikaniki J, Dehghani M. Agro- ecological zoning and evaluation of ecological potencies of south khorasan for jujube plantation. Journal of Geographic Space 2013; 3(7): 67-86. [In Persian].
17. Martins I, Pardal MA, Lillebo AI, Flindt MR, Marques JC. Hydrodynamics as a major factor controlling the occurrence of green macroalgal blooms in a eutrophic estuary: a case study on the influence of precipitation and river management. Estuarine, Coastal and Shelf Science 2001; 52(2): 165-77.
18. Marques JC, Neto JM, Patrício J, Pinto R, Teixeira H, Veríssimo H. Monitoring the Mondego estuary. [Online]. [cited 2007 Jan]; Available from: URL: http://scholar.google.nl/citations?view_op=view_citation&hl=nl&user=la84roQAAAAJ&citation_for_view=la84roQAAAAJ:ufrVoPGSRksC
19. Hering D, Borja A, Carstensen J, Carvalho L, Elliott M, Feld CK, et al. The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. Science of the Total Environment 2010; 408(19): 4007-19.
20. Noori H, Seidaei E, Kiani S, Soltani Z, Norouzi A. Assessment of ecologic environmental sources for determining rich farmland by GIS (central district of Kiar Sub County). Geography and Environmental Planning 2010; 21(1): 77-94. [In Persian].
21. Meire P, Ysebaert T, van Damme S, van den Bergh E, Maris T, Struyf E. The Scheldt estuary: a description of a changing ecosystem. Hydrobiologia 2005; 540(1-3): 1-11.
22. McLusky DS, Elliott M. The estuarine ecosystem:

ecology, threats, and management. 3rd ed. Oxford, UK: Oxford University Press; 2004. p. 216.
23. Paerl HW. Assessing and managing nutrient-enhanced eutrophication in estuarine and coastal waters: Interactive effects of human and climatic perturbations. Ecological Engineering 2006; 26(1): 40-54.
24. Fredriksen S, de Backer A, Boström C, Christie H. Infauna fromZostera marina L. meadows in Norway. Differences in vegetated and unvegetated areas. Marine Biology Research 2009; 6(2): 189-200.
25. Rasouli AA, Ghasemim K, Sobhani B. The role of precipitation and elevation in determine of the favorable area for dry-farming wheat with usage of GIS study case: Ardabil province. Geography and Development Iranian Journal 2005; 3(5): 183-200.
26. Veríssimo H, Bremner J, Garcia C, Patrício J, van der Linden P, Marques JC. Assessment of the subtidal macrobenthic community functioning of a temperate estuary following environmental restoration. Ecological Indicators 2012; 23: 312-22.