Research Article

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Ecological zoning for wheat production at province scale using geographical information system

Abstract

In the recent study, ecological zoning of wheat has been determined using Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) methods in Golestan province located in north of Iran. At first, agro ecological requirements of crop was identified from scientific resources then classified and required thematic maps were provided. In this study environmental components were including: average, minimum and maximum temperatures, precipitation, slope, slope aspects, elevation and soil characteristics such as organic matter, pH, EC, texture, nitrogen, phosphorus, potassium, calcium, iron and zinc. The AHP was used to determine the weight of criteria. The digital environmental layers overlaid and integrated in GIS media then zoning of lands was done in 4 classes, including highly suitable, moderately suitable, less suitable and not-suitable. The results showed that south and southwestern areas were highly suitable and moderately suitable for wheat cultivation. These zones had enough rainfall (>400mm) and high fertility. The less suitable and non-suitable regions are located in the north and northeast parts of Golestan province. In these areas the limitation factors were including: high EC, low precipitation and deficient of nutrition elements.

Keywords: analytical hierarchy process, ecological zoning, geographic information system, golestan province, wheat

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Abbreviations: GIS, geographic information system; AHP, analytical hierarchy process; MCE, multi criteria evaluation; SLA, simple limitation approach; IDW, inverse distance weighted; DEM, digital elevation model; IR, inconsistency ratios; TOPSIS, technique for order of preference by similarity to ideal solution; NS, non suitable; S1, highly suitable; S2, moderately suitable; S3, less suitable

Introduction

The problem of selecting the correct land for the cultivation of a certain agriculture product is a long-standing and mainly empirical issue. The increased need for food production and the shortage of resources stimulate a need for sophisticated methods of land evaluation to aid decision makers in their role to both preserve highly suitable lands and satisfy producers demand for increased profit.[1] Land suitability analysis is a prerequisite for sustainable crop production. Crops grow best in locations where the climatic conditions meet their growth requirements. Elevation, slope, aspect, soil, land cover and many climatic factors that affect crop growth, help in determining the most suitable crop growth areas. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a defined use.[2]

The suitable areas for agricultural use are determined by an evaluation of the environmental components and the understanding of local biophysical restraints. The topographic characteristics climatic conditions and the soil quality of an area are the most important determinant parameters of the land suitability evaluation. The use of GIS allows the construction of models from which a new thematic map (e.g. land suitability map) can be produced from a set of thematic maps.[3] In recent years GIS has provided much required spatial dimension to natural resource management and planning. GIS technology is useful for integration of bio-climate, terrain and soil-resource-inventory information.[4]

In this kind of situation, many variables are involved and each one should be weighted according to their relative importance on the optimal growth conditions for crops through Multi Criteria Evaluation (MCE) and GIS. One of the most useful features of GIS is the ability to overlay different layers or maps. However, the overlay procedure does not enable one to take into account that the underlying variables are not equally important.[5] One approach that can help overcome such limitations is MCE which has received renewed attention within the context of GIS-based decision making. The objective of using MCE models is to find solutions to decision making problems characterized by multiple alternatives, which can be evaluated by means of decision criteria.[6] Deriving weight for the selected map criteria (i.e. land characteristics map layers) is the base requirement for applying the Fuzzy, Analytical hierarchy process (AHP) and TOPSIS methods.[7]

Analytical hierarchy process (AHP) was first developed by Thomas Saaty[8] and has been modified by various researchers. AHP since its invention has been a tool at the hands of decision makers and researchers and it is one of the most widely used multiple criteria decision making tools. This technique based on ranking and importance of factors affecting on goal by attributing relative weight to factors with respect to comments provided in the questionnaires. Many outstanding works have been published based on AHP: they include applications of AHP in different fields such as planning, selecting best alternative, resource allocations, resolving conflict, optimization, etc and numerical extensions of AHP.[9]

Bhagat et al.,[2] analysis land suitability for cereal production in Himachal Pradesh (India) using GIS. In this study different parameters viz. climatic (precipitation and temperature), topographic (elevation), soil type and land cover/land use have been used in order to perform land suitability evaluation for cereals food grain crops. Also in comparison to the actual area under cereal crops the possibility of further expansion under each cereal crop was determined. These discriminated areas appear suitable for growing these crops and can be harnessed efficiently for achieving long term sustainability and food security. Land suitability analysis for rice cultivation based on multi-criteria decision approach through GIS carry out in Morobe province in the Papua New Guinea. This province has been classified into five categories of rice suitability. The result indicated that only four percent (4%) land can be demarcated as high and 21% as medium high suitability categories in the study area.[10] A multi-criteria evaluation (MCE) approach, within a GIS environment was used to identify suitable areas for oat (Avena sativa L.) crop production in Central Mexico. Fuzzy membership function was used to generate standardized factor maps. According to the weighting vectors the results indicated that the most important variables affecting the growth of an oat crop were precipitation, altitude and soil depth. This research provided information at regional level that could be used by farmers to select crop pattern and suitability.[11] Agricultural land use suitability analysis of Yusufeli district in Turkey has been carried using GIS and AHP. Results of this study showed that the soil depth is inadequate for agricultural production. In addition the slope in the area and therefore erosion degree is too high.[12]

For land suitability analysis rice, mustard, potato and wheat crops which were prominent in the Bogra district of Bangladesh. To standardize all of the factors for the MCE the AHP method was used. The results of the suitability analysis depicted that in the study area the land was highly to moderately suitable for the crops. Optimal cropping patterns for the flood and post flood season based on crop suitability and expert knowledge indicated that the rice-wheat/potato, rice (late sowing)-potato, rice-potato and rice- mustard combinations were found the most suitable suggested pattern for the study area.[13] Ghasemi Pirbalouti et al.,[14] evaluated agro climatologically variables to identify suitable areas for rapeseed in different dates of sowing by GIS. This study carried out in two provinces (Isfahan and Chaharmahal va Bakhtyiari), central and southwest of Iran. The results indicated that the main limited factors are GDD from sowing to physiological maturity and sowing to freezing start day. The overlay maps for climate variables and DEM suitability evaluation using SLA identified 11.2% (sowing date: 20 August to 5 September), 12.5% (sowing date: 6 September to 20 September), 0.4% (sowing date: 21 September to 5 October) and 0.06% (sowing date: 6 October to 20 October) of the surface area land had suitable in study area.

One of the most important areas for crops production in Iran is the Golestan province. The present study was therefore carried out with the objective of ecological zoning for wheat production using GIS and AHP in agricultural fields at province scale in the Golestan.

Materials and methods

Study area

This research was conducted in northern part of Iran, in Golestan province during the 2012. This province with an area of 20,033km² is located in the southeast of Caspian Sea between 36º44´ and 38º 5´ north latitude and 53˚ 51´ and 56º 14´east longitude (Figure 1). It covers

about 1.3% of the total area of the country. It has 270km² international borders with Turkmenistan at the north. Also it is situated in the vicinity of Semnan, Mazandaran and Northern Khorasan provinces on the south, west and east respectively. The eastern extension of Alborz Mountains Range surrounds the coastal plains of the Caspian sea as a high and long wall, thus all over the province the land slope decreases from the southern and eastern mountains towards sea with altitude ranging between -25 to 3000m. The some important townships of this province are Gonbad e Kavoos, Minoodasht and Gorgan with an area of 6856.8 km², 6485.6km² and 2848km² respectively. The climate of this province is under the influence of Alborz Mountains, Caspian Sea, the southern wildernesses of Turkmenistan, and forests. According to De-Martonne advanced climate classification system the province contains five different climates: Mediterranean in center, arid-desert in north, semi-arid in coast, center and northeast, humid in sub-south and semi humid in south.
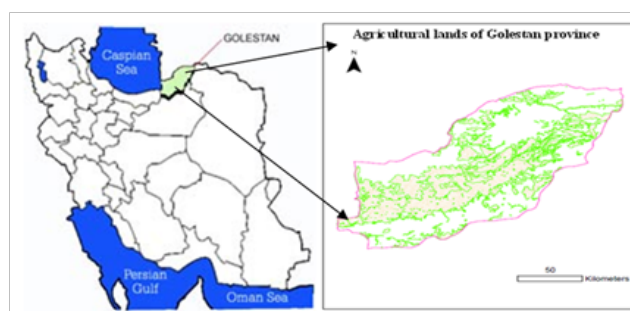

Figure 1 Location of the study area, Golestan province, Iran.

Ecological zoning

In order to ecological zoning of current agricultural lands in Golestan province for wheat cultivation, were used to match the environmental requirements of crop and the land characteristics. Schematic diagram of ecological zoning is shown in (Figure 2). At first agroecological requirements of wheat were identified from scientific resources and local expert's opinion then classified (Table 1) and needed thematic maps were provided. With allocation of AHP weight for any criteria, the digital environmental layers overlaid and integrated in GIS media by raster calculator functions (ArcGIS software, ver.9.3) then zoning of lands was done in 4 classes, including: highly suitable (S1), moderately suitable (S2), less suitable (S3) and non-suitable (NS). This system was based on matching between land qualities/characteristics and crop requirements. Highly suitable, moderately suitable and less suitable lands were expected to have a crop yield of 80-100%, 60-80% and 40-60% of the yield under optimal conditions with practicable and economic inputs, respectively. Non-suitable land was assumed to have severe limitations which could rarely or never be overcome by economic use of inputs or management practices.[1,2,4,15–20]

Data collection and analysis

In this study, various physical resources such as soil, climate and topography had been evaluated. Soil samples were randomly taken from 505 locations in May 2010. Samples were taken at depths of 0-30cm and air-dried to remove stones and coarse crop residues. Three samples from each sampling site were collected from the surface soil layer and samples were thoroughly mixed and one sample ground to pass a sieve, then stored in plastic bags prior to analysis. In this research, the spatial distribution of soil characteristics on agricultural lands of Golestan province were evaluated using different

geostatistical and interpolation methods such as Kriging and Inverse Distance Weighted (IDW). Climatic data obtained from Golestan meteorological stations. The rainfall and temperature data of the whole state and for 15years were used to interpolate and mapping of annual rainfall, annual average, maximum and minimum temperature by IDW method. In this research, topographical maps including slopes, slope aspect and elevation are used to ecological zoning. We used a digital elevation model (DEM) of Golestan province to mapping these factors in 1:50000 scale.

Analytical hierarchy process (AHP)

The AHP process, which was developed by Saaty,[21] is a multi-criteria decision-making approach where factors are arranged in a hierarchy structure. Some criteria were selected and used in order to identify the most suitable area for wheat production which is shown in (Figure 3).

The weight of factors for ecological zoning was obtained from local experts, through a pairwise comparisons statistical analysis in Expert Choice software (ver. 2000). Local experts in Golestan province have used their experience to generate weights for land characteristics for wheat. The Inconsistency Ratios (IR) for this pairwise comparison matrix was equal to 0.1. This shows that the comparisons of land characteristics were perfectly consistent, and the relative weights were appropriate for applying in land suitability analysis use AHP. In this study, the factors were ranked according to Saaty[22] underlying scale with values 1 to 9 by discussion with local crop specialist. Table 2 shows the ranking of the different classes to the different parameters.

Table 1 Criteria for delineating land suitability of wheat in Golestan province, Iran

| Features	Highly Suitable (S1)	Moderately Suitable (S2)	Less Suitable (S3)	Non-Suitable (NS)
Precipitation (mm)	400≤	300-400	200-300	<200
Average temperature(°C)	16-20	12-16 and 20-24	8-12 and 24-30	<8 and >30
Minimum temperature(°C)	10-15	7-10	4-7	<4
Maximum temperature(°C)	20-25	25-30	30-37	>37
EC(dS.m^{-1})	0-4	4-8	8-12	>12
pH	6.5-7.5	5.5-6.5 and 7.5-8.5	5-5.5	<5.5
Soil texture	loam , clay loam - clay and silty clay loam	sandy loam and sandy clay loam	Loam sandy , silty loam, sandy clay and silty clay	sandy
Slope (%)	0-4	4-8	8-12	>12
Slope aspects	south, southeast and no direction	east and northeast	southwest and northwest	west and south
Elevation(m)	1-1000	1000-2000	2000-3000	>3000
Fe (ppm)	10-15	15-18 and 8-10	18-20 and 5-8	<5 and >20
Zn (ppm)	0.9-1.1	1.1-2	2-6	>6 and <0.9
Ca (ppm)	5-15	15-25	25-50	and >50 <5
P (ppm)	10-12	7-10 and12-15	5-7 and 15-18	<5 and >18
K (ppm)	200-250	150-200 and 250-300	100-150	<100
Organic Matter (%)	≥3	2-3	1-2	<1
N (%)	1≤	0.7-1	0.5-0.7	0.5>

References.[1,2,4,16–20]
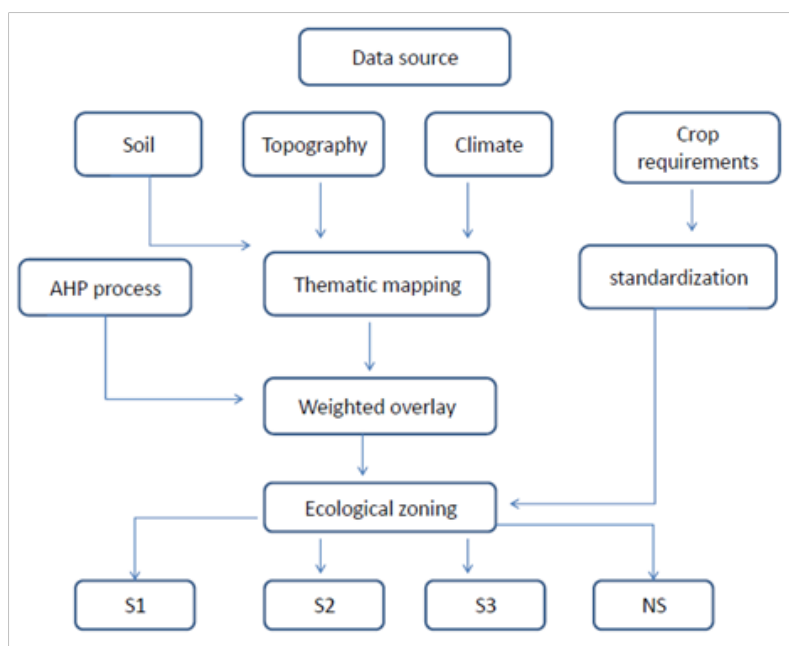
Figure 2 Schematic diagram of ecological zoning for wheat in Golestan province, Iran.
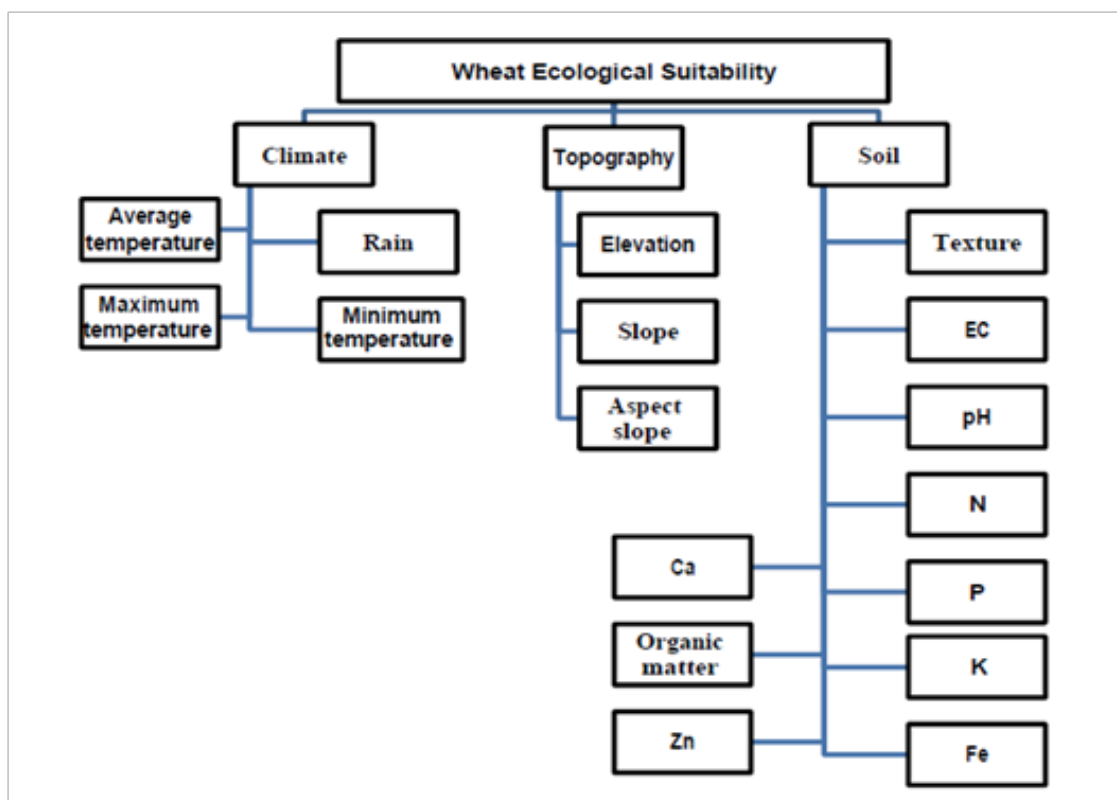

Figure 3 Hierarchy structure of suitability evaluation index of wheat in Golestan province, Iran.

Table 2 Explanation of the standard nine-point preference scoring system used for the AHP

Preference score	Explanation of numerical preference score
1	Two attributes preferred equally
3	Judgment slightly favors one attribute over another
5	Judgment strongly favors one attribute over another
7	Judgment very strongly favors one attribute over another
9	Extreme preference of one attribute over another

Result and discussion

Results of AHP questionnaires analysis showed that the among of factors influencing in wheat ecological zoning, climate (0.495) and topography (0.138) criteria had the highest and least weight, respectively. Also, among of the climate criteria, rain and maximum temperature had the highest and lowest weight, respectively. The results of AHP showed that in Table 3. Organic matter and nitrogen under soil factor had the highest importance. Also, results showed that soil texture and EC are more important in ecological zoning of wheat in Golestan province. In general combining the potential of GIS with AHP analysis enables us to understand the potential value of the wheat production in this province.

Suitability evaluation was the first important step for sustainable resource exploitation of wheat cropping fields. Our results show that most areas of Glestan province are suitable for wheat production (Figure 4). Table 4 shows that 23.4% and 29.35% of the study area are highly suitable (S1) and moderately suitable (S2) respectively. As shown in this table most of area was determined as moderately suitable (S2) class.

Proper land management practices, leaching, drainage, land preparation crop rotation, specific irrigation methods and using resistant crop help to increase crop yield in this area. Wheat is actually grow in 385380 ha area in this province, the results from present study indicated that the potential area where wheat can be successfully cultivated in 41927.7 ha, hence 7.6% more area can be put under wheat cultivation. It is found that the most areas of south western and southern parts of Golestan province are the highly suitable regions (Figure 5), (Figure 6). Highly suitable areas were characterized by precipitation >400mm during the crop growth cycle, elevation levels between 0-1000m, slope 4%, soil pH level between 6.5-7.5, EC<4dS.m^{-1}, organic matter amounts between 2-3% and soil texture classes of loam, clay loam and silt clay loam. Therefore, the highly suitable (S1) areas have a high potential production and sustainability of yield from year to year.[15] The results showed that the topography and climatic characteristics (temperature and precipitation) of this region were suitable for wheat growth. Norwood[23] concluded that in zoning of Kansas state for wheat, precipitation and evaporation are most effective factors compared to other climatic factors during the growth stages of wheat.
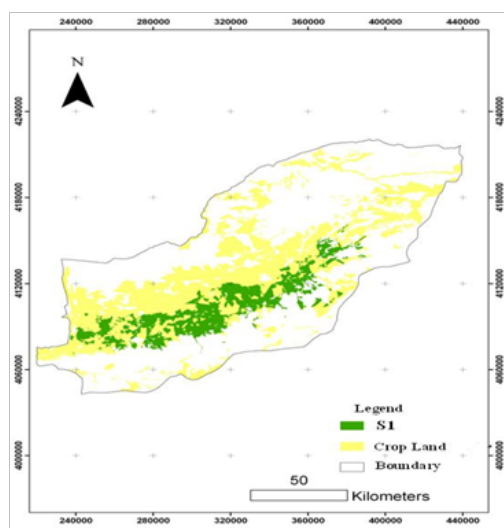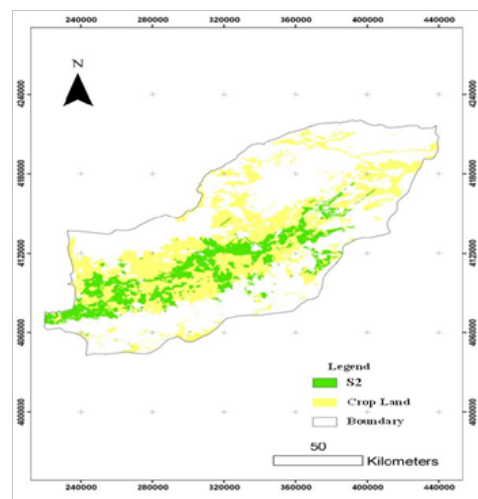
The results of this study indicate that the largest parts of the study area were classified as less suitable (S3) and non-suitable (NS) for wheat cultivation (Table 4). Lands with low suitable and non-suitable are seen scattered in parts of northern and eastern of province (Figure 7), (Figure 8). In these areas, dryland wheat production is associated with risk. This research results indicated that the main limited factors in these area, are high EC and low rainfall, organic matter, and deficient of nutrition elements such as P, Fe and Zn. The area of less suitable zone (S3) was about 27.86% of the whole areas of province (Table 4). It seems that with remove restrictions such as soil fertility, suitability level can enhance in this zone. Furthermore, cropping of wheat in these areas will not only increase yield, but also reduce environmental resources. Ashraf et al.,[16] announced that the salinity, exchangeable sodium and gravel were most important limiting factors for growth of irrigated wheat in Damghan plains (center of Iran), also this area was unsuitable for rainfed wheat. Briza et al.,[24] also suggested that the most limiting factors of the land suitability in the province of Ben-Slimane, Morocco, in wheat and barley productions, included physical characteristics such as soil texture, soil depth and slope.

Table 3 The results of AHP and important of criteria in ecological zoning of wheat in Golestan province, Iran

Criteria/Sub criteria	Weight	Rank	Criteria/Sub criteria	Weight	Rank
1-Climate	0.495		**3- Soil**	0.365	
Rain	0.561	1	EC	0.132	3
Maximum temperature	0.113	4	pH	0.083	7
Average temperature	0.204	2	N	0.14	2
Minimum temperature	0.123	3	Organic Matter	0.24	1
			Texture	0.103	4
2- Topography	0.138		P	0.093	5
Aspect slope	0.224	3	K	0.086	6
Slope	0.39	1	Ca	0.042	8
Elevation	0.252	2	Fe	0.038	9
			Zn	0.042	8
IR 0.02					

Table 4 Suitability level for wheat production in Golestan province, Iran

Zone	Area (ha)	Zone area/province area (%)
S1	184243.9	23.44
S2	230683.7	29.35
S3	219000	27.86
NS	151864.4	19.35
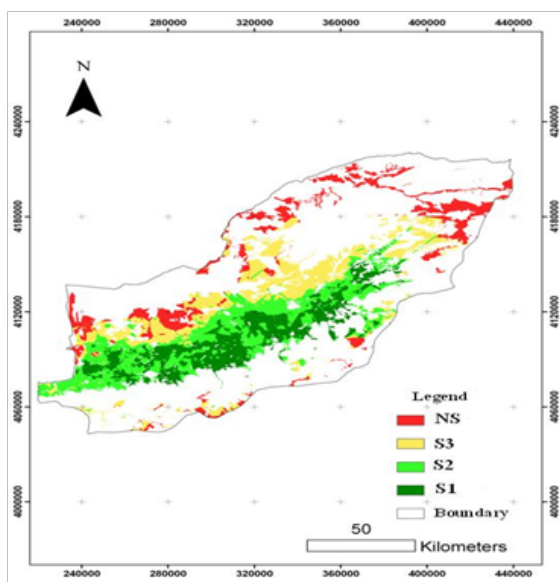
Figure 4 Ecological zones for wheat production in agricultural lands of Golestan province, Iran.

Figure 6 Moderately suitable zone (S2) for wheat production in agricultural lands of Golestan province, Iran.

Figure 5 Highly suitable zone (S1) for wheat production in agricultural lands of Golestan province, Iran.
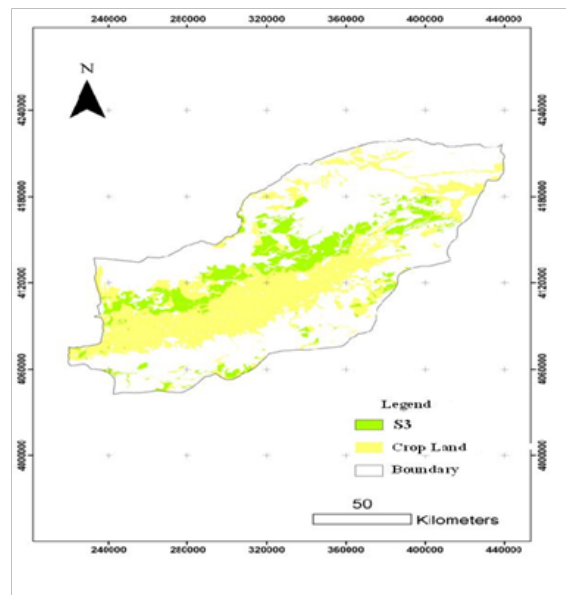
Figure 7 Less suitable zone (S3) for wheat production in agricultural lands of Golestan province, Iran.
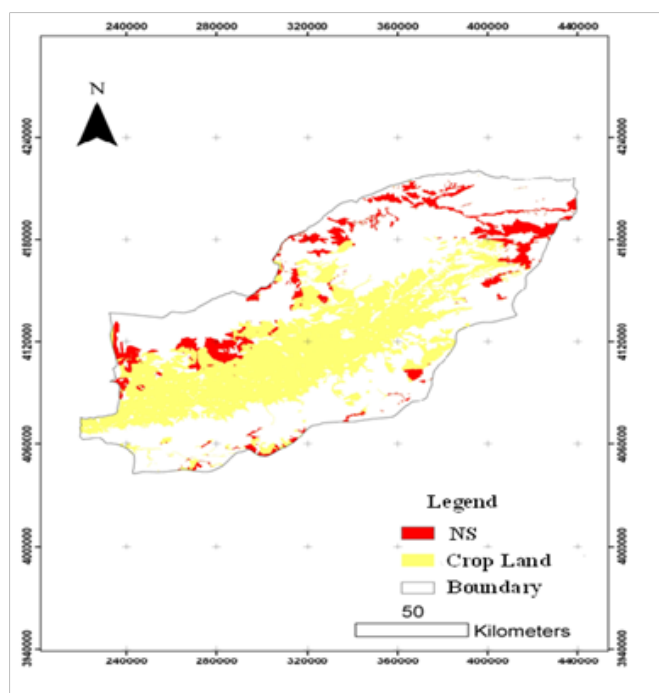
were located in parts of northern and eastern of province. In general, in highly suitable (S1) and moderately suitable (S2) zones, the other factors such as social-economic were also better than other zones. This research provides information at local level that could be used by farmers to select cropping patterns in accordance with suitability.

Conflict o interest

The author declares no conflict of interest.

Figure 8 Non-suitable zone (NS) for wheat production in agricultural lands of Golestan province, Iran.

Wheat is one major crop in Golestan province. Its production is an important source of income for many farmers. Salinity is a serious problem in cropland of north of Golestan. In general, soil salinity assessment is one of the important components in agriculture management and water allocation strategies.[25,26] Salt balance in plant root zone depends on irrigation water requirement, quality of water, irrigation scheduling and on overall soil and climatic conditions.[27] In addition, the variability of soil salinity could be high in regions with a great variety of microclimate. Note that Golestan province is a region where the climate changes from the south to the north and thus rainfall varies from 250mm to 700mm per year. It is clear; therefore that analysis of soil salinity is essential for understanding the environmental degradation processes in the province. The mitigation and control of soil salinity is one of the main challenges in the agriculture, particularly where irrigation is used.[28]

Conclusion

The present study provides a methodological approach to assessing the suitability of agricultural fields for wheat cropping. This study uses the GIS and AHP for ecological zoning of wheat production in Golestan province. This methodology combines ecological data with expert judgments for suitability mapping. The topographic characteristics, climatic conditions and soil conditions were the most important determinant parameters of this evaluation. This suitability is a function of crop requirements and land characteristics. In order to matching the land characteristics with the crop requirements gives the suitability.[29] Our results show that most areas of Glestan province (63%) are suitable for wheat production (S1, S2 zones). It is found that the most areas of south western and southern parts of this province are the highly suitable regions. Lack of suitable rain and soil salinity, some soil physics properties and poor soil fertility were the most serious problems influencing yield and quality of wheat. These lands

References

1. Kalogirou S. Expert systems and GIS:an application of land suitability evaluation. *Computers, Environment and Urban Systems*. 2001;26(2–3):89–112.

2. Bhagat RM, Singh S, Sood C, et al. Land suitability analysis for cereal production in Himachal Pradash (India) using Geographical Information System. *Journal of Indian Society of Remote Sensing*. 2009;37(2):233–240.

3. Al–Mashreki MH, Akhir JBM, Rahim SA, et al. Land suitability evaluation for sorghum crop in the Ibb governorate, Republic of Yemen, using remote sensing and GIS techniques. *Aus J Basic & Appl Sci*. 2011;5(3):359–368.

4. Sarkar A. *Geo–spatial approach in soil and climatic data analysis for agro–climatic suitability assessment of major crops in rainfed agro–ecosystem*. Indian Institute of Remote Sensing (IIRS), Agriculture and Soils Division, Master of Science, Dehradun, India: Andhra University; 2008.

5. Janssen R, Rietveld P. Multi–criteria analysis and geographical information systems: An Application to Agriculture Land Use in The Netherlands. In: Scholten HJ, et al. editors. *Geographical Information Systems for Urban and Regional Planning*. Netherlands, USA: Springer Netherlands; 1990. p. 129–139.

6. Jankowski P, Andrienko N, Andrienko G. Map–centered exploratory approach to multiple criteria spatial decision making. *Int J Geographical Information Science*. 2001;15(2):101–127.

7. Malczewski J. *GIS and Multi–criteria Decision Analysis*. New York, USA: Wiley; 1999.

8. Saaty TL. A scaling method for priorities in hierarchical structures. *J Math Mathematical Psycholgy*. 1977;15(3):234–281.

9. Vaidya OS, Kumar S. Analytic hierarchy process:an overview of applications. *European Journal of Operation Research*. 2006;169(1):1–29.

10. Samanta S, Pal B, Kumar D. Land suitability analysis for rice cultivation based on multi–criteria decision approach through GIS. *Int J Sci Emerg Tech*. 2011;2(1):12–21.

11. Ceballos–Silva A, Lopez–Blanco J. Evaluating biophysical variables to identify suitable areas for oat in Central Mexico:a multi–criteria and GIS approach. *Agriculture Ecosystems Environment*. 2003;95(1):371–377.

12. Akinci H, Ozalp AY, Turgut B. Agricultural land use suitability analysis using GIS and AHP technique. *Computers and Electronics in Agriculture*. 2013;97:71–82.

13. Rahman R, Saha SK. Remote sensing, spatial multi criteria evaluation (SMCE) and analytical hierarchy process (AHP) in optimal cropping pattern planning for a flood prone area. *J Spatial Science*. 2008;53(2):161–177.

14. Ghasemi Pirbalouti A, Golparvar A. Evaluating agro–climatologically variables to identify suitable areas for rapeseed in different dates of sowing by GIS approach. *American Journal of Agricultural and Biological Sciences*. 2008;3(4):656–660.

15. Ghafari A, Cook HF, Lee HC. Integrating climate, soil and crop information:a land suitability study using GIS. 4th International Conference on Integration GIS and Environmental Modeling (GIS/EM4), 2–8 September, Banff, Alberta, Canada; 2000.

16. Ashraf S, Munokyan R, Normohammadan B, et al. Qualitative land suitability evaluation for growth of wheat in northeast of Iran. *Research Journal of Biological Sciences*. 2010;5(8):548–552.

17. Choudhury S, Saha SK. Cropping pattern change analysis and optimal landuse planning by integrated use of satellite remote sensing and GIS. *Indian Cartographer*. 2003. p. 111–123.

18. Gool DV, Tille P, Moore G. *Land evaluation standards for land resource mapping*. 3rd ed. Department of Agriculture Government of Western Australia; 2005. 137 p.

19. Martin D, Saha SK. Land evaluation by integrating remote sensing and GIS for cropping system analysis in a watershed. *Research Communications*. 2009;96(4):569–575.

20. Sys I, Van–Ranst E, Debveye J. Land evaluation, part1:principles in land evaluation and crop production calculations. *General Administration for development Cooperation*. NO. 7, Brussels, Belgium: Agricultural Publications; 1991.

21. Saaty TL. The Analytical Hierarchy Process, Planing, Priorty, Pittsburgh, Resource Allocation, USA: RWS Publications; 1980.

22. Saaty TL. *Decision Making for Leaders*. Pittsburgh, Pennsylvania, USA: RWS Publications; 2012. 315 p.

23. Norwood CA. Dry land winter wheat as affected by pervious crops. *Agron J*. 2000;92(1):121–127.

24. Briza Y, Delionardo F, Spisni A. Land evaluation in the province of Ben Sliman, Morocco. In: *21st Course Professional Master*. Remote Sensing and Natural Resources Evaluation, 10 Nov 2000 – 22 June 2001, Italy: IAO Florence; 2001;21:62–78.

25. Brady NC, Weil RR. *The Nature and Properties of Soil*. Upper Saddle River, New Jersy, USA: Prentice Hall; 2001.

26. Gawel LJ. *A guide for remediation of salt/hydrocarbon impacted soil*. Bismarck, ND: North Dakota Industrial Commission, Ponca City, Oklahoma, USA: Department of Mineral Resources; 2009.

27. Ashraf, Manoukyan R, Ayoubi Sh. Land suitability evaluation for irrigated barley in Damghan plain, Iran .*Pak J Biol Sci*. 2011;14(2):123–127.

28. Pisinaras V, Tsihrintzis VA, Petalas C, et al. Soil salinization in the agricultural lands of Rhodope District, northeastern Greece. *Environ Monit Assess*. 2010;166(1–4):79–94.

29. Prakash TN. *Land suitability analysis for agricultural crops: A Fuzzy multucriteria decision making approach*. Master of Science, International Institute for Geo–Information Science and Erath Observation. Enschede, The Netherland; 2003.