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Qualitative evaluation of land suitability for wheat in Northeast-Iran Using FAO methods

Shahram Ashraf[1] and Behnam Normohammadan[2]

[1]*Department of Soil Science, Faculty of Agriculture, Armenian State Agrarian University, Armenia.*
[2]*Department of Chemistry, Damghan Branch, Islamic Azad University, Damghan, Iran.*
shahram_ashraf@yahoo.com

Abstract

In the recent study, land suitability evaluation for wheat has been determined using FAO methods in Damghan plain located in Semnan province of Iran. This study was carried out in an area including 5400 ha in the southern part of Damghan city in the form of surveying at a semi-detailed level. In study area, two orders including Aridisols and Entisols, three families and nine soil series were identified. The results showed that the climatic characteristics of the region were suitable for wheat growth. The main important limiting factors of land characteristics were soil physics properties, salinity and alkalinity. Assessment of the results by means of the two methods- Simple limitation and Square Root showed a close mutual correlation and only in case of Storie method, the number of land classes were much lower than in other methods. This study suggests that the use of Simple Limitation method and Square Root is more appropriate for evaluation of the qualitative land suitability than others.

Keywords: land suitability; wheat; Damghan plain; Square Root method; Simple Limitation method, Iran

Introduction

The growing rates of population, the conversions of prime farmlands, consumption and undervaluation of ecosystem services have caused irreversible losses, alteration of biogeochemical cycles and pollution of water, air and soil. Proper recognition of land abilities and allocation of them to the best and most profitable and stable revenue operation system has critical importance for preventing of ecosystem destruction. With the increase of demand for land, land evaluation has become more important as people strive for better utilization of the limited land resources. Land evaluation is the process of assessing land performance for specified purposes (Rossiter, 1996). Detailed soil spatial data is required for various environmental modeling and land management application (Burrough,1996). The most critical limitations of the current soil survey include uncertainties regarding the presence of inclusions, the lack of mechanism to quantify spatial variability and the assignment of properties derived from typical pedons to the entire map unit regardless of the inherent spatial and temporal variability of field soils (Breeuwsma *et al.*,1986). There are a number of methods for land suitability evaluation such as FAO methods. FAO guidelines on the land evaluation system (FAO, 1976, 1985) were widely used for the land suitability. This system was based on matching between land qualities/characteristics and crop requirements. Physical land evaluation methods (Sys *et al.*,1991) are crucial for evaluating potentials and constraints of land for an intended land use. Ogunkunle (1993) used FAO framework for evaluation of land suitability for coconut production in southern part of Nigeria. According to this method, climatic factors such as temperature and precipitation were suitable for coconut production. Chinene and Situmbanauma (1988) showed that some of the soil parameters including fertility and the amount of oxygen available to the root can be limiting factors for crop production using FAO guideline. Menjiver *et al.* (2003) evaluated the land suitability for olive plant in the Spain. They selected 35 pedons in the study area and used 6 methods for land evaluation. Their findings based on FAO guideline indicated that the limited factors in the study area were the high level of soil moisture and the intensity of slope. In this system, all areas were settled in the N_1 class (corrigible non-suitable). Wheat is one of the major crops in Damghan Plain and its production generates a prominent source of income for

Fig.1. Location map of the study area in Northeast of Iran (Semnan province)

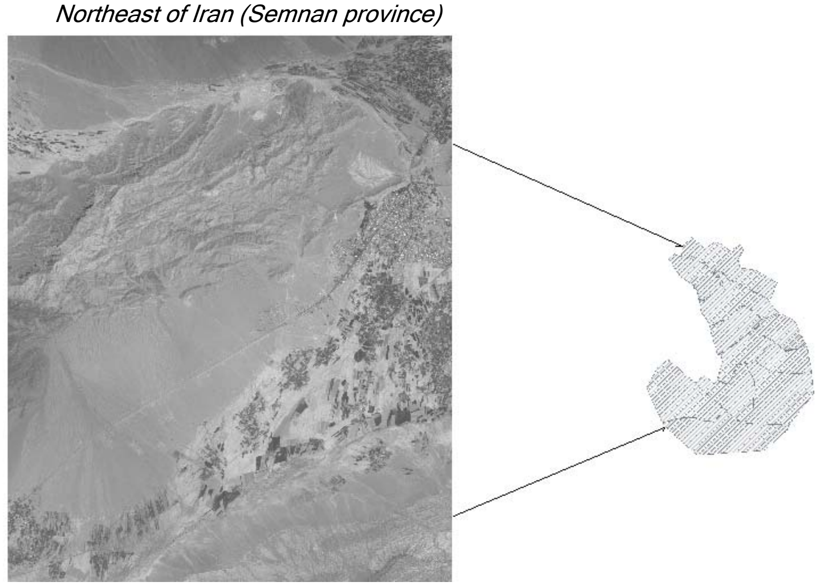

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Table 1. Determine classes of land suitability for FAO methods

Symbol	Description	Land index
S1	(highly suitable)	75-100
S2	(moderately suitable)	50-75
S3	(marginally suitable)	25-50
N1	(permanently unsuitable)	12.5-25
N2	(permanently unsuitable)	0- 12.5

Table 2. Growth periods and development stages of crops in study area

Crop	Initial stage	Development stage	Mid-season stage	Late season stage
Wheat	1 Nov -21 Nov	Nov-10Apr	10Apr-10May	10 May-21Jun

Table 3. Rating of climatic factors for wheat crop in Damghan plain

Climatic properties	Rating	Simple limitation	Parametric rating
Mean temp of growth	11.42	S2	77.75
Mean temp of vegetative stage	7.12	S1	90.6
Mean temp of or flowering stage	17.97	S1	97.48
Mean temp of for ripening stage	23.13	S1	99.45
Mean daily min temp coldest month	7.85	S1	100
Mean daily max temp coldest month	-1.075		
Climatic Index	Storie square root		77.75 77.75
Climatic rating	Storie climatic rating= 16.67+0.9CI square root		86.65
Climatic Class	-	S2	S1

many farmers. The aim of this study is to evaluate the accuracy of FAO methods for qualitative land suitability of wheat in Damghan plain and consequently, to simplify farmers 's choice for growing the best crop in the land.

Materials and methods

Study area

The study area is located in the south of Damghan Plain and in Semnan province of Iran (Fig. 1). This study was carried out in an area including 5400 ha between 36 º 02 ´ 31.6" - 36º 08 ´- 28.5" of the northern latitude and 54º 21 ´ 56.7" 'E- 54 º 27 ´24.1" of the eastern longitude in the form of surveying at a semi-detailed level for determination of soil characteristics and illustration of soil maps.

In this study, various physical resources such as soil, climate, hydrology, and topography had been evaluated. After interpretation of aerial photographs, the excavation sites of soil profiles were identified and selected pedons were evaluated. Climatic data obtained from Damghan Meteorological Station was used for climatic evaluation. Soil moisture and temperature regimes of the region were arid and thermic respectively. Besides, land characteristics were compared with the plant requirements tables introduced by Sys *et al*. (1991). Subsequently, to investigate the qualitative land suitability, Simple method as well as Storie and Square Root methods were used. Based on these methods, land suitability classes were determined for wheat crop. According to the results of measured land index in parametric method suggested by Sys *et al*. (1991), lands having indexes >75 are in S_1 (very suitable) class. On the basis of this method, land indexes in ranges of 50-75, 25-50 and <25 are classified as S_2 (moderate suitable), S_3 (marginal suitable) and N (non-suitable) respectively (Table 1).

Storie method (Storie & Earl,1976) is used for calculating the land index (I) following equation:

$$I = A * B/100 * C/100 * \ldots \ldots$$

I= land index

Where A, B, C Rating of different factors effective on land index

The Square Root method is used to calculate of land index (I) from the equation below:

$$I = R\min * \sqrt{A/100 * B/100 * C/100 * \ldots\ldots\ldots\ldots}$$

R: One of the factors with Minimum of Rating

A, B, C,,,,,: Rating of different factors effective on land index

Results and discussion

Based on the results obtained from description of soil profiles and physical and chemical analysis of soil samples (Table 3, 4), soils were classified as Entisols and Aridisols on the basis of soil taxonomy system 2006. In the study area, three families, two different physiography classes and 9 soil series were identified (Table 5). The results of climatic suitability evaluation showed that the climatic characteristics of the region according to climatic and growth data are suitable for wheat cultivation (Table 2, 3). Table 6 illustrates the qualitative land suitability results for wheat cultivation. This table indicates the range changes amongst classes in different land units based on the Simple limitation method, Storie parametric method and Square Root parametric method that are S_2-N_2, S_3-N_2 and S_2-N_2

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Table 4. Some physico-chemical properties of representative pedons

LMU	Coarse Loamy,Mixed, Thermic Typic Torrifluents Entisols										
1.1	Depth(cm)	Sand	Silt	clay	Sp	Ec	Ph	C%	Caco3	Caso4	Esp
Ap	0-30	70	25	5	22	8	7.7	0.3	20	0	16
C1	30-65	58	32	10	28	7	7.9	0.4	22	0	18
C2	65-95	56	30	14	33	9.5	7.55	0.05	21	0	13
C3	95-130	50	25	25	34	9	8	0.03	18	0	17
1.2	Coarse Loamy,Mixed, Thermic Typic Torrifluents Entisols										
Ap	0-20	58	30	14	19	10	7.71	0.45	14.7	5	9
C1	20-58	52.8	29.6	17.6	25	8	7.5	0.3	16	3	10
C2	58-95	53	28	19	27	8.5	7.55	0.1	14.5	0	12
C3	95-130	56	30	14	32	7	7.6	0.1	13	0	15
1.3	Coarse Loamy,Mixed, Thermic Typic Torrifluents Entisols										
Ap	0-25	60	26	14	27	19	8.1	0.4	25	2	20
C1	25-60	58	34	8	32	15	8.15	0.03	29	0	23
C2	60-95	56	30	14	34	18	7.75	0.02	33	0	30
C3	95-150	52	36	12	34	20	7.75	0.02	33	0	35
2.1	Fine loamy ,Mixed ,Thermic Typic Torriorthents Entisols										
A1	0-30	45	35	20	27	15	8	0.22	34.7	11	25
C1	30-60	22	37	41	44	18	8.1	0.23	36.2	0	35
C2	60-85	32	32	36	52	24	8.2	0.18	31.5	0	30
C3	85-120	30	33	37	41	15	8.1	0.22	32	0	25
2.2	Fine loamy ,Mixed ,Thermic Typic Torriorthents Entisols										
Ap	0-25	52	36	12	23	20	7.5	0.5	30.45	6	25
C1	25-60	46.8	24.6	28.6	28	16	8.44	0.08	28	0	28
C2	60-95	48	27.6	27.6	27	8	8.75	0.05	31.5	0	23
C3	95-125	23.27	45.43	31.3	30	10	8.5	0.05	33	0	29
2.3	Fine loamy ,Mixed ,Thermic Typic Torriorthents Entisols										
Ap	0-25	67.4	28.59	4.05	19	9	7.6	0.3	18	2	13
C1	25-60	53	25.3	21.7	30	10	7.9	0.15	20	0	15
C2	60-95	51	24	25	32	12	8.1	0.15	19	0	18
C3	95-125	55.5	21	23.5	33	14	8.2	0.13	20	0	16.5
3.1	Fine loamy ,Mixed ,Thermic Typic Aquisalids Aridisols										
A1	0-20	45	35	20	40	111	7.7	0.5	32.5	9.8	50
B	20-60	35	30	35	31	110	8.1	0.09	27	6.8	56.4
C2	60-100	36	29	35	30	113	8.2	0.04	38.5	14	28.5
C3	100-160	25	37	38	27	116	8.3	0.07	38.2	16	34.6
3.2	Fine loamy ,Mixed ,Thermic Typic Aquisalids Aridisols										
A1	0-25	51	25.5	23.5	40	100	7.7	0.3	32.5	8	47
C1	25-65	20	45	35	31	98	7.9	0.09	27	6	38
C2	65-95	36	30	34	30	80	8	0.04	38.5	10	45
C3	95-150	25	37	38	27	120	8.1	0.07	38	14	49
3.3	Fine loamy ,Mixed ,Thermic Typic Aquisalids Aridisols										
A1	0-20	44	36	20	25	40	8.18	0.35	31	4	40
C1	20-65	45	27	28	30	25	7.7	0.08	28	2	38
C2	65-95	35	28.5	36.5	28	60	7.8	0.05	34	0	40
C3	95-155	16.4	58.4	25.2	24	50	8.1	0	35	0	42

LMU:Land Mapping Unit

respectively. Based on Storie method, three units of separated units had marginal Suitability (S_3) and six units had non-suitability (N_2). Evaluating the land suitability with the use of Square root and Simple limitation methods both indicated that three units of separated units were moderately suitable (S_2), one unit was marginal suitable (S_3) and two units were corrigible non-suitable (N_1) and three units had non-suitability (N_2) for wheat cultivation. Also, Fig. 2, 3, 4 shows the maps of land suitability evaluation in the region obtained by means of different methods.

The results of the physical evaluation by different methods

Square Root and Simple Limitation methods: According to Square Root and Simple Limitation methods, three units of the studied area (35.08%) were classified as severe and unchangeable limitations. These results are caused by the close proximity to salt desert, the high level of Exchangeable Sodium Percentage (ESP), Electrical conductivity (EC) and a too close water table level to soil surface. Based on these methods, unsuitable areas or N1 formed 27.66% of the study areas, which included limiting factors such as medium to severe limitation in salt concentration and alkaline condition. According to Square Root and Simple Limitation methods, three units (28.79%) were classified as moderately suitable and one unit as marginally suitable (8.47%). The most important reason for growing wheat in this area was the relatively large distance from salt desert and the lower level of ESP and EC. The general characteristics of the investigated soil corresponding to the requirements of wheat include soil drainage, the amount of salinity as well as alkalinity and lime content. The results of this study represented that some of the physical and chemical characteristics of soil were limiting factors for wheat cultivation. The main limiting factors in this area were soil salinity, alkalinity, soil texture and structure. The most suitable land units in the study area based on the results of both Square Root and Simple Limitation methods were 1.1, 1.2, 2.3 (S_2) and 2.2 (S_3), respectively. These results are confirmed by the calculated land index for each land unit. The findings from the description of soil profiles and physical and chemical analysis of soil samples demonstrated the high level of Exchangeable Sodium Percentage, salinity,

Fig.2. Qualitative land suitability evaluation by Storie method

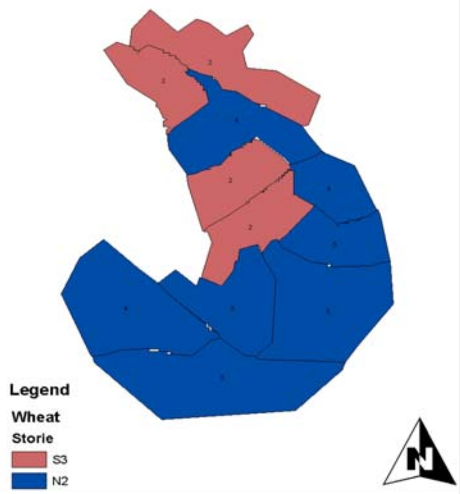


Fig.3. Qualitative land suitability evaluation by Squre root method

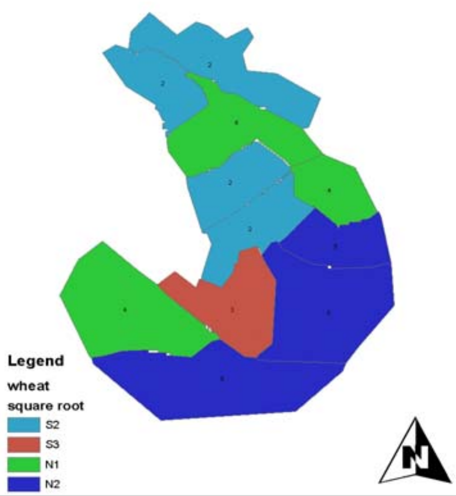
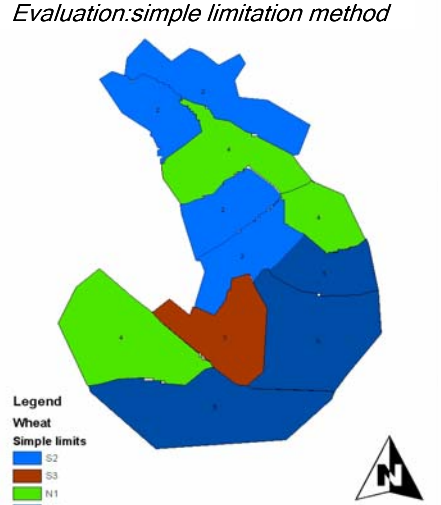


Fig.4. Qualitative land suitability Evaluation:simple limitation method



and some of unsuitable soil physics properties in land units 1.3, 2.1, 3.1, 3.2 and 3.3. Therefore, these parameters affect the yield value of wheat crop.

According to Storie method, the 6 units (71.21 %) of the study area were classified as severely and unchangeably limited despite the proper cultivation of wheat crop in some of these units. The remaining units were marginally suitable (28.79%). The results of this study showed that some of physical and chemical characteristics of soil were limiting factors for wheat growth. The major limiting factors in wheat production were soil salinity and alkalinity, and soil infertility. The most suitable land units in the study area based on Storie method were 1.1, 1.2, 2.3 (marginal suitable or S_3) respectively. In this method, due to the multiplication of land suitability rating with one another and conversion of the calculated climatic index to a climatic rating, a lower class was obtained in comparison with Simple Limitation method. This can be clearly observed on land series of 1.1, 1.2, 1.3, 2.1, 2.2, and 2.3.

The results of the physical evaluation showed a close correlation between Simple Limitation method and Square Root parametric method. This is because of the interaction of many-sided impacts. The land classes based on the Storie method were underestimated compared to other methods (Fig. 5). By comparing different methods of land evaluation, it can be perceived that the results of parametric methods, in particular the Square Root parametric method, lead to far more reasonable results. Calculated land index (Table 6) by Square Root is deeply correlated with actual yield. Similarly, Mandal *et al*. (2002) reported that the calculated land index by Khidir method (Square Root) was highly correlated with cotton yield. Jafarzadeh *et al*. (2006) indicated that Simple Limitation and Square Root parametric methods had similar suitability classes, which indeed confirms the findings of the study. Behzad *et al*. (2009) showed that amongst the applied methods including Square Root and Storie and Simple Limitation methods, Square Root method produced more realistic results for barley, wheat and alfalfa according to the existing conditions of the region. Yasmina *et al*. (2001) demonstrated by the help of the parametric methods that much of the croplands of the region were in critical conditions. Shahbzi and Jafarzadeh (2004) suggested that the parametric method based on square root is more realistic than others. Based on our findings and previous studies, we recommend that Simple limitation and Square Root methods are more appropriate for qualitative land suitability classification.

Conclusion

The results of this study indicate that the largest parts of the study area were classified as unsuitable for wheat cultivation. The results of various methods demonstrated that the most important limiting factors are salinity and alkalinity that lead to independent or mutual interactions. Evaluation by Simple Limitation and Square

Table 6. Results of the qualitative suitability evaluation of different land series for Wheat by using square root , Storie and simple limitation methods

Land units	area	Percent %	Square root		Storie		Simple limitation
			Land index	Land class	Land index	Land class	Land class
1.1	868.32	16.08	53.66	S2s	38.50	S3s	S2s
1.2	316.44	5.86	62.90	S2s	45.90	S3s	S2n
1.3	507.60	9.40	21.60	N1n	11.11	N2n	N1n
2.1	986.04	18.26	20.95	N1n	11.26	N2n	N1n
2.2	457.38	8.47	33.47	S3n	22.45	N2n	S3n
2.3	369.90	6.85	55.85	S2ns	35.17	S3ns	S2n
3.1	844.02	15.63	2.37	N2n	0.44	N2n	N2n
3.2	738.18	13.67	4.80	N2n	1.50	N2n	N2n
3.3	312.12	5.78	6.10	N2n	1.80	N2n	N2n

Root methods show similar suitability classes that confirms the previous findings of other researchers for different crops. This study suggests using Simple Limitation and Square Root methods for evaluation of the qualitative land suitability as these methods are more appropriate than others. Therefore, according to the results of Square Root and Simple limitation methods, cultivation of wheat is suggested to be held in Northern parts of Damghan plain.

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