Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Land suitability evaluation for irrigated barley in Damghan plain, Iran

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Abstract

The aim of this study is evaluating of accuracy of FAO methods for qualitative land suitability of barley in Damghan plain and make easy farmers' choice for planting the best crop in the land. This study was carried out in an area including 5400 ha in the southern part of Damghan city in the form of semi-detailed surveying level. The results showed that the climatic characteristics of the region were suitable for irrigated barley plantation. Lack of suitable water for irrigation, soil salinity and alkalinity, some soil physics properties and poor soil fertility were the most serious problems influencing yield and quality of barley. Assessment results showed Square Root method (SL) and Simple limitation method (SR) had close correlation. This study suggested to use SL method and SR for evaluation of the land suitability. According to the obtained results of SR and SL methods cultivation of barely with moderately and marginally suitable class are recommended. 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.

Keywords: Land suitability, Barley, Damghan plain, Iran.

Introduction

In agricultural context, finding optimal locations for crops can increase economic benefits, as well as reduce negative environmental consequences (Ashraf *et al.,* 2010). Proper recognition of land abilities and allocation of them to the best and most profitable and stable revenue operation system has special importance for preventing of ecosystem structure destruction. With the increase of demand for land, land evaluation has become more important as people strive to make better use of the limited land resources. Land evaluation is the process of assessment land performance for specified purposes (Rossiter, 1996). Biophysical evaluation provides information at a local level that could be used by farmers to select their cropping pattern (Ashraf, 2010). Detailed soil spatial information is required for many environmental modeling and land management application (Burrough, 1996). The most serious limitation of the current soil survey include uncertainly regarding presence of inclusions, 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 (Breeusma *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 and crop requirements. Physical land evaluation methods (Sys *et al .,* 1991) are crucial for evaluating potentials and constraints of land for 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, the climatic factors like temperature and precipitation were suitable for coconut production. Chinene and Situmbanauma (1988) showed that some of the soil parameters including fertility and root available oxygen 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 results on the basis of FAO guideline showed that the limited factors in the study area were the high level of soil moisture and the intensity of slope. In this system all of areas settled in the N_1 class (corrigible non-suitable). Barley is one of the major crops in Damghan Plain and its production is an important source of income for many farmers (Ashraf *et al*., 2011). The aim of this study is to evaluate the accuracy of FAO methods for qualitative land suitability of barley in Damghan plain and make easy farmers 's choice for planting the best crop in the land.

Study area

The study area is located in the south of Damghan plain and in Semnan province of Iran. This study carried out in an area including 5400 ha between 36 º 02´ 31.6″ - 36 º 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 semi-detailed surveying level for determination of soil characteristics and illustration of soil maps. The Damghan is located in desert margins and low rainfall, plant of crops has encountered with some difficulties. Most of study area soils are new alluvial sediments in period of the Fourth of Geology. Parent material in the northern and western of plain are sediments mixed with sand and gravel.

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Materials and methods

In this study, different physical resources, such as soil, climate, hydrology, and topography had been evaluated. After interpretation of aerial photographs, the digging sites of soil profiles were identified and selected pedons were evaluated. Climatic data obtained from Damghan Meterological Station was used for climatic evaluation. Soil moisture and temperature regimes of the region were arid and thermic, respectively. Profile descriptions were made using standard terminology (USDA, 2003) and also after preparation and analyzing of samples , soil were classified by USDA classification system (USDA, 2006) . We compared the land characteristics with the plant requirements tables introduced by Sys *et al.* (1991) as well. Subsequently, in order to investigate the qualitative land suitability, SL method, Storie and SR methods were used. Also, based on these methods, land suitability classes were determined for barley 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. Also, on the basis of this method land indexes of 50-75, 25-50 and <25 are in S_2 (moderate suitable), S_3 (marginal suitable) and N (non-suitable) classes, respectively (Table 1).

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

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	Corrigible unsuitable	12.5-25
N2	Permanently unsuitable	0- 12.5

I = A * B/100 * C/100 * ...

I : land index.

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

The square root method is used to calculate t of land index(I) the equation below**:**

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

Rmin: One of the factors with minimum of rating

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

Results and discussion

We have shown earlier (Ashraf *et al*., 2010) that the climatic characteristics of the region (without regarding to rainfall) are suitable for barley plantation (Table 2 , 3).

With regarding to the results obtained from description of soil profiles and physical and chemical analysis of soil samples in this study, soils were classified as Entisols and Aridisols on the basis of soil taxonomy system 2006 (Table 4 , 5) .

Table 6 illustrates the qualitative land suitability results for barley plant. This table indicates the range changes amongst classes in different land units according to SL method, Storie parametric method and SR parametric method that are S_2-N_2, S_2 -N_2 and S_2-N_2, respectively. Based on Storie method, two units of separated units had marginal suitability (S_3) , two units corrigible (N1) and ,two unit S_2 and three units non-suitability (N_2) respectively. Evaluating the land suitability with the use of Square Root and SL methods both indicated that four units of separated units were moderately suitable (S_2), two units were marginal Suitable (S_3) and three units were non-suitability (N_2)for *barley* cultivation. Also, the Fig. 1 to 3 shows the land suitability evaluation maps of the region obtained from different methods.

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

Crop	Initial stage	Development stage	Mid-season stage	Late season stage
Barley	12 Oct-11Nov	11Nov-30 Mar	30Mar-30 Apr	30Apr-31May

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

Climatic properties	Rating	SL	Parametric Rating
Mean temp of Vegetative Stage	6.60	S1	92.0
Mean temp of or flowering stage	16.82	S1	98.24
Mean temp of For ripening stage	19.80	S1	97.40
Mean daily min temp coldest month	-1.075	S1	97.50
Mean daily max temp Coldest month	7.85		
Climatic Index	Storie SR		92.00 92.00
Climatic Rating	Rating= 16.67+0.9CI		99.47
Climatic Class	-	S1	S1

The division of land into suitability classes was the major step in this study by using SL, SR and Storie methods in barley production under irrigation.

SR and SL methods

According to SR and SL methods, About 37.26% of the studied area was found to be moderately suitable (S_2) for barley production. The permanently unsuitable area (35.08%) had properties that restrict water movement and the penetration of roots and the high level of Exchangeable Sodium Percentage (ESP), Electrical conductivity(EC) and very close water table level to soil surface .According to SR and SL methods, about 27.66% of the study area were classified as marginally suitable. The main limited chemical factors in this area were soil salinity, alkalinity, soil texture and structure. The most suitable land units in the study area based on both SR and SL methods were 1.1, 1.2, 2.2,2.3 (S_2) respectively. A tolerable production potential in barely is because high tolerance of barley against salinity of water and soil.

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Table 4 . Some of 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

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Table 5. Morphological characteristics of representative pedons

1.1	Depth (cm)	Color (Dry)	Color (Moist)	Texture	Structure	Boundry	Consistence Dry	Consistence Wet	Hcl reaction
Ap	0-30	5YR3/4	5YR4/4	SL	1fabk-ma	gw	sh	ss/ps	esf
C1	30-65	10YR7/2	10YR 5/3	SL	ma	gw	h	ss/ps	esc
C2	65-95	10YR7/2	10YR 5/4	SL	ma	gw	h	s/p	esc
C3	95-130	10YR7/2	10YR 5/4	SCL	ma		h	s/p	esm
1.2									
Ap	0-20	5YR3/4	5YR4/4	SL	1fabk-ma	gw	sh	ss/ps	esf
C1	20-58	5YR3/4	5YR4/4	SL	ma	gw	sh	ss/ps	esf
C2	58-95	5YR 5/4	5YR4/4	L	ma	gw	h	s/p	esf
C3	95-130	5YR 4/4	5YR5/4	L	ma		h	s/p	esf
1.3									
Ap	0-25	10YR6/2	10YR 5/3	SL	1fabk-ma	gw	sh	ss/po	esm
C1	25-60	10YR7/2	10YR 5/3	SL	ma	gw	sh	ss/ps	esm
C2	60-95	10YR7/3	10YR 5/3	SL	ma	gw	h	ss/ps	esm
C3	95-150	10YR7/2	10YR 5/4	SL	ma		h	ss/ps	esm
2.1									
A1	0-30	10YR5/4	10YR4/4	L	ma	gw	h	s/p	esm
C1	30-60	10YR5/4	10YR4/4	CL	ma	gw	vh	s/p	esm
C2	60-85	10YR5/54	10YR4/4	CL	ma	gw	vh	s/p	esm
C3	85-120	10YR5/4	10YR4/4	CL	ma		vh	s/p	esm
2.2									
Ap	0-25	10YR6/3	10YR 4/3	SL	1fabk- ma	gw	h	ss/po	esm
C1	25-60	10YR6/3	10YR 4/3	SCL	ma	gs	h	s/p	esm
C2	60-95	10YR6/3	10YR5/3	SCL	ma	gs	h	s/p	esm
C3	95-125	10YR 7/3	10YR5/3	CL	ma		h	s/p	esm
2.3									
Ap	0-25	10YR6/3	10YR 4/3	SL	1fabk-ma	gw	sh	ss/po	esf
C1	25-60	10YR7/2	10YR5/3	SCL	ma	gw	h	s/p	esc
C2	60-95	10YR 6/2	10YR5/3	SCL	ma	gw	h	s/p	esf
C3	95-125	10YR7/3	10YR5/3	SCL	ma		h	s/p	esc
3.1									
A1	0-20	10RY5/4	10YR4/4	L	ma	gw	h	ss/ps	esm
C1	20-60	7.5RY5/4	7.5YR4/4	CL	ma	gw	vh	s/p	esm
C2	60-100	7.5YR4/4	7.5YR4/4	CL	ma	gw	h	s/p	esm
C3	100-160	7.5YR4/4	7.5YR4/4	CL	ma		h	s/p	esm
3.2									
A1	0-25	10RY5/4	10YR4/4	SCL	ma	gw	h	ss/ps	esm
C1	25-65	7.5RY5/4	10YR4/4	CL	ma	gw	vh	s/p	esm
C2	65-95	7.5YR4/4	10YR4/4	CL	ma	gw	vh	s/p	esm
C3	95-150	7.5YR5/4	7.5YR4/4	CL	ma		vh	s/p	esm
3.3									
A1	0-20	10RY5/4	10YR4/4	L	ma	gw	h	s/p	esm
C1	20-65	10RY6/4	10YR4/4	SCL	ma	g	vh	s/p	esm
C2	65-95	10RY5/4	10YR4/4	CL	ma	gs	vh	s/p	esm
C3	95-155	7.5YR4/4	7.5YR4/4	CL	ma		vh	s/p	esm

LMU:Land Mapping Unit

1 = weak, 2 = moderate, m = medium, f = fine, abk = angular blocky, ma = massive, (2) SiCL = Silty Clay Loam, SCL = Sandy Clay Loam, SL = Sandy Loam, LS = Loamy Sand

Storie Storie method

According to Storie method about 35.08 % of the study area was classified as severe limitations and unchangeable. Regarding to Storie method, about 12.71% of the study area were classified as moderately suitable and 24.55% had marginal suitable. The corrigible unsuitable area (27.66 %) had properties including limited factors such as medium limitation to much in salt concentration and alkaline condition in these units. The results of this study showed that some of physical and chemical characteristics of soil were limited factors for *barley* plantation. The most suitable land units in the study area based on Storie method were 2.3 and 1.2 (moderately suitable or S2). In this method, due to the multiplication of land suitability rating by each other and converting of the calculated climatic index to a climatic

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

Fig.1. Qualitative land suitability evaluation by SL method

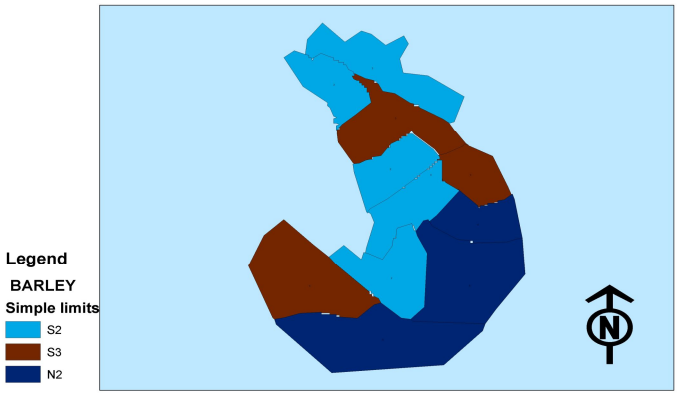


Fig.2. Qualitative land suitability evaluation by Storie method

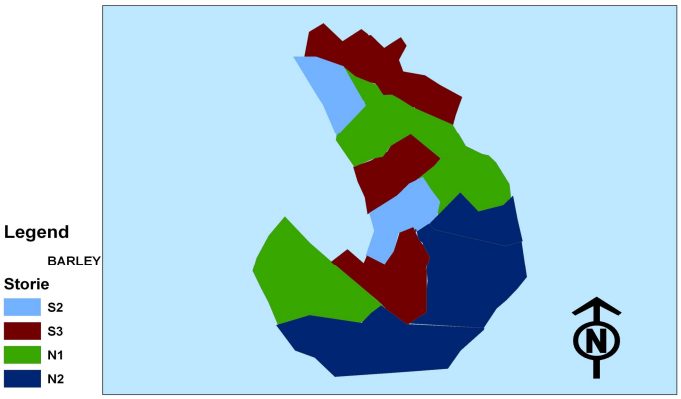
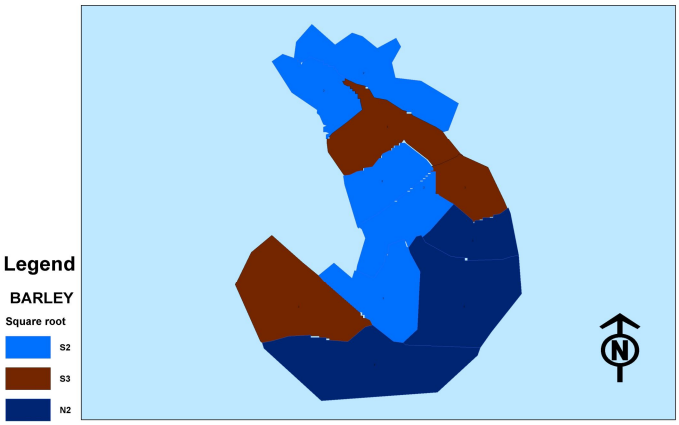


Fig.3. Qualitative land suitability evaluation SR method



rating ,a lower class has been obtained in comparison with SL method.

Assessment results showed Square Root method (SL) and Simple limitation method (SR) had close correlation .Ashraf *et al.* (2011) emphasized on correlation between SL method and Square Root parametric method and suggests that the use of SL method and SR is more appropriate for evaluation of the qualitative land suitability than others. Jafarzadeh *et al.* (2006) indicated that SL and SR methods had similar suitability classes, which confirms the previous findings for several crops by other researchers. Behzad *et al.* (2009) showed that from the methods used including SR, SL and Storie methods, SR method produced more realistic results for barley, wheat and alfalfa on the existing conditions of the region. Yasmina *et al.* (2001) showed by the use of the parametric methods, much of the croplands of the region were in critical conditions. Shahbazi and Jafarzadeh, (2004) suggested that the parametric method based on SR is more realistic than others.

Conclusion

The results of the evaluation land showed a close correlation between SL and SR methods and only in the Storie method due to the interaction of many-sided impacts of the land properties in determining of the land index will lead to underestimate of the land classes obtained compared with others. Regarding to obtained results and other studies, this study suggests using SL and SR methods for evaluation of the qualitative land suitability because of these methods more appropriate than others. Therefore according to the results of SR and SL methods, cultivation of barley can be recommended in more units of Damghan plain.

Lack of irrigation suitable water, soil salinity, low rainfall and poor soil fertility are the most serious problems influencing yield and quality of barley.

One of the major factors which were considered during suitability assessment for irrigated barley was irrigation quality and quantity since the climate of the area was classified as arid. Under arid condition, soil drainage is an important factor to be considered to avoid irrigation-induced secondary drainage (Fischer *et al.*, 2000). Salt balance in plant root zone depends on irrigation water requirement, quality of water, irrigation scheduling and on

Table 6. Results of the qualitative suitability evaluation of different land series for barley , using Square Root , Storie and Simple Limitation methods

Land units	Area	Percent	SR		Storie		SL
			Land index	Land class	Land index	Land class	Land class
1.1	868.32	16.08	60.60	S2s	49.00	S3s	S2s
1.2	316.44	5.86	69.31	S2s	56.65	S2s	S2s
1.3	507.60	9.40	30.50	S3n	18.60	N1n	S3n
2.1	986.04	18.26	37.50	S3n	23.50	N1n	S3n
2.2	457.38	8.47	50.20	S2n	36.10	S3n	S2n
2.3	369.90	6.85	69.78	S2ns	57.29	S2ns	S2s
3.1	844.02	15.63	3.00	N2n	0.69	N2n	N2n
3.2	738.18	13.67	5.78	N2n	1.96	N2n	N2n
3.3	312.12	5.78	6.46	N2n	2.10	N2n	N2n

Indian Journal of Science and Technology Vol. 4 No. 9 (Sep 2011) ISSN: 0974- 6846

overall soil and climatic conditions.

The guidelines are flexible and should be modified in accord with local experience, special conditions of crop, soil, climate, method of irrigation and specific agronomic practices used in the area. Proper land management practices, leaching, drainage, land preparation crop rotation, specific irrigation methods, using resistant crop may help to increase crop yield in this area.

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