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QUALITATIVE EVALUATION OF LAND SUITABILITY FOR PRINCIPAL CROPS IN THE WEST SHOUSH PLAIN, SOUTHWEST IRAN

M. ALBAJI[1], A. A. NASERI[1], P. PAPAN[2], and S. BOROOMAND NASAB[1]
[1]*Department of Irrigation and Drainage, Faculty of Water Science, Shahid Chamran University, P. Code: 61357-43311, Ahwaz, Iran*
[2]*KWPA, Ahwaz, Iran*

Abstract

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Today's excessive use of croplands and the resulting damages along with the ever-increasing demand for further crop productions have necessitated the best land management practices more than ever. Due to the current lack of any proper land management practices for West Shoush plain in Khuzestan Province, southwest Iran, a land suitability evaluation study for key productions of the region, including wheat, alfalfa, maize, and barley, covering an area of 41958 ha was carried out in the region. Using the findings of the semi-detailed soil studies for this area, 4 soil families and 32 soil series in 2 physiographic units was identified. Physiologic requirements of each crop were also determined and rated based upon the proposed method of Sys et al. (1991) and the tables provided by the Iranian Soil and Water Research Institute (Givi, 1997). Qualitative evaluation was carried out by means of simple limitation and parametric methods (Storie and Root Square Method) and comparing land and climate characteristics with crop needs. The indexes obtained for alfalfa, barley and wheat were higher in comparison to that developed for maize. Limiting factors in different crop yield in the region along with climatic variables included soil physical properties, especially its texture and carbonate contents and slope. From the two methods used i. e, simple limitation and parametric methods (Storie and Square Root Methods), the latter(Square Root Methods)produced more realistic results in respect to the existing conditions of the region.

*Key words: l*and suitability evaluation, parametric methods (Storie and Square Root Method), simple limitation methods, land series, wheat, alfalfa, maize, barley

Introduction

Considering the rapid growth of the world populations, which is in its turn a limiting factor to the arable lands around the world, the dire need for effective and efficient application of the croplands have been felt more than ever. Sustainable agriculture would be achieved if lands be categorized and utilized based upon their different uses (FAO.1983). Qualitative evaluation of the land suitability consists of determi-

e-mail: m_albaji2000@yahoo.co.uk

nation of the land use for particular applications regardless of yield fulfillment and socio-economic issues (FAO.1976 and 1983). In this view, FAO (Food and Agriculture Organization) took a stride in its Soils Bulletins No. 32, 42, 48, 52 and 55 by introducing various methodologies based upon the above framework.

In their research in the Province of Ben Slimane, Morocco, Briza et al. (2001) carried out the qualitative land evaluation for crop production and fruit-bearing trees under rainfed and irrigated conditions. By the use of the parametric method, they showed that much of the croplands of the region were in critical conditions the most limiting factors of which including soil texture ,soil depth and slope. The main crops of the area were wheat, barely, pea, bean and onion.

Ljusa and Pajovic (2002) investigated the Land suitability for rainfed agriculture in the province of Larache, Morocco .The study area was characterized by crops which were separated into three groups as food crops (maize, sugarcane, chickpea, potato, tomato, green pepper, onion, sunflower, and wheat), fodder crops (barley, sorghum, and alfalfa) and tree crops (citrus and olives), all with different agricultural management. The methodology used for the evaluation refers to the Sys et al. (1991) parametric method based on land evaluation framework for rainfed agriculture. The main step of this methodology was matching land characteristics against crop needs, giving in that way suitability rating for each land characteristic. After suitability analysis for rainfed agriculture, all crops could be separated into two groups; the first one where there are crops good for this kind of agriculture and the second one can't grow without good moisture condition. In the first group are presents the main of the difference crops: maize suitable in the whole agricultural part; sugarcane suitable in the northern and southern reliefs; potato suitable in the southern reliefs; sunflower suitable in the northern and southern reliefs; wheat suitable in the northern reliefs and in the valley; barley suitable only in the northern reliefs; citrus suitable in small parts in the northern and southern reliefs and olives suitable in the valley and in the southern reliefs. For almost all crops any kind of irrigation is necessary for increasing suitability class. Other crops like chickenpea, tomato, green pepper, onion, sorghum and alfalfa belong to group of crops, which are not recommended for rainfed agriculture.

Bienvenne et al. (2003) conducted land evaluation of Thies Region, Senegal, for crops such as maize, sorghum, pea, sesames, etc. The evaluation showed that the northern part of the region contained suitable (*S1*) or relatively suitable (*S2*) lands for all the crops under study while in northwest part along the shoreline the croplands were unsuitable (*N1* and *N2*) which was due to the domination of sandy soils. The study also indicated that from 60387 ha of the studied lands, 12522 ha were highly suitable (*S1*) for all the crops, 31540 ha were relatively suitable (*S1*) and 16325 ha were totally unsuitable (*N1 and N2*).

Breda et al. (2004) using parametric (square root) method conducted a research on Oud Rmel Catchment of Tunisia on wheat, barely, sorghum, potato, etc. The most influential limiting factor to the study area were found to be land slope, coarse-grained soil texture of the area, dominant existence of stones and aggregates, alkaline pH and the excessive amount of the soil carbonate calcium .

Calderon et al. (2005) performed a land evaluation project for Shouyang County in Shanxi Province, China, in which maize, soybean, potato; sunflower, wheat as well as tree crops were studied. For this purpose, land suitability classification was carried out using parametric method and the consequent land suitability maps were prepared for crops under traditional and mechanized cultivations.

Liu et al. (2006) investigated the land suitability for agricultural crops in Danling County - Sichuan province, China-using the Sys's parametric evaluation system. The final aim of this evaluation is to facilitate farmers in choosing the best crop to be cultivated (for small areas)and decision makers in planning the rural development (for large areas).Several crops were analyzed; in particular, the suitability for rice was compared to the one for other summer crops like sweet potato and maize. A comparison between wheat and rape was carried out since these are the more common crops to be rotated with rice. The more widespread tree crops, like orange and loquat, were also included in the analysis as well as mulberry tree which is becoming more widespread due to the growth of the silk market. The evaluation of some cash crops that do not currently grow in the agricultural landscape of *Danling* County was carried out too in order to gain an indication about future productivity of the area.

Azzat et al. (2007) evaluated the land suitability for key agricultural crops in Essaouira Province, Morocco. The principal crops cultivated in the study area were barley, maize, onion and wheat which are the main source of subsistence for the families in *Essaouira*. Olive is the main perennial crop. The aim of this evaluation was to find out which parcels of land may best support the different crops commonly grown by the local farmer based on the physical and chemical properties of the soils in the study area and recommend these results to the local stakeholder for an increase in yield. Suitability maps were produced for each specific crop. In general, the evaluation class for the crops suitability ranges from “moderately suitable” to “permanently not suitable”. This is due to the different condition that the crops require for their developments in the local area in question. Barley and wheat are the most important crops for the economy and subsistence of the families in the region since most families earn their livelihoods from the cultivation of these crops. Livestock farming constitutes a significant financial reserve for the majority of the farmers. The animals also take advantage of the leftovers of cropfields after the harvest. These areas have limitations due to the presence of coarse fragments and rock outcrops, poor drainage, steep slope, high $CaCO_3$ content and texture which are considered to be important factors since they determine the capacity for the penetration of the roots and the capacity to retain water and nutrients.

The main objective of this research is to evaluate and compare land suitability for principal crops based on the simple limitation and parametric evaluation systems for West Shoush Plain, Khuzestan Province, Iran.

Materials and Methods

The study area was West Shoush Plain with an area of 41958 ha. in the Khuzestan Province at a distance of 5 km of west and north west Shoush between 31º 38´ and 31º 49´ N and 48º 57´ and 49º 07´ E. This area has an arid climate with a mean annual rainfall of 295 mm and minimum and maximum relative humidity of 32% and 67%, respectively. The mean annual temperature is 24.4ºC. The warmest month of the year is Tir (June-July) with a maximum temperature of 46.3ºC while the coldest month of the year is Dey (late October to early January) when the minimum temperature is as low as 7.2ºC. The annual evapotranspiration has been measured as 2250 mm (KWPA, 2005).

Common agricultures in the region include fall growth of irrigated wheat, irrigated barley, irrigated maize and irrigated alfalfa. The agriculture in the area uses traditional to semi-mechanized techniques and equipment. The power supply is usually tractors. Karkheh River is the main water resource to the region where gravity irrigation is predominant. According to the available data, the growth periods and development stages for the crops in the region include initial stage, development stage, med-season stage and late season stage (Table 1).

The properties of the above croplands to be considered in the present study included climatic characteristics (including relative humidity, temperature and sun radiation during different phases of plant growth), topography (including soil slope), and soil (including soil depth, soil texture, gypsum and lime contents, soil salinity (EC) and alkalinity (ESP), drainage and percentage of aggregates). Also, Properties of soil fertility such as cation exchange capacity (CEC), percentage of basic saturation (PBC), organic mater (%OM) and soil acidity (pH) were considered in terms of soil fertility. Sys et al. (1991) suggested that soil characteristics such as %OM and PBS do not require any evaluation in the arid regions while clay CEC rate usually exceeds the plant requirement without further limitation, thus, only soil acidity (pH) has been considered sufficient in any assessment of the soil fertility.

According to the particular semi-detailed studies of the region, samples were taken from each soil series profiles and laboratory analysis were carried out based upon the conventional methods of the Iranian soil and water research institute methodologies and the following properties were measured by due methods: soil acidity by electrometric method by using a pH meter, electrical conductivity by conductivity-meter, soil texture by agitator and hydrometer, lime settlement rate by titration method, gypsum by sediment measurement by using acetone, cation exchange capacity by replacing of the exchangeable sodium ions with ammonium ions, mineral carbon content by titration by using dichromate potassium and nitrate Ferro ammonium sulfate (Page et al., 1992). Based upon the profile description and laboratory analysis, that group of soils that had similar properties and located in a same physiographic unit were considered as a series of soils and were taxonomied to form a soil family as per to keys to Soil Taxonomy 2006.

In the present study almost totally 32 soil series were categorized and climatic, topography and soil properties were prepared and ranked based upon Sys et al. (1991) tables and proposed tables of the Iranian soil and water research institute (Givi, 1997) and the Manual of land classification for irrigation (Mahler, 1979), (Table 2). Climate data and those related to different stages of plant growth were taken from Khuzestan soil and water research institute and physiological requirements of each plant were extracted from tables prepared specifically for Iran (Givi, 1997). In evaluating of the qualitative land suitability, land properties were compared with the corresponding plant requirements. In this stage, in order to classify the lands the simple limitation and parametric methods (i. e, Story and Square Root Methods) were used. Simple limitation method compares the plant requirements with its corresponding qualitative land and climatic characteristics and the most limiting characteristics defines land suitability class while in parametric method land and climate characteristics are defined using different ratings. The measurement of theses characteristics can be done using the followings:

1. Storie Method:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100} \qquad (1)$$

where I is the specified index and A, B, C, …., are different ratings given for each property.

2. Square Root Method:

$$I = R\min\sqrt{\frac{A}{100} \times \frac{B}{100} \times ...} \qquad (2)$$

in which Rmin is the minimum rank.

By determining the specific land index and using the guidelines given by Sys et al. (1991), the qualitative land suitability classes (Table 3) and the limiting factors of the plant growth in different soil series for each plant were determined.

Results and Discussion

Thirty two soil series and seventy nine series phases were derived from the semi-detailed soil study of the area. The soil series are shown in Figure 1 as the basis for any land evaluation practice. The soils of the area are of Inceptisols and Entisols orders. Also, the soil moisture regime is Ustic while the soil temperature regime is Hyperthermic (KWPA, 2006).

The ultimate evaluation of the qualitative land suitability for different typical land uses using simple limitation and parametric methods are given in Tables 4, 5 and 6 and land suitability maps in Figures 2 to 5. The results of the physical evaluation showed a close correlation between the simple limitation method and parametric method (square root method); however, due to the interaction of many-sided impacts of the land properties, using Storie method in determining of the land index will lead to underestimation of the land classes obtained compared to what gained through simple limitation and square root methods. Hence yet, in some of the soil series there are minor differences

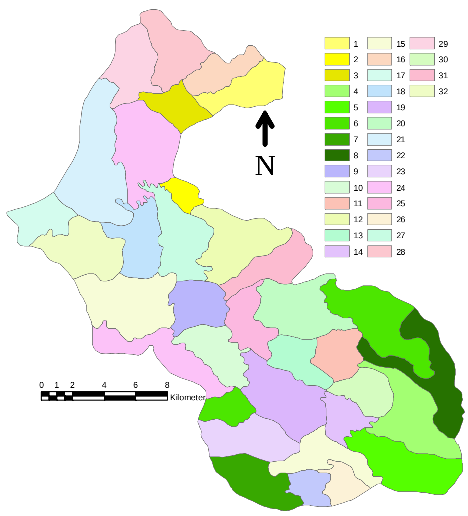

Fig. 1. Soil map of the study area (Mohammad Albaji)

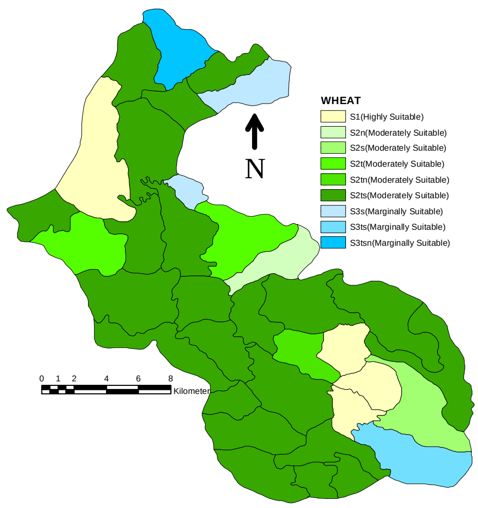

Fig. 2. Land suitability map for wheat (Mohammad Albaji)

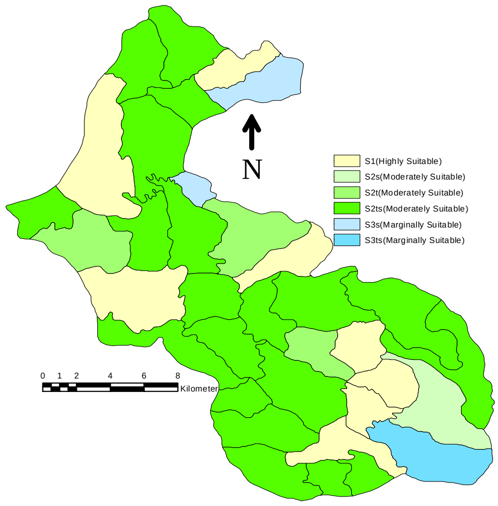

Fig. 3. Land suitability map for barley (Mohammad Albaji)

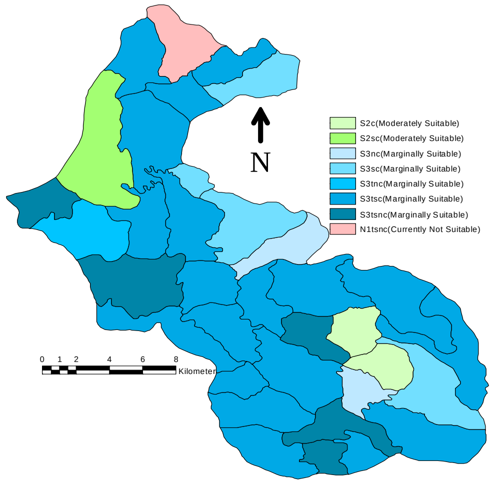

Fig. 4. Land suitability map for maize (Mohammad Albaji)

in land class evaluation by these methods for some plants which are mainly due to the different estimation of the climatic, soil and topographic characteristics of the region. Each is estimated individually and differently in the simple limitation method.

In parametric method, however, a land index which contains the three of the above properties is usually evaluated. For example, due to climatic limitations, lime presence, soil texture limitation and soil slope, a land series 1 for maize belongs to class *S3* in simple limitation method while in parametric method (Storie method) it goes to class N_1. Part of the differences in results can be explained by the results of multiplication of the land suitability ratings by each other used in calculating of the land index in parametric method (Storie method). In this method, due to the multiplication of different land suitability ratings by each other and converting of the calculated climatic index to a climatic rating, a lower class has been obtained compared to that developed by limitation method. This

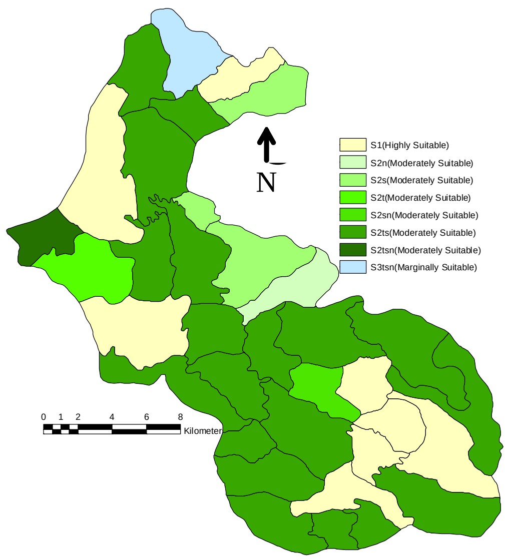

Fig. 5. Land suitability map for alfalfa (Mohammad Albaji)

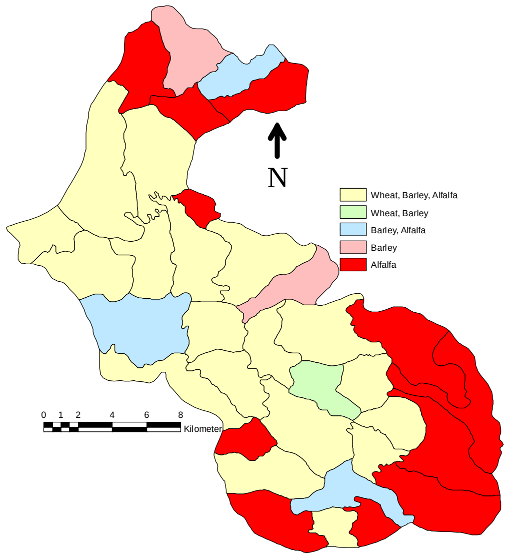

Fig. 6. The most suitable map for Principal Crops (Mohammad Albaji)

can be clearly observed in land series of 2,3,5,6,7,8,9,10,13,17,19,22,24,26,28,29 and 31 for maize.

Regarding the accuracy and several advantages of the parametric method (square root method) the results obtained by this method in the present study will be reviewed briefly.

As the results of the Maps 3 to 6 reveal, the land series 11, 14, 21 and 30 with an area of 4872 ha (11.61%) shows the best land suitability for wheat, barley and alfalfa productions. Land series 15 and 16 with an area of 3839 ha (9.15%) shows the highest land suitability for barley and alfalfa ,and only land series 31 with an area of 1012 ha (2.41%) shows the best land suitability for barley. Land series 4 with an area of 1688 ha (4.02%) shows the highest suitability for alfalfa. Land series

3, 6, 7 ,8, 9, 10, 12, 13, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 29 and 32 with an area of 26208 ha (62.46%) shows moderate suitability for wheat ,barley and alfalfa productions, and series 4 with an area of 1688 ha (4.02%) show an average suitability for wheat and barley. Land series 15, 16 and 31 also with an area of 4851 ha (11.56%) shows an average suitability for growing wheat. Land series 1,2,5 and 31 with an area of 4104 ha (9.78%) shows moderate suitability for alfalfa, and series 11,21 and 30 with an area of 4228 ha (10.08%) shows an average suitability for maize. Only land series 28 with an area of 1247 ha (2.97%) shows an average suitability for growing barley. Land series 1, 2 and 5 with an area of 3092 ha (7.37%) shows a low suitability for wheat, barley and maize. Only land series 28 with an area of 1247 ha (2.97%) shows marginal suitability for wheat and alfalfa, and series 3, 4, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 29, 31 and 32 with an area of 33391 ha (79.58%) exhibited a low suitability for maize. Land series 28 with an area of 1247 ha (2.97%) demonstrated physically unsuitable for maize production.

The mean land index (Li) for alfalfa was 68.72 (moderately suitable) while for barley was 65.42 (moderately suitable). Also, for wheat it was 62.39 (moderately suitable). And. Finally for maize were 40.67(slightly suitable).

The comparison of the land indexes for wheat, barley, alfalfa and maize, Tables 5 and 6 indicated that in land series

9, 10, 11, 12, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 30 and 32 with an area of 23073 ha (54.99%) growing wheat, barley and alfalfa was the most suitable than maize. In land series coded 15 and 16 with

Table 1
Growth periods and development stages of crops in the study area

Crop	Initial stage	Development stage	Mid-season stage	Late season stage
Wheat	20(Day) 13 DEC -23 NOV	55(Day) 6 FEB -14 DEC	65(Day) 13 APR -7 FEB	15(Day) 27 APR -14 APR
Maize	15(Day) 10 AUG-27 JUL	40(Day) 19 SEP-11 AUG	33(Day) 22 OCT-20 SEP	34(Day) 25 NOV-23 OCT
Barley	20(Day) 13 DEC -23 NOV	55(Day) 6 FEB -14 DEC	65(Day) 13 APR -7 FEB	15(Day) 27 APR -14 APR
Alfalfa	75(Day) 4 APR-27 JUN	80(Day) 26 JUN-5 APR	80(Day) 16 SEP-27 JUN	85(Day) 11 DEC-17 SEP

Table 2
Values of different characteristics in defining different phases of each soil series[1]

	Degree of limitation				
Characte-ristics	Without limitation	Slight limitation	Moderate limitation	Sever limitation	Very sever limitation
Salinity(Ds/m)	<4	8-Apr	16-Aug	16-32	>32
Alkalinity(SAR)	<6.5	6.5-13	13-18	18-24	>24
Drainage	Well drained	Moderately drained	Imperfectly drained	Poorly drained	Very poorly drained

[1]Data have been prepared and used as per the Plant Requirements Table (Givi, 1997) and Guidelines for Description of Soil Profiles (Iranian Soil and Water Research Institute Bulletin No. 758).

Table 3
Qualitative land suitability classes for the different land indices

Land index	Definition	Symbol
75-100	Highly suitable	S1
50-75	Moderately suitable	S2
25-50	Marginally suitable	S3
12.5-25	Currently not suitable	N1
0-12.5	Permanently not suitable	N2

an area of 3839 ha (9.15%) growing barley and alfalfa was the most suitable compared with wheat and maize. Only in land series 13 with an area of 829 ha (1.97%) growing wheat and barley was the most suitable than alfalfa and maize. In land series 1, 2, 3, 4, 5, 6, 7, 8, 26 and 29 with an area of 11958 ha (28.50%) growing alfalfa was the most suitable than other crops. and finally, in land series coded 28 and 31 with an area of 2259 ha (5.38%) growing barley was the most suitable compared with other productions. Figure 6 shows the most suitable map for Principal Crops in the West Shoush Region, by notation to land index (Li). As seen from this map, nearly all of this plain was suitable for alfalfa and the largest portion of this plain was suitable for wheat and barley. also, there was not founded area that was suitable for maize.

Generally, the most important limiting factors in wheat and barley productions in the region under study included physical properties of the soil especially soil texture and slope. Briza et al. (2001) 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

Table 4
Results of the qualitative suitability evaluation of different land series for crops under study using simple limitation method[1]

Land series	Wheat Suitability Classes	Maize Suitability Classes	Barley Suitability Classes	Alfalfa Suitability Classes
1	S_3s	S_3sc	S_3s	S_2s
2	S_3s	S_3sc	S_3s	S_2s
3	S_2ts	S_3tsc	S_2ts	S_2ts
4	S_2s	S_3sc	S_2s	S_2s
5	S_3ts	S_3tsc	S_3ts	S_2ts
6	S_2ts	S_3tsc	S_2ts	S_2ts
7	S_2ts	S_3tsc	S_2ts	S_2ts
8	S_3ts	S_3tsc	S_3ts	S_3ts
9	S_3ts	S_3tsc	S_3ts	S_3ts
10	S_3ts	S_3tsc	S_3ts	S_3ts
11	S_1	S_3c	S_1	S_1
12	S_2t	S_3sc	S_2t	S_2s
13	S_2tn	S_3tsnc	S_2t	S_2sn
14	S_1	S_3nc	S_1	S_1
15	S_2ts	S_3tsnc	S_2ts	S_2ts
16	S_2ts	S_3tsc	S_2ts	S_2ts
17	S_2ts	S_3tsnc	S_2ts	S_2tsn
18	S_2ts	S_3tsc	S_2ts	S_2ts
19	S_2ts	S_3tsc	S_2ts	S_2ts
20	S_2ts	S_3tsc	S_2ts	S_2ts
21	S_2s	S_3sc	S_2s	S_2s
22	S_2ts	S_3tsnc	S_2ts	S_2ts
23	S_2ts	S_3tsc	S_2ts	S_2ts
24	S_2ts	S_3tsc	S_2ts	S_2ts
25	S_2ts	S_3tsc	S_2ts	S_2ts
26	S_2ts	S_3tsc	S_2ts	S_2ts
27	S_2ts	S_3tsc	S_2ts	S_2ts
28	S_3tsn	S_3tsnc	S_3ts	S_3tsn
29	S_3ts	S_3tsc	S_3ts	S_3ts
30	S_1	S_3c	S_1	S_1
31	S_2n	S_3nc	S_1	S_2n
32	S_2t	S_3tnc	S_2t	S_2t

[1]Designates c, n, s and t represent the climatic limitations, salinity and alkalinity, physical properties of soil and topography.

Table 5
Results of the qualitative suitability evaluation of different land series for crops under study using parametric method (square root)

Land series	Wheat		Maize		Barley		Alfalfa	
	Suitability Classes	Land index	Suitability Classes	Land Index	Suitability Classes	Land Index	Suitability Classes	Land index
1	S_3s	42.51	S_3sc	33.87	S_3s	45.11	S_2s	63.86
2	S_3s	42.89	S_3sc	33.8	S_3s	45.41	S_2s	64.88
3	S_2ts	56.48	S_3tsc	39.45	S_2ts	58.13	S_2ts	70.33
4	S_2s	62.91	S_3sc	44.78	S_2s	63.03	S_1	82.08
5	S_3ts	38.17	S_3tsc	28.59	S_3ts	39.21	S_2ts	57.04
6	S_2ts	55.21	S_3tsc	37.32	S_2ts	57.86	S_2ts	68.67
7	S_2ts	56.94	S_3tsc	39.87	S_2ts	58.45	S_2ts	70.38
8	S_2ts	54.01	S_3tsc	36.72	S_2ts	55.49	S_2ts	63.24
9	S_2ts	57.81	S_3tsc	38.97	S_2ts	60.48	S_2ts	61.34
10	S_2ts	57.4	S_3tsc	40.33	S_2ts	60.96	S_2ts	62.19
11	S_1	77.1	S_2c	52.14	S_1	81.84	S_1	85.19
12	S_2t	66.01	S_3sc	46.61	S_2t	69.32	S_2s	70.29
13	S_2tn	65.33	S_3tsnc	26.63	S_2t	67.36	S_2sn	55.09
14	S_1	78.71	S_3nc	49.62	S_1	82.38	S_1	83.96
15	S_2ts	72.06	S_3tsnc	43.69	S_1	75.67	S_1	75.86
16	S_2ts	72.94	S_3tsc	48.18	S_1	77.39	S_1	77.78
17	S_2ts	62.43	S_3tsnc	36.92	S_2ts	67.31	S_2tsn	65.37
18	S_2ts	64.24	S_3tsc	43.31	S_2ts	67.12	S_2ts	67.78
19	S_2ts	63.09	S_3tsc	41.06	S_2ts	66.45	S_2ts	66.98
20	S_2ts	63.74	S_3tsc	44.07	S_2ts	68.25	S_2ts	69.6
21	S_1	75.05	S_2sc	50.48	S_1	78.39	S_1	78.58
22	S_2ts	64.09	S_3tsnc	39.45	S_2ts	65.18	S_2ts	65.77
23	S_2ts	65.72	S_3tsc	43.9	S_2ts	66.39	S_2ts	68.07
24	S_2ts	63.89	S_3tsc	41.51	S_2ts	66.26	S_2ts	67.36
25	S_2ts	65.04	S_3tsc	42.96	S_2ts	67.36	S_2ts	67.59
26	S_2ts	55.21	S_3tsc	35.59	S_2ts	57.17	S_2ts	67.36
27	S_2ts	64.89	S_3tsc	43.61	S_2ts	67.69	S_2ts	68.91
28	S_3tsn	45.39	N_1tsnc	17.6	S_2ts	52.58	S_3tsn	46.44
29	S_2ts	52.38	S_3tsc	35.17	S_2ts	54.97	S_2ts	61.38
30	S_1	79.68	S_2c	52.78	S_1	83.02	S_1	83.16
31	S_2n	70.14	S_3nc	31.16	S_1	80.19	S_2n	61.52
32	S_2t	66.74	S_3tnc	43.48	S_2t	70.24	S_2t	67.45

Table 6
Results of the qualitative suitability evaluation of different land series for crops under study using parametric method (storie)

Land series	Wheat		Maize		Barley		Alfalfa	
	Suitability Classes	Land Index	Suitability Classes	Land Index	Suitability Classes	Land Index	Suitability Classes	Land Index
1	S_3s	36.15	N_1sc	19.37	S_3s	40.7	S_2s	55.79
2	S_3s	36.89	N_1sc	19.27	S_3s	41.29	S_2s	57.63
3	S_3ts	44.03	N_1tsc	21.52	S_3ts	46.63	S_2ts	61.35
4	S_2s	54.64	S_3sc	27.74	S_2s	54.82	S_1	75.47
5	S_3ts	29.19	N_1tsc	13.78	S_3ts	30.79	S_3ts	44.55
6	S_3ts	42.08	N_1tsc	19.26	S_3ts	46.22	S_2ts	58.52
7	S_3ts	44.74	N_1tsc	22	S_3ts	47.18	S_2ts	61.39
8	S_3ts	40.28	N_1tsc	18.66	S_3ts	42.51	S_2ts	54.75
9	S_3ts	46.17	N_1tsc	21.02	S_2ts	50.49	S_2ts	51.49
10	S_3ts	45.51	N_1tsc	22.51	S_2ts	51.31	S_2ts	52.91
11	S_2ts	66.11	S_3c	37.63	S_2ts	74.5	S_1	76.85
12	S_2t	54.51	S_3sc	30.08	S_2t	60.1	S_2s	61.23
13	S_3tn	33.41	N_2tsnc	10.88	S_2t	56.73	S_3sn	39.8
14	S_2ts	68.87	S_3nc	34.05	S_1	75.49	S_1	76.02
15	S_2ts	60.79	S_3tsnc	26.41	S_2ts	67	S_2s	66.77
16	S_2ts	61.37	S_3tsc	32.13	S_2ts	69.06	S_2s	69.17
17	S_3ts	48.75	N_1tsnc	18.88	S_2ts	56.7	S_3tsn	49.5
18	S_2ts	51.62	S_3tsc	25.97	S_2ts	56.39	S_2ts	56.95
19	S_3ts	49.81	N_1tsc	23.31	S_2ts	55.27	S_2ts	55.62
20	S_2ts	50.81	S_3tsc	26.87	S_2ts	58.24	S_2ts	60.08
21	S_2ts	64.07	S_3sc	35.23	S_2s	69.88	S_2s	69.6
22	S_2ts	51.4	N_1tsnc	21.53	S_2ts	53.16	S_3ts	35.72
23	S_2ts	54.06	S_3tsc	26.69	S_2ts	54.98	S_2ts	54.78
24	S_2ts	51.11	N_1tsc	23.84	S_2ts	54.97	S_2ts	56.26
25	S_2ts	52.93	S_3tsc	25.53	S_2ts	56.74	S_2ts	56.69
26	S_3ts	42.09	N_1tsc	17.53	S_3ts	45.14	S_2ts	56.24
27	S_2ts	52.7	S_3tsc	26.33	S_2ts	57.29	S_2ts	58.85
28	S_3tsn	28.46	N_2tsnc	5.23	S_3ts	38.14	S_3tsn	30.16
29	S_3ts	37.9	N_1tsc	17.13	S_3ts	41.71	S_2ts	51.54
30	S_2ts	70.63	S_3c	38.55	S_1	76.63	S_1	76
31	S_2n	58.12	N_1nc	14.89	S_2ts	71.51	S_2n	50.85
32	S_2t	55.73	S_3tnc	26.17	S_2t	61.68	S_2t	56.45

such as soil texture, soil depth and slope.

The major limiting factors in maize production are low relative humidity and high n/N ratio during the plant growth, lime content and soil texture among the soil physical properties and slope. Limiting factors in producing alfalfa also include slope and soil texture among the soil physical properties.

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