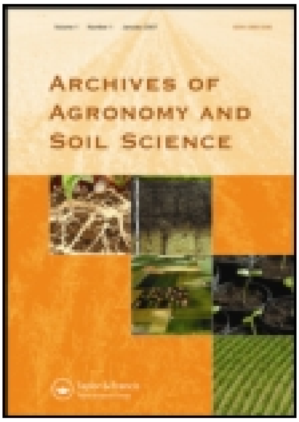

Archives of Agronomy and Soil Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gags20

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Version of record first published: 27 Sep 2011.

To cite this article: A. Pakpour Rabati , A. A. Jafarzadeh , F. Shahbazi , S. Rezapour & H. R. Momtaz (2012): Qualitative and quantitative land-suitability evaluation for sunflower and maize in the north-west of Iran, Archives of Agronomy and Soil Science, 58:11, 1229-1242

To link to this article: http://dx.doi.org/10.1080/03650340.2011.579597

Archives of Agronomy and Soil Science
Vol. 58, No. 11, November 2012, 1229–1242

Qualitative and quantitative land-suitability evaluation for sunflower and maize in the north-west of Iran

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(*Received 27 October 2010; final version received 4 April 2011*)

Land evaluation is the act of predicting the use potential of land on the basis of its attributes. The objective of this study was to evaluate qualitative and quantitative land suitability for the north-west of Iran on the basis of a FAO model for sunflower and maize crops. Growing cycle was determined using the CDBm (Monthly Climate Database) model and soils were classified in two orders of Mollisols and Vertisols, which consisted of seven soil families based on soil data and Keys to Soil Taxonomy 2010. Qualitative evaluation was carried out using the square root of parametric (SRP) method and quantitative evaluation was performed on the basis of observed yields under an average management level. The results showed that in the surveyed area, the climatic class had moderate suitability (S2) for maize and sunflower due to limitations imposed by the relative humidity of the growing cycle. The most important land limitation factors were soil parameters like pH, $CaCO_3$ content, texture and coarse fragments, as well as topography and drainage in the area of study. Based on qualitative evaluation with SRP, 24.69 and 17.71% of land had non-suitable class (N1) for maize and sunflower, respectively. Quantitative land suitability for maize and sunflower showed that 24.69 and 9.81% of land had non-suitable class (N1), respectively.

Keywords: CDBm; parametric method; qualitative and quantitative land evaluation

Introduction

Land is the ultimate source of wealth and the foundation on which many civilizations are constructed. Land evaluation may be defined as 'process of assessment of land performance when used for specified purposes' (FAO 1985). Sustainability of ecosystem productivity and biodiversity is needed to investigate the quality and quantity of natural resources and their suitability for a range of land-use planning processes in future rural, urban and industrial activities (Kilic et al. 2005). Land evaluation plays a major part in comparison of each type of land for different uses, and provides information for subsequent activities such as optimum land-use planning or increasing area per unit with respect to land-suitability evaluation. There are two main types of land evaluation: the qualitative and the quantitative approach (FAO 1976). Qualitative land-suitability evaluation refers to the determination of

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ISSN 0365-0340 print/ISSN 1476-3567 online

http://dx.doi.org/10.1080/03650340.2011.579597
http://www.tandfonline.com

land characteristics such as landscape, soil and climate. Quantitative evaluation determines land suitability based on crop yield and productivity of a unit area of land (i.e. t ha^{-1}), in which economic factors and the FAO's model are implemented to determine critical production and production potential, respectively. Land evaluation is a tool for strategic land-use planning. Francesco et al. (2003) conducted a land evaluation of Thies Region, Senegal, for crops such as maize, sorghum, pea and sesame. The evaluation showed that the northern part of the region contained suitable (S1) or relatively suitable (S2) land for all the crops under study, whereas in the north-west, along the shoreline, the crop lands were non-suitable (N1 and N2), which was due to the domination of sandy soils. The study also indicated that of 60,387 ha of studied land, 12,522 ha were highly suitable (S1) for all the crops, 31,540 ha were relatively suitable (S1) and 16,325 ha were totally unsuitable (N1 and N2). Njiki et al. (2005) performed a land evaluation project for Shouyang County in Shanxi Province, China, in which maize, soybean, potato, sunflower and wheat, as well as three other crops were studied. For this purpose, land-suitability classification was carried out using the parametric method and consequent land-suitability maps were prepared for crops produced using traditional and mechanized cultivation. After quantitative land-suitability evaluation in the northern Braan region in Esfahan Province of Iran for agricultural crops such as irrigated wheat, barley, maize and rice, Ayoubi et al. (2002) concluded that land units had medium to low suitability classes and some land units were non-suitable. Shahbazi and Jafarzadeh (2004) performed a land-evaluation project in Bonab region, Iran, using three methods: simple limitation, numeric or intensity limitation and the parametric method (Storie and SR method) on wheat, barley, alfalfa, onions, sugarbeet and maize. The results revealed that SRP had higher accuracy and efficiency than the other methods of study. Many studies related to various aspects of land suitability for crop cultivation have been conducted on the basis of the FAO framework in different areas (Young and Goldsmith 1977; Sarvari and Mahmoudi 2001; Hassan et al. 2002; Bellinfonte et al. 2003; Menjiver et al. 2003). Most of these studies confirm the advantages and the reason for preference of this method. The objective of this study is to evaluate qualitative and quantitative land suitability of the Pasveh and Jaldyan Region (West Azarbyjan province) in north-west Iran on the basis of the FAO model for sunflower and maize.

Materials and methods

Study area

This study was performed in Pasveh and Jaldyan province of West Azerbaijan, Iran, (Figure 1). The area is ~9680 ha and is located between 36°30′ to 36°50′N and 45°05′ to 45°25′E. Climate data for last 20 consecutive years (1986–2006) were collected from Piranshaher Meteorological Station, the data included: maximum and minimum daily temperature in July (32.4°C) and January (−5.3°C), average annual temperature (12°C), and total annual precipitation (627.7 mm). The soil temperature and moisture regimes of study area are mesic and xeric, respectively (Banaei 1998). The climate data were integrated into the CDBm (Monthly Climate Database) program (De la Rosa et al. 1992). The CDBm developed for the Microcomputer Land Evaluation Decision Support System (MicroLEIS DSS) is a computer-based tool for the organization, storage and manipulation of agro-climatic data for land evaluation (Figure 2). The basic data of CDBm are mean values of the daily dataset

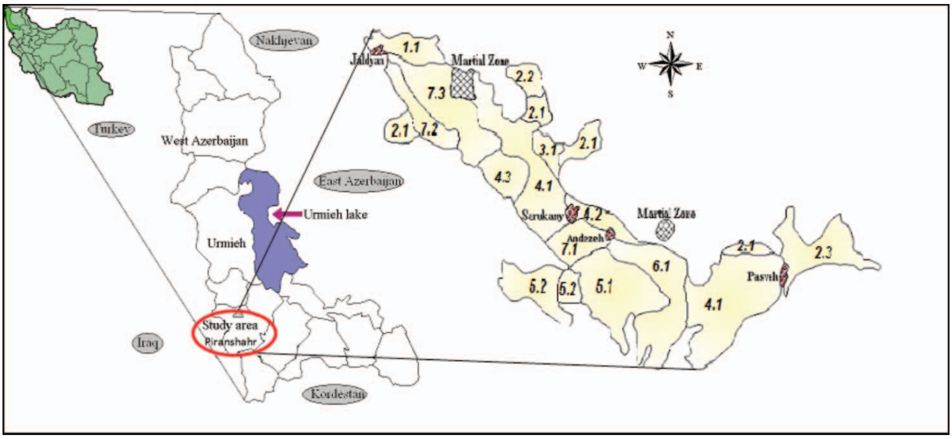

Figure 1. Location of the study area.

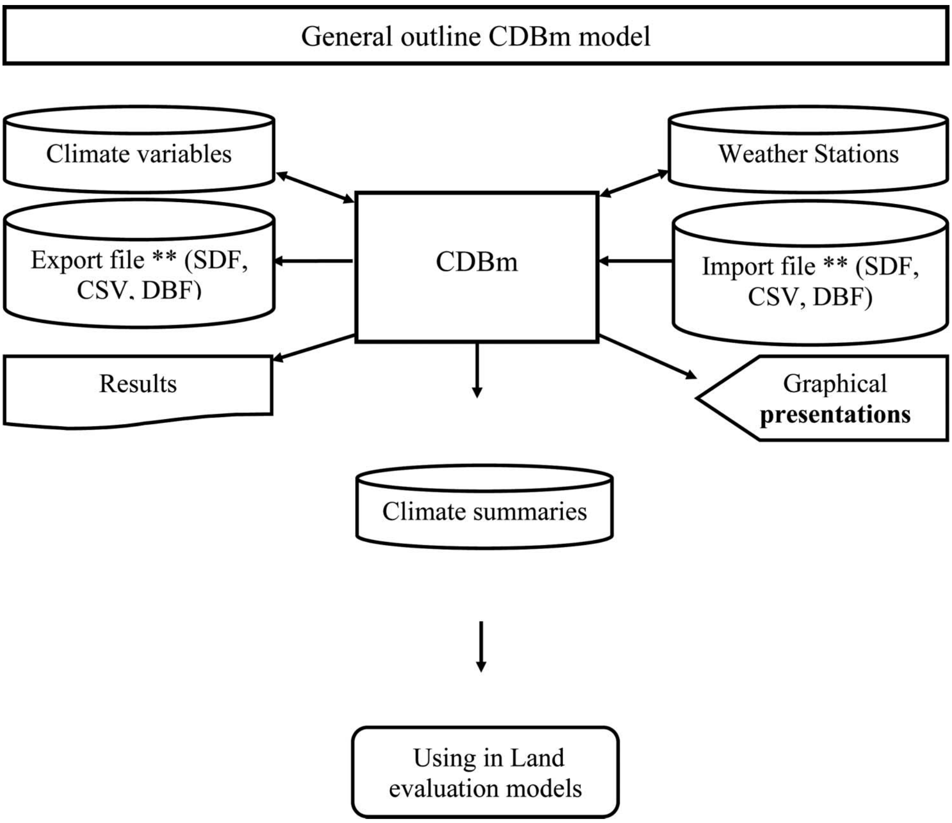

Figure 2. The CDBm model shown diagrammatically (De la Rosa et al. 1992). **SDF (Standard Data File), CSV (Comma Separated Values), DBF (dBase File).

for a particular month. The stored mean of monthly values correspond to a set of temperature and precipitation variables (maximum temperature, minimum temperature, accumulative precipitation, maximum precipitation per day and days of precipitation). In summary, CDBm produces a graphical presentation of a weather station over a period of years. This presentation always refers to the following observed and calculated variables: T_m (mean temperature), P (precipitation), ET_o (potential evapotranspiration; T, Thornthwaite; H, Hargreaves), *ARi* (aridity index) and *GS* (vegetative period).

Growing cycle

Finding the best time for planting each crop according to regional climatic conditions is necessary for farm management. Sowing time, irrigation practices and suitable harvest time can be determined to obtain the highest crop yield considering the meteorological data of each study area and crop requirements. To achieve optimum yield at any area, it is now essential to distinguish between different climatic crop requirements because climate data are uncontrollable agents that have an impact on germination.

A graphical representation of the results from Piranshaher Meteorological Station using CDBm program of MicroLEIS is shown in Figure 3. In the studied region, agricultural lands were cultivated in a traditional way using semi-mechanized techniques and equipment. According to the available data, the growth periods and development stages for the crops in the region include: initial stage, development stage, mid-season stage and late season stage (Table 1). Overall, unfavorable growth conditions such as rainfall, temperature and evapotranspiration in June, July and August reduced yield because drought occurred more than in the other months.

Land evaluation studies

At first, semi-detailed soil reports of Piranshahr region were studied. The required characteristics of qualitative land evaluation (Sys et al. 1991a), including climate data (precipitation, evaporation and potential transpiration, temperature, solar radiation, relative humidity, altitude), land characteristics (slope, drainage, flood,

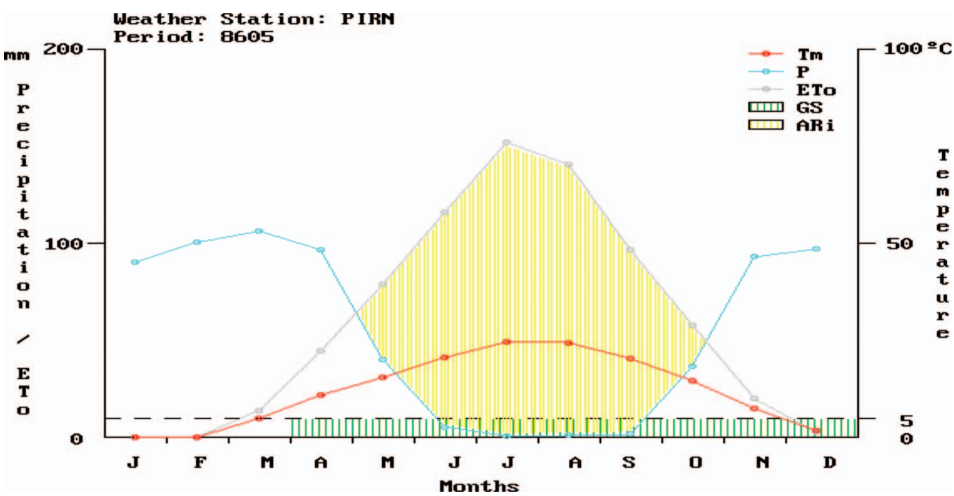

Figure 3. Graphical representation of results for Piranshaher station using CDBm.

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

Crop	Initial stage	Developed stage	Mid-season stage	Late	Total
Sunflower	25 day (30 April–23 May)	35 day (24 May–28 June)	45 day (29 June–12 August)	25 day (13 August–6 September)	130
Maize	25 day (30 April–23 May)	40 day (24 May–3 July)	45 day (4 July–17 August)	30 day (18 August–17 September)	140

microrelief) and soil parameters (texture, soil structure, coarse fragments, soil depth, $CaCO_3$ content, cation exchange capacity, soil pH, organic carbon content, salinity) were collected. After that, land characteristics were compared with plant requirements tables introduced by Sys et al. (1991b). Finally, SRP was used for maize and sunflower crops.

For quantitative land-suitability evaluation, most of the methods that classify areas according to land productivity values were used. Therefore, it was necessary to delineate the boundary between two consecutive classes with high accuracy before land classification. To determine these limits, the potential yield calculation of maize and sunflower was required. FAO (1976) and De Wit (1965) models were used to estimate the maize and sunflower potential productivity in the study area, according to Equation (1):

$$Y = \frac{0.36 \times Bgm \times KLAI \times HI}{(1/L) + 0.25Ct}. \quad (1)$$

The representation of the symbols in Equation (1) is as follows: Y, potential yield (kg ha^{-1}); Bgm, gross biomass production (kg CH_2O ha^{-1} h^{-1}); $KLAI$, adjusting leaf area index; HI, harvest index; L, growing cycle; and Ct, respiration coefficient.

To measure marginal yield, the essential production expenses for the studied crops in each land unit must be estimated. Hence, total information about current expenses including entire expenditures related to planting practices in each land unit was collected. First, the accuracy of land evaluation must be verified. In this step, the predicted yield was calculated by multiplying the potential yield by soil index, as represented by Ayoubi et al. (2002). In the next step, a significant relationship between observed yield (Y) and predicted yield (X) [Equations (2) and (3)] could prove the accuracy of selected land evaluation manner.

$$\text{Maize: } Y = 0.77X - 0.175 \quad R^2 = 0.986 \quad (2)$$

$$\text{Sunflower: } Y = 0.737X - 0.087 \quad R^2 = 0.952 \quad (3)$$

After recognition of the accuracy of the quantitative land-suitability evaluation – through a significant relationship – linear regressions among land index and observed yield for crops were applied. Patterns introduced by Sys et al. (1991a) were used to determine land class limits.

Results and discussion

Soil surveys

Tables 2 and 3 show the morphological and physico-chemical properties of typic profiles in the studied area. Also, based on soil taxonomy (Soil Survey Staff 2010),

Table 2. Some morphological and physical properties of representative soil profiles.

Depth (cm)	Horizon	Color		Boundary	Structure	Moisture %	
		Dry	Wet			FC	PWP
Profile 1, Situation; East of Jaldyan with slope 2–5% and Microrelief 30–60, Unit 1–1							
0–20	Ap	10YR 5/3	10YR 3/3	–	2gr	33.5	19
20–70	$Bkss_1$	10YR 5/3	10YR 3.5/3	aw	2cpr	33.8	19.8
70–120	$Bkss_2$	10YR 5.5/3	10YR 3.5/3	gw	2cpr	32.3	19.8
120–150	$Bkss_3$	10YR 5/3	10YR 4/4	gw	2cpr	32.9	18.7
Profile 2, Situation; South of Jaldyan with slope ––8% and Microrelief 15–30; Units 2–1							
0–20	Ap	10YR 5/3	10YR 3/3	–	3gr	27.1	12.7
20–60	Bk_1	7.5YR 5/3	7.5YR 3/4	gw	2csbk	25.4	14.9
60–85	Bk_2	7.5 YR 5/4	7.5YR 4/4	gw	2csbk	32.3	21.4
85–115	Bk_3	7.5 YR 5/4	7.5YR 4/4	gw	2csbk	30.7	18.9
115–150	Bk_4	7.5 YR 5/4	7.5YR 4/4	gw	2csbk	30.7	18.5
Profile 3, Situation; West of Sarukany with slope 1–2% and Microrelief 15–30; Unit 3–1							
0–25	Ap	10YR 5/2	10YR 3/2	-	3gr	38.3	21.3
25–80	Bkg_1	10YR 5/3	10YR 3/3	aw	2fcpr	35.4	20.7
80–125	Bkg_2	10YR 5/3	10YR 4/3	gw	2fcpr	33.4	17.3
125–150	Bkg_3	10YR 5/4	10YR 3/3	gw	m	31.8	19
Profile 4, Situation; Junction Naghadeh-Pasveh with slope 0–1% and Microrelief 0–15; Unit 4–1							
0–20	Ap	10YR 5/3	10YR 3/3	-	2gr	26.2	15.7
20–50	Bw_1	10YR 5/3	10YR 3/3	gw	1csbk	24.9	15
50–80	Bw_2	7.5YR 5/3	7.5YR 3/4	gw	1cpr	34.1	19.1
80–125	Bk_1	7.5YR 5/4	7.5YR 3/4	gw	1cpr	36.6	19.7
125–150	Bk_2	7.5YR 5/4	7.5YR 3/4	gw	1cpr	35.5	19
Profile 5, Situation; South of Andezeh with slope 1–2% and Microrelief 15–30; Unit 5–1							
0–20	Ap	10YR 5/3	10YR 3/3	–	2gr	37.4	21.8
20–60	Bkss	10YR 5/3	10YR 3.5/3	aw	2mpr	37.5	20.3
60–100	Ck_1	–	10YR7/4	gw	m	32.4	18.6
100–150	Ck_2	–	10YR7/4	gw	m	31.1	16.8
Profile 6, Situation; South of Sarukany with slope 0–1% and Microrelief 0–15; Unit 6–1							
0–10	Ap	10YR 5/3	10YR 3/3	–	2gr	35	18.1
10–30	A	10YR 5/3	10YR 3/3	as	2sbk	34.3	17.8
30–70	Bss_1	10YR 5.5/3	10YR 3.5/3	gw	2csbk	34.5	18.7
70–125	Bss_2	10YR 5.5/3	10YR 3.5/3	gw	2csbk	33	18
125–150	CB	10YR 5.5/3	10YR 4/3	gw	1vfsbk	32.3	16.1
Profile 7, Situation; West of Andezeh with slope 1–2% and Microrelief 0–15; Unit 7–1							
0–25	Ap	10YR 5/3	10YR 3/3	–	1gr	23.1	10.8
25–65	Bw1	10YR 5/3	10YR 3.5/3	gw	1msbk	20.4	8.6
65–95	Bw2	10YR 5/3	10YR 3.5/4	gw	1msbk	16.7	6.2
95–125	C1	10YR 5/3	10YR 4/3	gw	sg	12.2	5.6
125–150	C2	10YR 5/3	10YR 4/3	as	sg	23	11.4

Note: FC, field capacity; PWP, permanent wilting point. aw, abrupt wavy; gw, gradual wavy; as, abrupt smooth; gr, granular; csbk, coarse subangular bloky; fcpr, fine columnar; pr, prismatic; mpr, medium prismatic; cpr, columnar; sg, single grain; m, massive.

Table 3. Some physical and chemical properties of representative soil profiles.

Depth (cm)	Horizon	Soil particles (%) Sand	Silt	Clay	Soil Texture	CF (%)	$CaCO_3$ (%)	pH	CEC Cmol (+)/kg	EC (dS m^{-1})	OC (%)
Profile 1											
0–20	Ap	11.8	37	51.2	C	5	14	7.6	30.8	0.65	1.1
20–70	$Bkss_1$	11.8	33	55.2	C	–	17.5	7.7	29.4	0.28	0.68
70–120	$Bkss_2$	11.8	34	54.2	C	–	19.4	7.7	28	0.27	0.48
120–150	$Bkss_3$	13.8	33	53.2	C	–	21.2	7.9	27	0.26	0.41
Profile 2											
0–20	Ap	27.8	32	40.2	C	15	4.12	7.4	15.23	1.44	1.5
20–60	Bk_1	29.8	22	48.2	C	10	7.12	7.7	21.08	0.29	0.62
60–85	Bk_2	15.8	35	49.2	C	5	18.1	7.8	10.9	0.23	0.37
85–115	Bk_3	10.8	45	44.2	C	–	18.7	7.8	12.42	0.27	0.34
115–150	Bk_4	15.8	33	51.2	C	4	18.9	7.5	20.86	1.17	0.27
Profile 3											
0–25	Ap	9.6	33.7	56.7	C	–	7.5	7.9	32	0.73	1.5
25–80	Bkg_1	13.6	31.7	54.7	C	–	17.5	8.2	31.5	0.6	0.57
80–125	Bkg_2	9.6	36.7	53.7	C	–	20.6	8.3	28.4	0.77	0.45
125–150	Bkg_3	5.6	38.7	55.7	C	–	28.7	8.3	28	0.67	0.33
Profile 4											
0–20	Ap	27	28.6	44.4	C	–	3.5	6.8	20	0.44	1.1
20–50	Bw_1	34	22.6	34.4	CL	–	3.62	7.1	20.6	0.52	0.56
50–80	Bw_2	18	37.6	44.4	C	–	3.12	7.1	23	0.22	0.52
80–125	Bk_1	14	35.6	50.4	C	–	15.25	7.8	28	0.27	0.4
125–150	Bk_2	12	32.6	55.4	C	–	17.62	7.8	28	0.55	0.33
Profile 5											
0–20	Ap	10.4	30.6	59	C	–	5.62	7.7	29.63	0.52	1.3
20–60	Bkss	12.4	33.6	54	C	–	13.7	7.6	27.47	0.42	0.62
60–100	Ck_1	30.4	33.6	36	CL	–	30	7.8	23	0.33	0.43
100–150	Ck_2	24.4	39.6	36	CL	–	29	7.9	22.5	0.32	0.23
Profile 6											
0–10	Ap	12.6	32.7	54.7	C	–	1.87	7.3	38	0.51	1.2
10–30	A	11.6	32.7	55.7	C	–	2.5	7.2	32.5	0.37	0.95
30–70	Bss_1	14.6	32.7	52.7	C	–	2.8	7.5	33	0.21	0.56
70–125	Bss_2	17.6	32.7	49.7	C	–	3.5	7.7	33	0.24	0.47
125–150	CB	23.6	31.7	44.7	C	–	5	7.7	30.8	0.38	0.25
Profile 7											
0–25	Ap	31.8	42	26.2	L	5	1.62	7.4	17.5	0.45	1.5
25–65	Bw1	39.8	39	21.2	L	5	3.12	7.5	15	0.31	0.49
65–95	Bw2	45.8	36	18.2	L	10	1.75	7.5	13.4	0.32	0.39
95–125	C1	60.2	26.6	13.2	SL	20	2.1	7.5	11.7	0.35	0.35
125–150	C2	34.8	39	26.2	L	5	1.5	7.6	16.8	0.27	0.33

Note: C, clay; L, loamy; SL, sandy loamy; OC, organic carbon; CF, coarse fragment.

soils were classified into two orders of Mollisols and Vertisols, which consisted of seven soil families and series (Table 4). These soils were classified into the following main great groups: Typic Calcixererts, Vertic Calcixerolls, Aeric Calciaquolls, Typic Haploxererts and Fluvaquentic Haploxerolls.

Qualitative land suitability

The results of the climatic suitability evaluation showed that in the studied area the climatic classes were of moderate suitability (S2) for maize and sunflower due to the limitation imposed by the relative humidity of the growing cycle (data not shown).

Table 4. Soil classification of the mapping units

Sample	Series	Soil classification		Soil units	Area (ha)
		Family	Order		
1	Jaldyan 1	Fine, mixed, active, mesic Typic Calcixererts	Vertisols	1.1	850
2	Kalij	Fine, mixed, active, mesic Vertic Calcixerolls	Mollisols	2.1	1100
				2.2	125
				2.3	550
3	Sarchah	Fine, mixed, active, mesic Aeric Calciaquolls	Mollisols	3.1	90
4	Pasveh	Fine, mixed, active, mesic Vertic Calcixerolls	Mollisols	4.1	1800
				4.2	750
				4.3	225
5	Andezeh	Fine, carbonatic ,active, mesic Typic Calcixererts	Vertisols	5.1	915
				5.2	625
6	Sarukany	Fine, mixed, superactive, mesic Typic Haploxererts	Vertisols	6.1	1750
7	Jaldyan 2	Fine-loamy, mixed, superactive, mesic Fluvaquentic Haploxerolls	Mollisols	7.1	475
				7.2	250
				7.3	275
Total					9680

The qualitative land suitability results revealed that ~46.75, 35.54 and 17.71% of the land had moderate suitability class (S2), critical suitability class (S3) and non-suitable class (N1) for sunflower, respectively (Figure 4). For maize crops, ~75.31 and 24.69% of land had critical suitability class (S3) and non-suitable class (N1), respectively (Figure 5). Based on the results, as well as the climatic attributes, the most important limitation factors for crop growth were soil parameters like pH, $CaCO_3$ content, texture, coarse fragments and topography. Also, some land units with Aeric Calciaquolls, Vertic Calcixerolls and Typic Haploxererts classification had drainage limitations (Table 5).

Quantitative land suitability

The potential yields of sunflower and maize were estimated to be ~5.28 and 9.91 t ha^{-1} in the surveyed area, respectively. The high correlation between observed and predicted yield indicated the high accuracy of the evaluation method. To calculate this relationship, predicted yield was calculated by multiplying soil index (computed by SRP) by potential production. To prevent interaction, because climatic factors were used in calculating the potential production, soil index was also considered in this calculation. Land index includes soil as well as climatic index. Mandal et al. (2002) reported that land index calculated using the Khidir method (SRP) was highly correlated with actual cotton yield in Nagpur district in India. At the second stage, the critical production value, total variable costs divided by crop unit price, was calculated to be 1.27 and 2.63 t ha^{-1} for sunflower and maize, respectively (Table 6).

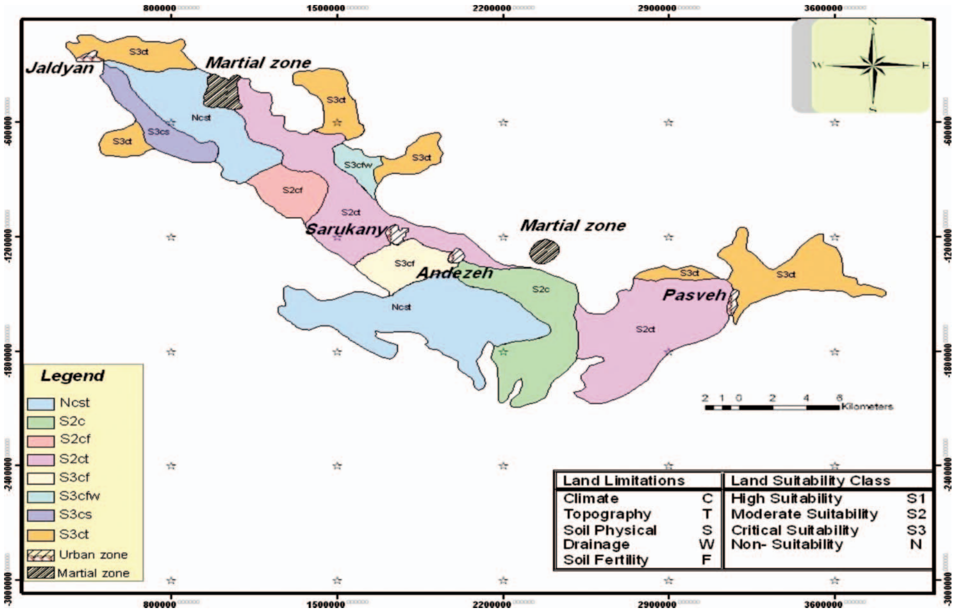

Figure 4. Qualitative land suitability map for sunflower in different land units using the parametric method (scale: 1:50,000).

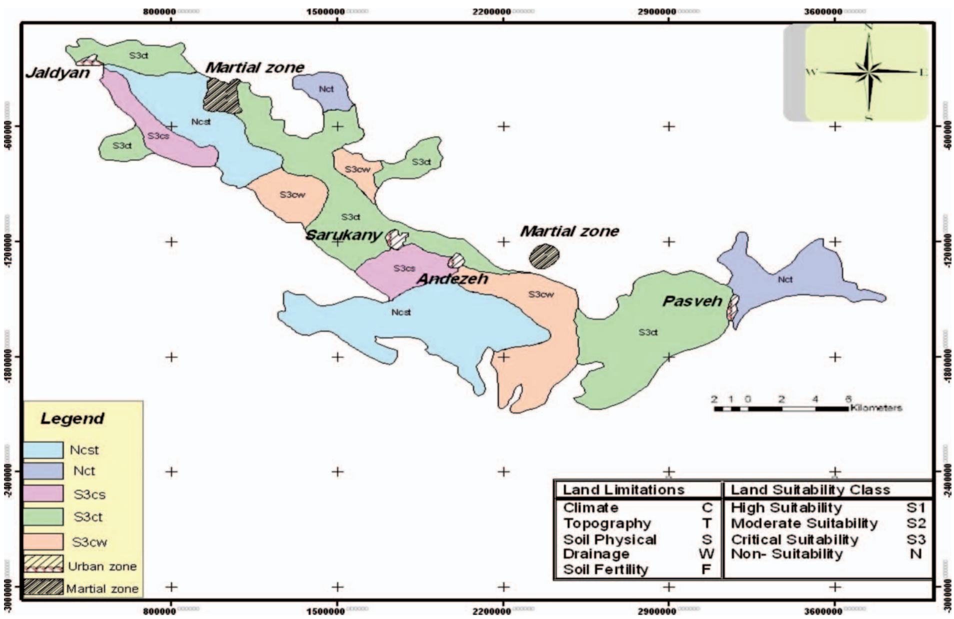

Figure 5. Qualitative land suitability map for maize in different land units using the parametric method (scale: 1:50,000).

Marginal yield reflected the level of productivity and showed that the total profit was in equilibrium with total expenses. The boundary between classes is determined by Sys et al. (1991a) as follows:

Table 5. Qualitative land suitability of mapping units for different land utilization types by parametric method.

Land units	Soil classes	Climate index		Climate class		Land index		Land class	
		Maize	Sunflower	Maize	Sunflower	Maize	Sunflower	Maize	Sunflower
1.1	Typic Calcixererts	51.52	71.58	S2	S2	29.89	41.24	S3ct	S3ct
2.1	Vertic	51.52	71.58	S2	S2	26.98	34.65	S3ct	S3ct
2.2	Calcixerolls	51.52	71.58	S2	S2	23.87	28.27	Nct	S3ct
2.3		51.52	71.58	S2	S2	22.97	27.51	Nct	S3ct
3.1	Aeric Calciaquolls	51.52	71.58	S2	S2	28.54	29.73	S3cw	S3cfw
4.1	Vertic	51.52	71.58	S2	S2	36.47	53.06	S3ct	S2ct
4.2	Calcixerolls	51.52	71.58	S2	S2	39.04	50.42	S3ct	S2ct
4.3		51.52	71.58	S2	S2	39.94	54.53	S3cw	S2cf
5.1	Typic	51.52	71.58	S2	S2	24.76	23.76	Ncst	Ncst
5.2	Calcixererts	51.52	71.58	S2	S2	24.12	22.03	Ncst	Ncst
6.1	Typic Haploxererts	51.52	71.58	S2	S2	45.26	62.18	S3cw	S2c
7.1	Fluventic	51.52	71.58	S2	S2	43.16	57.02	S3cs	S3cf
7.2	Haploxerolls	51.52	71.58	S2	S2	33.60	45.54	S3cs	S3cs
7.3		51.52	71.58	S2	S2	21.82	24.87	Ncst	Ncst

Note: S2, moderate suitability; S3, critical suitability; N, non-suitable; c, climate; w, drainage; s, soil; f, fertility; t, topography.

Table 6. Economical investigations for determining critical production in the studied area.

Crops Input	Maize			Sunflower		
	Value	Unit price (Rial)	Total price (Rial)	Value	Unit price (Rial)	Total price (Rial)
Operation till and to prepare	–	–	750,000	–	–	750,000
Consumer chemical fertilizer	–	–	955,000	–	–	930,000
Cost of fertilizer practices	–	–	250,000	–	–	250,000
Seed planting	–	–	350,000	–	–	350,000
Simoom (L)	5.5	–	387,500	8	–	1,225,000
Worker (Person)	15	150,000	2,250,000	15	150,000	2,250,000
Harvest cost	–	–	900,000	–	–	870,000
Transportation	–	–	250,000	–	–	250,000
Purchase of seed (kg)	25	20,000	500,000	10	40,000	400,000
Total variable of coast	–	–	6,592,500	–	–	7,275,000
Price each unit of production	–	–	2510	–	–	5700
The number of critical production (t ha^{-1})	–	–	2.63	–	–	1.27

The boundary between S1 and S2 classes is 75% of potential yield level for crops. This was calculated as:

$$\text{Sunflower: } 0.75 \times 5.28\,\text{t ha}^{-1} = 3.96\,\text{t ha}^{-1}$$

$$\text{Maize: } 0.75 \times 9.91\,\text{t ha}^{-1} = 7.43\,\text{t ha}^{-1}$$

Table 7. The boundaries of quantitative land suitability class based on critical production and land index.

	Land suitability class							
	Sunflower				Maize			
Crops	S1	S2	S3	N	S1	S2	S3	N
Yield (t ha^{-1})	> 3.96	3.96–1.77	1.77–1.14	< 1.14	> 7.43	7.4–3.68	3.68–2.36	< 2.36
Land index	> 80.06	80.06–39.05	39.05–27.83	< 27.83	> 52.45	52.45–31.02	31.02–23.47	< 23.47

Note: S1, high suitability; S2, moderate suitability; S3, critical suitability; N, not suitable.

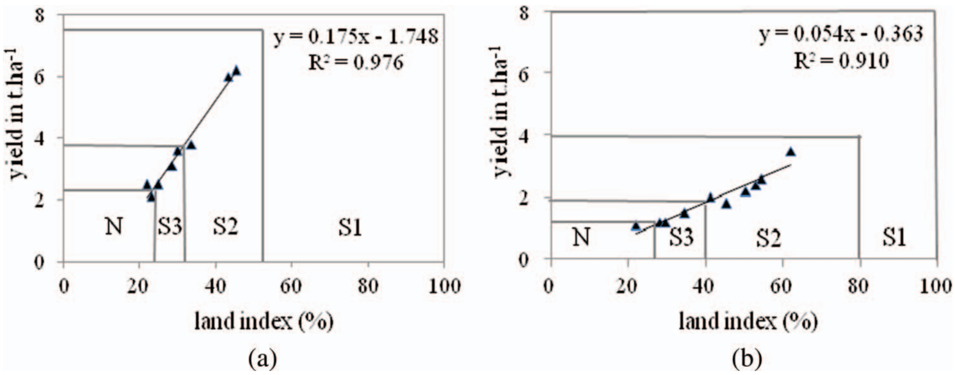

Figure 6. Application of linear regression between land index and actual yield. (a) Maize, (b) sunflower.

Table 8. Quantitative land suitability of mapping units for different land utilization types

		Maize			Sunflower		
Land units	Soil classes	Land index	Estimated yield (t ha^{-1})	Land class	Land index	Estimated yield (t ha^{-1})	Land class
1.1	Typic Calcixererts	29.89	3.48	S3	41.24	1.86	S2
2.1	Vertic	26.98	2.97	S3	34.65	1.51	S3
2.2	Calcixerolls	23.87	2.43	N	28.27	1.16	N
2.3		22.97	2.27	N	27.51	1.12	N
3.1	Aeric Calciaquolls	28.54	3.25	S3	29.73	1.24	S3
4.1	Vertic	39.47	4.63	S2	53.06	2.50	S2
4.2	Calcixerolls	39.04	5.08	S2	50.42	2.36	S2
4.3		39.94	5.24	S2	54.53	2.58	S2
5.1	Typic Calcixererts	24.76	2.59	S3	23.76	0.92	N
5.2		24.12	2.47	S3	22.03	0.83	N
6.1	Typic Haploxererts	45.26	6.17	S2	62.18	2.99	S2
7.1	Fluventic	43.16	5.81	S2	57.02	2.72	S2
7.2	Haploxerolls	33.60	4.13	S2	45.54	2.10	S2
7.3		21.82	2.07	N	24.87	0.98	N

Note: S1, high suitability; S2, moderate suitability; S3, critical suitability; N, not suitable.

The boundary between S2 and S3 classes is 40% more than the critical production level for crops. This is equal to:

$$\text{Sunflower: } 1.27\,\text{t ha}^{-1} + \left(0.4 \times 1.27\,\text{t ha}^{-1}\right) = 1.77\,\text{t ha}^{-1}$$

$$\text{Maize: } 2.63\,\text{t ha}^{-1} + \left(0.4 \times 2.63\,\text{t ha}^{-1}\right) = 3.68\,\text{t ha}^{-1}$$

The limit between S3 and N classes is 10% less than the critical production level for crops. This is equal to:

$$\text{Sunflower: } 1.27\,\text{t ha}^{-1} - \left(0.1 \times 1.27\,\text{t ha}^{-1}\right) = 1.14\,\text{t ha}^{-1}$$

$$\text{Maize: } 2.63\,\text{t ha}^{-1} - \left(0.1 \times 2.63\,\text{t ha}^{-1}\right) = 2.36\,\text{t ha}^{-1}$$

Table 7 shows the boundaries of quantitative land-suitability class based on the critical production and potential yield in Pasveh and Jaldyan regions. One of the most important advantages of this stage of land evaluation is that the obtained equation can be used to calculate actual yield level according to the land index for similar situations in other areas in the region or for larger areas. After recognition of the accuracy of quantitative land-suitability evaluation, a linear regression among land index and observed yield for maize and sunflower was applied (Figure 6).

Based on liner regression between observed yield and land index, estimated yield and quantitative land suitability were determined for mapping units for different land utilization types (Table 8). As Table 8 shows, the cultivation of sunflower in 63.02, 12.29 and 24.69% of land had moderate suitability (S2), critical suitability (S3) and non-suitable (N), respectively. For maize, 54.23, 35.96 and 9.81% of land had S2, S3 and N classes for cultivation, respectively.

Conclusion

The climate characteristics of the region were moderately suitable for maize and sunflower in this study. The main limiting climate factor was the relative air humidity during the growth cycle. Therefore, a modification of climatic suitability classes is suggested. The most land-limiting physical, fertility and topographical factors were soil parameters like texture, coarse fragments, pH, $CaCO_3$ content and microrelief. Also, some land areas with Aeric Calciaquolls, Vertic Calcixerolls and Typic Haploxererts soil classification had drainage limitations. In some areas, the results of quantitative land-suitability classes for crops were close to the qualitative land-suitability classes because SRP used the land and soil index. Poor management in the studied area was the main reason for differences between actual and potential yield due to the lack of some necessary inputs such as observing cultivation time, optimum use of fertilizers, pesticide application, breeding seeds, weed confliction and irrigation, or the suggested methods of FAO (1979) and De Wit (1965) were not efficient for application in Iran and should be corrected.

References

Ayoubi SH, Jalalian A, Amini AM. 2002. Quantitative land suitability in northern Braan region in Esfahan Province of Iran for agricultural crops such as irrigation wheat, barley, maize and rice. Iran J Sci Technol Agr Nat Resourc. 3:105–118.

Banaei MH. 1998. Soil moisture and temperature regimes map of Iran. Tehran (Iran): Soil and Water Research Institute, Ministry of Agriculture of Iran.

Bellinfonte N, Anaya-Romero M, Martinez-Zavala L, Jordan A. 2003. Agriculture soil and forestry suitability map in southern Spain. International symposium on sustainable use and management of soil in arid and semiarid regions; Cartagena. Spain. p. 544–547.

De la Rosa D, Moreno JA, Garcia LV, Almorza J. 1992. MicroLEIS: a microcomputer-based Mediterranean Land Evaluation System. Soil Use Manage. 8:89–96.

De Wit CT. 1965. Photosynthesis of leaf canopies. Agr. Res. Report No. 663. Wageningen (The Netherlands): Pudoc. p. 57.

FAO. 1976. A framework for land evaluation. Soils Bulletin 32. Rome, Italy: FAO.

FAO. 1985. Guidelines land evaluation for irrigated agriculture. Soils Bulletin 55. Rome (Italy): FAO.

Francesco A, Abu El-Ish B, Pierre D, Vladan D, Mirjana I, Rosa K. 2003. Land evaluation in the province of Thies, Senegal. Proceedings of the 23rd Professional MASTER course on Geomatics and Natural Resources Evaluation, Ministry of Foreign Affairs; Institute Agronomic Per Loltremare, Italy. p. 1–148.

Hassan M, Lilienthal H, Schnug E. 2002. Evaluation of land suitability for agriculture in El-Salam region of the North Sinai [internet]. Federal Agriculture Research Center. Institute of Plant Nutrition and Soil Science. Germany. Available from: www.tropentag.de/2022/abstracts/links/Lilienthal_vonN5K3i.pdf
Kilic S, Evrendilek F, Senol S, Celik I. 2005. Developing a suitability index for land uses and agricultural land covers: a case study in Turkey. Environ Monit Assess. 102:323–335.
Mandal DK, Kandare NC, Mandal C, Chalk O. 2002. Assessment of quantitative land evaluation methods and suitability mapping for cotton growing soils of Nagpur District. J Indian Soc Soil Sci. 50:74–80.
Menjiver JC, Aquilar J, Garcia I, Bouza P. 2003. Evaluation of olive orchard soils of map (Torres, se Spain). International symposium on sustainable use and management of soil in arid and semiarid regions. p. 984.
Njiki AGA, Antonio B, Fernanda CVM, Sara C, Wenqiang F, Edoardo F. 2005. Land evaluation in the Shouyang County, Shanxi Province, China. Proceedings of the 25th Professional MASTER course on Geomatics and Natural Resources Evaluation, Ministry of Foreign Affairs; Institute Agronomic Per Loltremare, Italy. p. 1–141.
Sarvari SA, Mahmoudi SH. 2001. Qualitative land suitability evaluation for irrigated sugar beet in Ghazvin region. Iran J Soil Water. (Special Issue) 15:66–75.
Shahbazi F, Jafarzadeh AA. 2004. Qualitative evaluation of land suitability in Khushe Mehr region of Bonab for wheat, barley, alfalfa, onion, sugar beet and maize. Agr Sci. 14:67–85.
Soil Survey Staff. 2010. Keys to soil taxonomy. 11th ed. Washington, DC: US Department of Agriculture, Natural Resources Conservation Service.
Sys C, Vanranst E, Debaveye J. 1991a. Land evaluation. Part I. Principles in land evaluation and crop production calculation, International training center for post graduate soil scientist. Ghent (Belgium): Ghent University. p. 274.
Sys C, Vanranst E, Debaveye J. 1991b. Land evaluation. Part II. Methods in land evaluation, International training center for post graduate soil scientist. Ghent (Belgium): Ghent University. p. 247.
Young A, Goldsmith RF. 1977. Soil survey and land evaluation in developing countries. A case study in Malawi. Geograph J. 143:407–438.