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Original article

Investigation on soil genesis and land suitability evaluation of Anarak region: a case study in Fars province

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A B S T R A C T

Land capability is governed by the different land attributes such as the types of soil, underlying geology, topography, hydrology, and etc. This study was conducted in order to study of soil genesis of Anarak region in Fars province. Using the findings of the semi-detailed soil studies for this area, 8 land units were selected. Results showed that climate and topography are two important soil forming factors affecting genesis, characteristics, and classification of soils. Soils of study area were classified as Calcixerepts, Haploxerepts (Inceptisols) and Xerorthents (Entisols). Moreover, land suitability evaluation study for some crops including irrigated wheat, barley and potato was carried out in the study area. Qualitative evaluation was carried out by means of parametric methods (Storie and Square root) and comparing land and climate characteristics with crop needs. Results of this investigation showed that the most important limiting factors in wheat and barley productions in study area included physical properties. Limiting factors in potato yield in the region along included soil physical properties and fertility. The land indices obtained for Barley was higher in comparison to irrigated wheat and potato. Minimum values of land indices observed in potato crop. It can be showed that the cultivation of potato cannot be recommended for this area.

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1. Introduction

Knowledge of soil genesis is imperative and basic to soil use and management. It provides important information to scientists who classify them. Pedogenesis is typically slower in warmer climates. For example, soils in Mediterranean regions and hot semi-arid climates are not strongly weathered (Schaetzl and Anderson, 2005). For many soils, especially weakly developed such as Entisols, Gelisols and Inceptisols, discernment of their parent material may be relatively easy (Schaetzl and Anderson, 2005). The solum may be thin enough and the soil young enough that a pit a few meters deep exposes the C horizon. In such soils, one can surmise some characteristics of the parent material, e.g., color and texture, by examining the profile (Schaetzl and Anderson, 2005).

Qualitative evaluation of the land suitability consists of determination of the land use for particular applications regardless of yield fulfillment and socio-economic issues (FAO, 1983). In different areas of Iran, land suitability was evaluated for some of crops in order to find an optimum use for each land unit such as onion, potato, maize, and alfalfa (Jafarzadeh and Abbasi, 2006), tea (Darvishi Foshtomi et al., 2011), German chamomile (Ghasemi Pirbalouti et al., 2011), cereal crops (Bagherzadeh and Mansouri Daneshvar 2011), barley (Ashraf et al., 2011) and tobacco (Sabeti Amirhendeh et al., 2013) in recent years. Nazari Barsari et al. (2014) investigated qualitative land suitability for cultivation of irrigated wheat and barley by using simple limited and the number and limiting intensity method in Esfarvarin, Qazvin province. They reported that irrigated wheat and barley had same results with both methods. 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.

Suitability analysis in a GIS context is a geographic, or GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of GIS suitability analysis is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being planned. Suitability is determined through systematic, multi-factor analysis of the different aspect of the terrain (Murphy, 2005).

The aim of this paper was study of soil genesis and classification of soils in Anarak region, Fars province. The other goal of this study also to find out which parts of land may best support the different crops (irrigated wheat, barley and potato) commonly grown by the local farmer based on the physical and chemical properties of the soils in the study area. Moreover, suitability maps were produced for each specific crop. In general, the evaluation class for the crops suitability ranges from suitable to permanently not suitable.

2. Materials and methods

2.1. Study area

Fars province is located in the southern part of Iran, at the 50º 33′–55º 38′ longitude and 27º 33′–31º 42′ latitude, with a land area of 1.32 million km2. The Zagros mountain range, with a north-west to south-east direction, is extended towards the central parts of the province. Elevations in the north reach higher than 3900 m above sea level, but in the southern parts are mostly less than 500 m a.s.l (Sadeghi et al., 2002). Anarak watershed is located in Khorambid city (215 km distance from Shiraz city). The study area is about 21008 hectare in areas of Fars province, located between 30º 35′ 24″ to 30º 47′ 44″ northern latitude and 52º 39′ 51″ to 52º 56′ 46″ eastern longitude. This watershed has not permanent rivers, but has a number of seasonal streams and floodways. Climatic data were prepared from Aliabad Komain climatology weather forecasting data station that is nearest station to study area (Table 1). Due to the geographic location of the Zagros mountain range, a major part of the rain producing air masses enter the region from the west and the north-west, with relatively high precipitation amounts for those areas. As one moves south and south-east, a reduction of rainfall is observed (Sadeghi et al., 2002).

The study area has various geological status (Figure 1a). The dominant geological formations consist of Asmari formation (include of thick calcareous dolomite and metamorphic rocks), Kazhdom formation (include of limestone and shale), Darian formation (include of limestone, thick-bedded sandstone and conglomerate), Fahlian formation (include of laminated to massive limestone with gray to brown color), Surmeh formation (include of limestone and dolomitic limestone and parts consists of schist, slate Cretaceous limestone units). Anarak basin has flat and relatively flat land areas during the Pleistocene as alluvium form (Darvishzadeh, 1991). The region is surrounded by mountains and hills. Plateau and upper terraces, plain, fan-shaped debris lands and fan-shaped alluvial lands are in study area (Table 2). Topographic map of study area presented in Figure (1b).

Table 1
Climatic characteristics from the Aliabad Komain climatology weather forecasting station.

Month	Monthly temperature (°C)			Total Rainfall (mm)	Mean Relative humidity (%)
	Mean monthly	Min. Mean	Max. Mean		
Feb	9.2	1.9	16.4	77.0	58.9
Mar	14.0	6.1	21.8	32.5	52.8
Apr	16.6	9.9	28.3	7.2	42.6
May	21.3	13.6	34.0	1.5	32.5
Jun	24.1	17.1	36.1	3.9	30.3
Jul	23.0	15.7	35.2	0.2	30.8
Aug	19.1	11.4	31.7	0.0	32.3
Sep	12.1	6.5	25.6	5.2	39.6
Oct	10.0	1.4	18.6	17.6	51.5
Nov	5.6	-1.4	12.7	78.7	63.9
Dec	3.4	-3.2	10.0	92.2	68.8
Jan	5.8	-1.1	12.8	73.9	65.5

Based on climatic data during 1972- 2009.

Table 2
Descriptive information about land types and area of land units.

Land types	Profile number	Land unit	Area (ha)	%
Mountain	-	1.1	8355.5	39.8
hill	7	2.1	1437.6	6.8
Plateau and upper terraces	1	3.1	1521.8	7.2
	6	3.2	2752.6	13.1
	8	3.3	2373.9	11.3
Plain	5	4.1	1694.0	8.1
Fan-shaped debris lands	2	8.1	920.8	4.4
	4	8.2	539.8	2.8
Fan-shaped alluvial lands	3	9.1	1267.9	6.0
Riverbed	-	RW	90.5	0.4
Total			21008.4	100.0

Descriptive information about land types and area of land units.

After interpretation of aerial photographs and output results obtained from DEM/GIS, profiles were dug. In order to obtain a reliable soil data, the soil survey reports from the profiles inspected and then 8 profiles within different land types such as hill, plateau and upper terraces, plain, fan-shaped debris lands and alluvium lands were chosen as representative for a more detailed investigation.

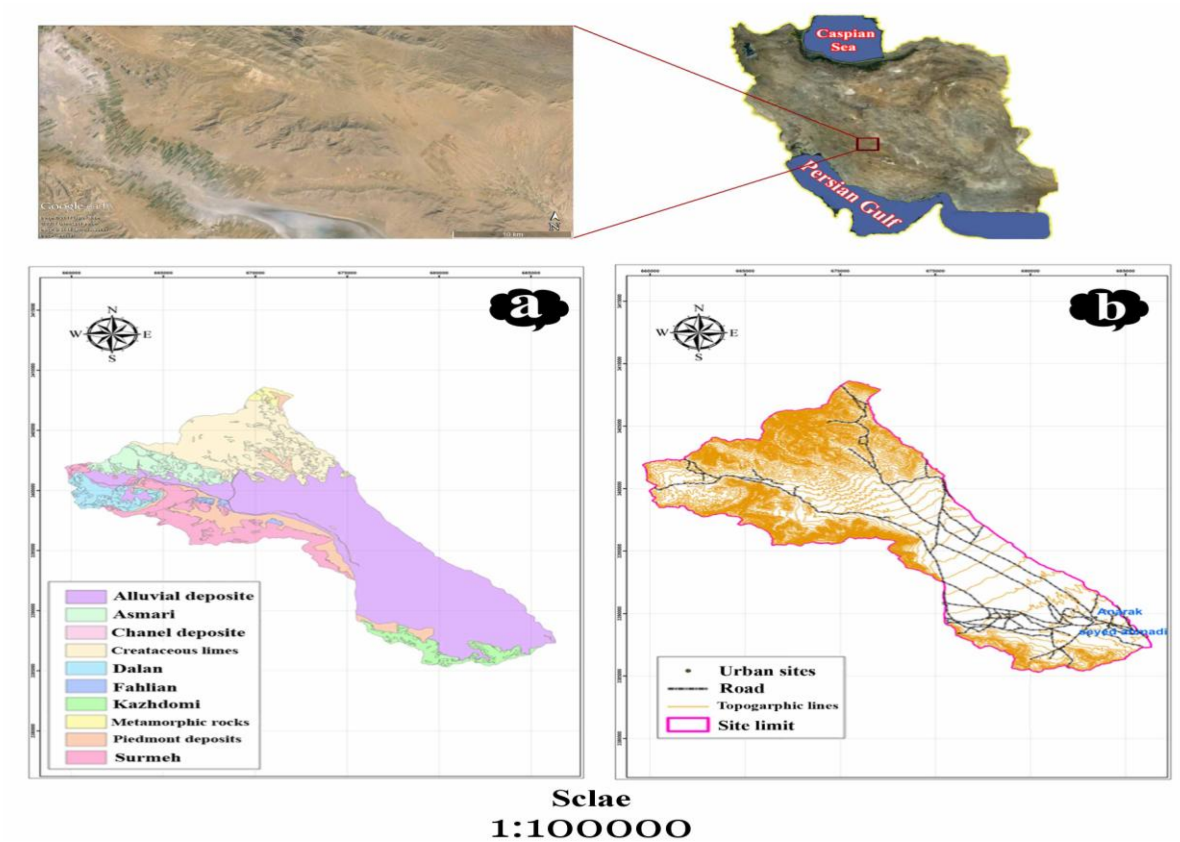

Fig. 1. Location of study area in Anarak region, Fars province.

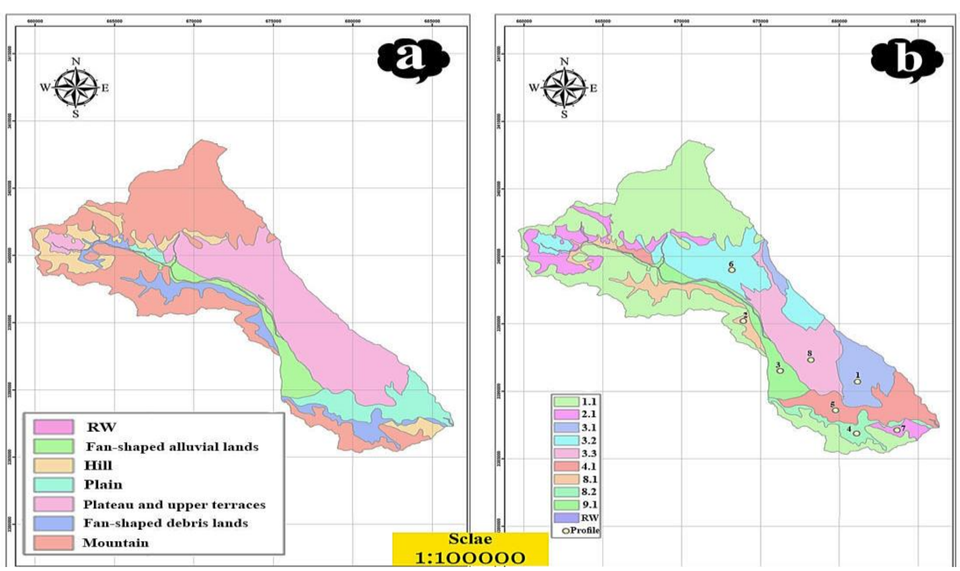

Fig. 2. a- land types and b- land units of study area.

2.2. Soil sampling and Laboratory analysis

Physical and chemical properties of the sieved soil samples (<2mm) were determined after being air-dried. Particle size analysis by hydrometer method (Gee and Or, 2002), and bulk density by clod method (Blake and

Hartge, 1986) were measured. The samples pH values were measured in the mixture of soil/water (1:1) (Thomas, 1996). Electrical conductivity (EC) was determined in a saturation extract of soil using conductivity meter (Rhoades, 1996). Organic carbon (OC) content was measured by the Walkley–Black wet oxidation method (Nelson and Sommers, 1996). Calcium carbonate was determined by simple titration method with 0.1 M HCl (Loeppert and Suarez, 1996). Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at pH=8.2 (Sumner and Miller, 1996). Phosphorous Soluble cations (Ca, Mg, Na and K) were extracted using water and were determined by atomic absorption and flame emission spectrometer (Suarez, 1996; Helmke and Sparks, 1996). Sulphate ions (SO42-) were determined by direct titration with lead nitrate with dithizone as indicator. The results were converted sulphate to the sulphur content (Nelson, 1982). Chloride in soil extracts is most commonly analyzed using potentiometric titration with AgNO3 (Rhoades, 1996). Bicarbonate ions (HCO3-) determined by titrating (titrimetric method) samples to an endpoint of pH 4.7 using methyl orange (Rhoades, 1996).

2.3. Land suitability evaluation and parametric methods (PM)

A wide range of limiting physical, economic and social factors can restrict suitability of the land for different kinds of use (FAO, 2007). In evaluating of the qualitative land suitability, land properties were compared with the corresponding plant requirements presented by Sys et al. (1993). It should be noted that, in the process of qualitative land suitability evaluation, there are several factors such as topography (slope), physical soil characteristics (texture, stones, profile depth, CaCO3 status and gypsum status), wetness status (flooding and drainage), the fertility characteristics (pH in H2O), and the salinity and alkalinity (EC and ESP) which can have dramatically impacts (Table 2). For qualitative land suitability investigation, parametric methods (Storie and square root) were used in this study.

In the parametric land evaluation different characteristics obtained a numerical scale and if a characteristic is appropriate for crop so it'll receive the maximum rate (normalised as 100%) and if the same characteristics have limitation, it'll get a less rate. Finally, the climatic index, as well as the land index, is calculated from these individual ratings (Sys et al., 1991). The land Index is a multiplicative index, derived from any number of factors which affect the 'value' of the land, usually land characteristics. The calculation of these indices can be carried out through following two procedures (Equations 1 and 2);

1. The Storie method (Storie, 1976):

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

Where:

I = index (%)

A, B, C etc. = ratings (%)

2. Square root method (Khiddir, 1986):

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

where:

I = index (%)

Rmin = minimum rating (%)

A, B, C etc. = remaining ratings (%)

Application of these methods implies that requirement tables have to be produced for each land utilization type. We compared the land characteristics with the plant requirements tables introduced by Sys et al. (1993). For determination, the limits of land classes we used pattern introduced by Sys et al. (1991). The land suitability classes are defined as follows:

Lands having indexes >75 are in S1 (very suitable) class.

Lands having indexes 50-75 are in S2 (moderate suitable) class.

Lands having indexes 25-50 are in S3 (marginal suitable) class.

Lands having indexes < 25 are in N (non-suitable) class.

Of course, there is a sub division for N class as N1 and N2 classes. For N1 class, correction is possible in the future but N2 class has not any correction in future. In addition, after determination of qualitative land suitability classes, the output results as georeferenced soil suitability maps using Arc GIS software version 10.1 were presented.

3. Results and discussion

3.1. Soil genesis of study area

Topographical variation from upper plateaus to lands of riversides and also rate of runoff, amount of water penetration into soil and vertical translocation of salts and materials within the soil profile have affected soil development and genesis. Probably, topography is the most important soil-forming factor here. As topography can be changes parent material by erosion or addition. The results of Abtahi (2008) in soils of Fars province showed that soil formation affected by topography and time. Topographic features were related to variations in soil texture and salinity. Due to the arid and semi-arid conditions, precipitation is very low and vegetation is poor, so soils have weakly developed. The major of soil evolution observed in calcic horizon.

Soils of study area were classified as Calcixerepts (in land units 3.1, 4.1, 3.2 and 3.3), Xerorthents (in land units 8.1 and 2.1) and Haploxerepts (in land units 9.1 and 8.2) according to key to soil taxonomy of U.S. Department Agriculture (USDA, Soil Survey Staff, 2010). Moreover, they were classified as Calcisols (in land units 3.1, 4.1, 3.2 and 3.3), Regosols (in land units 8.1 and 2.1) and Cambisols (in land units 9.1 and 8.2) according to world reference base for soil resources (IUSS Working Group WRB, 2006). Entisols (Xerorthens) are observed in hill (land unit 2.1, profile 7) and fan-shaped debris lands (land unit 8.1, profile 2) without distribution of secondary calcium carbonate. High slope in these lands don’t permit soil evolution. Entisols are soils that evidence of deposition of soil material not erased by soil forming processes, or only ochric epipedon present as evidence of soil formation (Arnold and Eswaran, 2003). Inceptisols (Calcixerepts and Haploxerpts) showed two B horizon, calcic horizon (in land units 3.1, 4.1, 3.2, 3.3) and cambic horizon (in land units 9.1 and 8.2), which are characteristic of an early stage of soil development (Table 3). These horizons developed in a tropical climate that shifted gradually towards semi-arid conditions (Emadi et al., 2008). Inceptisols have minimal expression of development due to low intensity of accumulation of material, alteration of minerals, or other processes. Weak subsurface structure development or evidence of alteration and hydrolysis to release iron resulting in some reddening of soil material (Arnold and Eswaran, 2003). Calcic horizons are common in arid and semi-arid climates in calcareous and non-calcareous soils (Emadi et al., 2008).

Abbreviated physical and chemical properties of horizons for the selected profiles are presented in Table 4. Results showed that clay content of land units 9.1, 8.2 and 3.2 decreased with depth while other land units had reverse trend and maximum contents of clay observed in C horizons of land units 4.1 and 3.3. Silt content was higher than clay and sand contents and had not specific trend in the most soil profiles (Table 4). Similar to silt content, sand content had not specific trend in some profiles. But it had decreasing or increasing trend with depth in some soil profiles (land units 8.1 and 4.1 had decreasing trend, but land units 8.2, 2.1 and 3.3 had increasing trend). In general, silty loam, clay, clay loam, silty clay loam and loam texture classes observed in soil profiles (Table 4).

Soils had basic reaction and pH increased with depth in the most soil profiles due to leaching of bases from upper horizons to lower one (Table 4). CaCO3 contents was remarkable for the most of soil profiles. Thus, the soils of study area in the semiarid climate are calcareous either in their subsoils or throughout the soil profile. EC values were low (< 1 dS.m-1) and it had not any problem (salinity) for all soil profiles. The content of OC in sub horizons were very low and OC contents have decreased with depth (Table 4). CEC content was low in all profiles that can be related to clay type and low content of OC. K and P concentrations showed a same trend. They decreased with depth that can be related to adding of fertilizers to soil.

The type of soluble materials (cations and anions) that are translocated in soils is a function of function of solubility, precipitation and permeability (Schaetzl and Anderson, 2005). The cationic and anionic compositions of the soil soluble indicate that Mg2+ and SO4 ions were dominate among the cations and the anions, respectively. The most likely source for soluble SO42- is gypsum dissolution, use of fertilizers in arable lands and sewage effluents (Shakeri et al., 2009). K concentration was lower than other cations. A part of K concentration is definitely contributed by irrigation return flow (Shakeri et al., 2009). HCO3- concentration was lower than other anions. The concentration of HCO3- is attributed to natural process such as dissolution of carbonate minerals in presence of soil CO2 (Shakeri et al., 2009). Climate of study is arid and semi-arid so microorganism activity is low that can be decrease CO2 content.

Table 3
Position and classification of soil profiles.

Land unit	Profile	Position (UTM) X	Position (UTM) Y	Soil taxonomy	WRB
3.1	1	681127	3390777	Loamy,mixed (calcareous),mesic Typic Calcixerepts	Haplic Calcisols
8.1	2	673938	3395259	Clayey-skeletal,mixed (calcareous),mesic Typic Xerorthents	Regosols (Calcaric)
9.1	3	676290	3391486	Loamy-skeletal,mixed (calcareous),mesic Typic Haploxerepts	Cambisols(Calcaric)
8.2	4	681127	3386877	Loamy-skeletal,mixed (calcareous),mesic Typic Haploxerepts	Cambisols(Calcaric)
4.1	5	679765	3388569	Fine,mixed (calcareous),mesic Typic Calcixerepts	Haplic Calcisols
3.2	6	673203	3399081	Loamy,carbonatic,mesic Typic Calcixerepts	Haplic Calcisols
2.1	7	683647	3387165	Loamy-skeletal,mixed (calcareous),mesic Typic Xerorthents	Regosols (Calcaric)
3.3	8	678214	3392328	Fine,mixed (calcareous),mesic Typic Calcixerepts	Haplic Calcisols

Table 4
Some physico-chemical properties of horizons for the selected profiles.

Land unit	Horizon	Depth (cm)	Texture (%) Clay	Silt	Sand	Tex Class	pH	CaCO3 (%)	EC (dS/m)	OC (%)	CEC (Cmol/kg)	K (mg/kg)	P
3.1	Profile 1												
	A	0-30	26	55.6	18.4	SiL	7.75	14.22	0.31	1.11	26.86	490	9.37
	Bk1	30-60	18	61.6	20.4	SiL	7.97	27.32	0.19	0.76	27.86	90	2.36
	Bk2	60-80	46	35.6	18.4	C	7.91	24.57	0.21	0.67	26.86	90	3.53
	C	80-100	48	37.6	14.4	C	8.05	24.20	0.22	0.64	29.34	100	2.42
8.1	Profile 2												
	A	0-15	34	35.6	30.4	CL	7.95	29.63	0.27	0.99	29.34	340	14.1
	Ck	15-50	50	29.6	20.4	C	8.16	43.89	0.22	0.58	20.65	70	6.27
9.1	Profile 3												
	A	0-20	30	33.6	36.4	CL	7.97	18.81	0.39	1.21	20.65	370	15.51
	Bw	20-40	28	35.6	36.4	CL	8.04	30.32	0.21	0.72	20.65	240	5.74
	C	40-80	26	37.6	36.4	L	8.04	39.06	0.25	0.58	22.82	140	4.12
8.2	Profile 4												
	A	0-30	30	43.6	26.4	CL	7.78	25.49	0.45	0.94	21.73	480	8.62
	Bw	30-60	32	33.6	34.4	CL	7.77	31.23	0.41	0.86	17.39	150	4.31
	C	60-100	20	23.6	56.4	SiCL	7.78	35.15	0.62	0.52	15.21	140	4.06
4.1	Profile 5												
	AP	0-15	38	31.6	30.4	CL	7.95	26.86	0.23	1.28	32.6	300	5.08
	Bk	15-30	48	31.6	20.4	C	8.05	42.74	0.26	1.13	29.34	150	3.20
	Ck	30-55	50	32.6	17.4	C	8.0	51.25	0.12	0.75	20.65	70	7.53
3.2	Profile 6												
	Ap	0-20	26	39.6	34.4	L	8.0	41.81	0.22	0.93	19.56	370	19.56
	Bk	20-40	36	35.6	28.4	CL	8.01	57.91	0.20	0.76	16.30	100	16.30
	Ck	40-60	26	37.4	36.6	L	7.96	55.00	0.21	0.14	15.21	70	7.53
2.1	Profile 7												
	A	0-20	34.0	49.6	16.4	SiCL	7.76	15.36	0.39	1.19	21.00	560	5.10
	C	20-60	38.0	35.6	26.4	CL	7.81	25.72	0.30	0.85	21.73	510	6.08
3.3	Profile 8												
	A	0-25	42	41.6	16.4	SiC	7.90	19.97	0.27	1.13	22.82	650	8.62
	Bk1	25-60	43	27.6	31.4	C	8.03	24.57	0.27	0.98	20.65	140	2.19
	Bk2	60-100	41	25.6	33.4	C	8.05	28.02	0.21	0.44	20.65	90	1.60
	Ck	100-150	50	17.6	32.4	C	8.01	39.05	0.23	0.40	19.56	95	3.01

Tex-texture, SiL- silty loam, C- clay, CL- clay loam, SiCL- silty clay loam, L- loam; EC- Electrical conductively; OC- Organic carbone; CEC- Cations exchange capacity; K- exchangeable potassium; P- available phosphorous

Table 5
Soluble cations and anions concentrations of horizons for the selected profiles.

Land unit	Horizon	Depth (cm)	Soluble cations (meq/L)				Soluble anions (meq/L)		
			K+	Na+	Mg2+	Ca2+	SO42-	Cl-	HCO3-
3.1					Profile 1				
	A	0-30	0.06	0.23	4.00	3.40	4.90	1.50	1.20
	Bk1	30-60	0.03	0.24	3.40	3.20	4.30	1.75	1.00
	Bk2	60-80	0.03	0.52	3.42	3.00	4.70	1.25	1.05
	C	80-100	0.02	0.41	5.20	1.40	4.80	1.75	1.20
8.1					Profile 2				
	A	0-15	0.03	0.19	1.50	1.80	2.30	1.77	1.20
	Ck	15-50	0.04	0.23	3.20	1.60	2.10	1.75	0.60
9.1					Profile 3				
	A	0-20	0.06	0.52	7.80	3.00	6.60	1.25	8.0
	Bw	20-40	0.03	0.41	9.40	1.80	7.60	1.25	2.00
	C	40-80	0.02	0.51	7.60	3.40	6.80	1.00	2.01
8.2					Profile 4				
	A	0-30	0.21	0.84	3.60	4.6	4.50	1.75	2.00
	Bw	30-60	0.03	0.67	7.00	1.0	4.80	1.77	2.22
	C	60-100	0.05	0.95	7.00	5.0	6.80	2.00	1.60
4.1					Profile 5				
	AP	0-15	0.04	0.15	5.40	0.80	2.00	1.50	2.20
	Bk	15-30	0.03	0.52	4.60	1.40	2.40	1.25	3.00
	Ck	30-55	0.03	0.15	2.60	2.00	1.60	1.00	1.80
3.2					Profile 6				
	Ap	0-20	0.03	0.41	4.40	2.04	2.20	2.25	1.60
	Bk	20-40	0.01	0.26	2.80	2.00	2.40	1.25	1.10
	Ck	40-60	0.04	0.53	4.60	1.40	1.80	1.75	2.20
2.1					Profile 7				
	A	0-20	0.18	0.28	8.60	5.20	8.50	2.00	2.20
	C	20-60	0.17	0.17	7.40	2.60	4.80	1.75	2.80
3.3					Profile 8				
	A	0-25	0.10	0.15	5.20	2.00	4.60	1.50	0.40
	Bk1	25-60	0.03	0.45	2.40	2.20	3.40	1.52	1.00
	Bk2	60-100	0.03	0.52	4.60	1.60	3.45	1.55	0.40
	Ck	100-150	0.02	0.32	5.40	2.60	4.90	1.00	1.40

Results of qualitative land suitability for studied crops were presented in Table 6. There was not any problem from the point of flooding and drainage in all land units (Table 6). Land units had sandy clay loam, clay and clay loam texture classes. The coarse fragment (gravel) was high (>30%) in some land units (3.1, 8.1, 9.1, 8.2 and 2.1) that was a limitation. Minimum gravel content observed in 3.2 land unit. The pH values was very high that can be related to $CaCO_3$ content. The EC was very low and land units had not any limitation about ESP. The most suitable land units for irrigated wheat in the study area based on the results of both Square Root and Storie methods were 3.1, 4.1, 3.2 and 3.3, respectively. These land units had S3 (marginal suitable) class. The other land units had N (non-suitable) class (Table 7). Land unit No. 2.1 had N2 class that this class has not any correction in future. Results of Storie method for barley showed that land unit 3.3 had S2 class, land units 3.1, 4.1 and 3.2 had S3 class and for other land units had N class. Furthermore, the results of Square root showed that 3.1, 4.1 land units and 3.3 had S2 (moderate suitable) class and 8.1, 8.2, 9.1 and 3.2 land units had S3 class. Land unit 2.1 was only N class. This land unit had minimum values of land index for all crops. Generally, the most important limiting factors in wheat and barley productions in the region under study included physical properties. The results of Briza et al. (2001) in the Province of Ben Slimane, Morocco also showed that the most limiting factors of the land suitability, in wheat and barley productions included physical characteristics such as soil texture, soil depth and slope. Results also showed undesirable conditions for potato crop. In Storie method, land units 3.1 and 3.3 had S3 class and other land units had N (N1 and N2) class. In Square root method, land unit 3.1 had S2 class, 4.1, 3.2 and 3.3 land units had S3 class and other land units had N class. Soil physical properties and fertility were limiting factors in potato production in study area. The shallow and sparse rooting system of potato plants, often resulting from soil compaction (Stalham et al. 2007), makes it very sensitive to soil moisture stress (Onder etal. 2005). In general, Square root showed more suitable results for crops in study area. Malekian and Jafarzadeh (2011) reported that the accuracy of obtained results by the square root method is high and revealed to be more realistic in comparing with other methods result.

Table 6
Results of qualitative land suitability for land units.

Land unit	Profile	Topography (T)	Wetness (W)		Physical characteristics (S)					Fertility properties (F)	Salinity/alkalinity (N)	
		Slope (%)	Flooding	Drainage	Tex	Gravel (%)	Depth (cm)	CaCO3 (%)	CaSO4	pH	EC (dS/m-1)	ESP
3.1	1	2-5	NL	Wd	SCL	30	95	22.75	poor	7.75	0.26	NL
8.1	2	8	NL	Wd	C	40	35	40.31	poor	7.97	0.26	NL
9.1	3	8	NL	Wd	CL	40	80	36.88	poor	7.98	0.36	NL
8.2	4	8	NL	Wd	CL	45	100	30.21	poor	7.78	0.46	NL
4.1	5	5	NL	Wd	C	10	55	45.70	poor	7.99	0.20	NL
3.2	6	2-5	NL	Wd	CL	5	60	54.92	poor	8.00	0.21	NL
2.1	7	15	NL	Wd	CL	45	60	23.09	poor	7.80	0.37	NL
3.3	8	2-5	NL	Wd	C	15	150	23.16	poor	7.90	0.25	NL

Table 7
Qualitative land suitability classes for irrigated wheat, barley and potato crops in study area LI- land index, LC- land class.

Land unit	Profile	Irrigated wheat				Barley				Potato			
		Storie		Square root		Storie		Square root		Storie		Square root	
		LI	LC	LI	LC	LI	LC	LI	LC	LI	LC	LI	LC
3.1	1	36.87	S3s	49.42	S3s	44.00	S3s	53.99	S2s	38.03	S3f	50.82	S2f
8.1	2	17.56	N1s	31.08	S3s	20.95	N1s	33.95	S3s	9.56	N2s	22.13	N1s
9.1	3	13.65	N1s	27.40	S3s	16.29	N1s	29.93	S3s	9.97	N2s	23.16	N1s
8.2	4	17.88	N1s	29.90	S3s	21.34	N1s	32.67	S3s	12.55	N1s	24.06	N1s
4.1	5	30.99	S3t	41.21	S3t	36.98	S3t	52.67	S2t	17.92	N1f	33.27	S3f
3.2	6	28.96	S3s	42.08	S3s	34.56	S3s	45.93	S3s	20.19	N1f	35.22	S3f
2.1	7	6.35	N2t	11.27	N2t	7.58	N2t	13.31	N1t	3.99	N2t	9.04	N2t
3.3	8	42.15	S3t	58.07	S2t	50.30	S2t	63.44	S2t	28.11	S3f	42.44	S3f

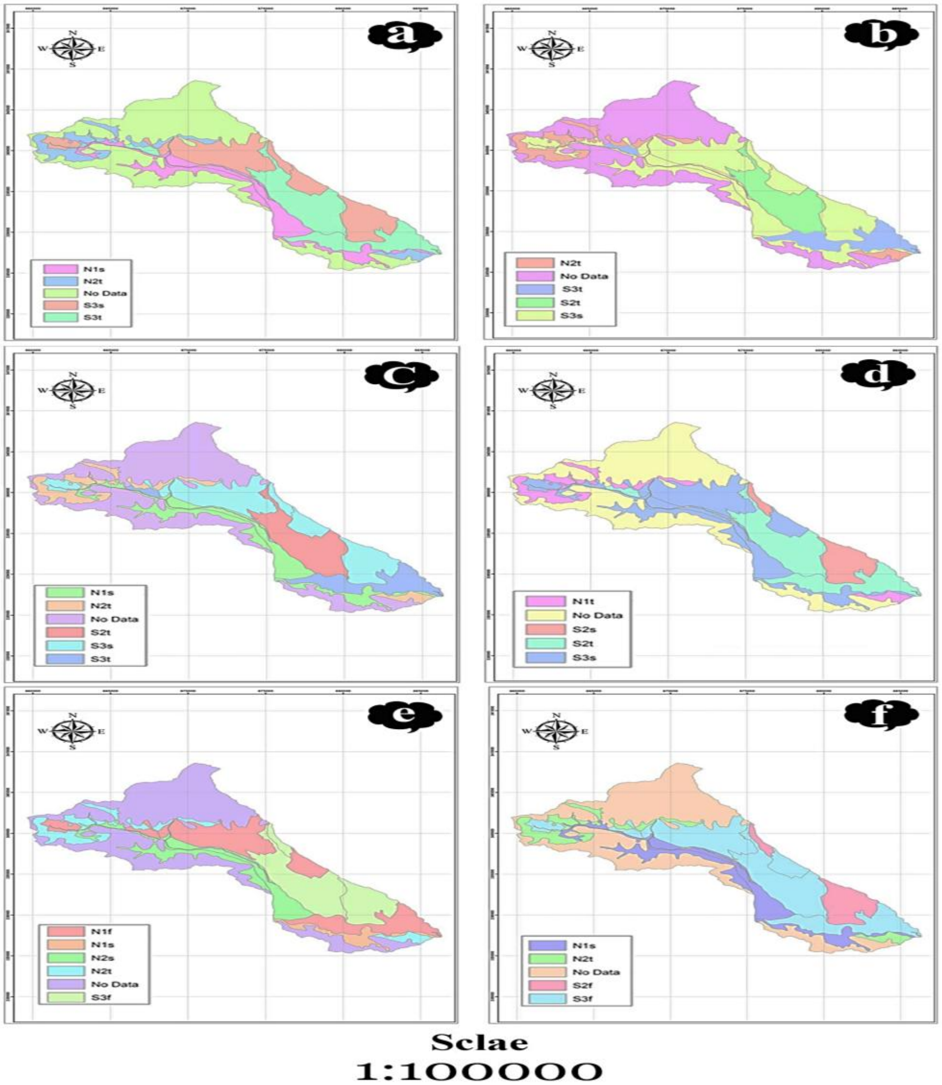

Fig. 3. Qualitative land suitability evaluation maps of study area obtained from a- Storie method for irrigated wheat, b- Square root for irrigated wheat, c- Storie method for barley, d- Square root for barley, e- Storie method for potato and f- Square root for potato crops

4. Conclusion

In the studied soils, Calcixerepts, Haploxerepts (Inceptisols) and Xerorthents (Entisols) were observed. The accumulation of $CaCO_3$ and formation of calcic horizons was the most important pedogenic process in Calcixerepts. The calcic horizons in the study area had pedogenic origin. The land indices obtained for Barley was higher in comparison to irrigated wheat and potato. Minimum values of land indices observed in potato crop. It can be showed that the cultivation of potato cannot be recommended for this area. Limiting factors in potato yield in the region along included soil physical properties and fertility. Generally, the accuracy of obtained results by the square root method is high and more realistic when compared with Storie method results.

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