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Characteristics and suitability of some arid soils in Southeastern Iran for wheat cultivation

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A study was conducted to characterize the calcareous soils of the Askara plain in Southeastern Iran and evaluate their potential for wheat production. Sixteen soil profiles within the colluvial fan in different physiographic units were studied. Four phases of soils were identified namely the Ashkara, Dareabad, Khalandi, and Sheikhabad soils. All soils were classified as Entisols, namely Aridic Ustortents and Aridic Ustifluvents. The Ashkara soils were marginally suitable while the Dareabad and Khalandi soils were moderatelly suitable for wheat growing. The Sheikhabad soil units, however, were evaluated as S1, S2, S3 and N1 classes. The results suggested that most important limiting are high $CaCO_3$, pH, texture and salinity as the major constraints to wheat productivity for soils of the Ashkara plain. There are about 60% of the plain that are suitable for wheat growing and only 1.15% that is not suitable due to poor moisture availability. The rest 38.85% of the plains are marginal soils.

Key words: Calcareous soils, wheat cultivation, land suitability evaluation.

INTRODUCTION

The arid and semi-arid regions cover more than 60% of the country. In this agro-pastoral transition region, the rains are highly variable in time, space, amount and duration, and water is the most important limiting factor for biological and agricultural activities. Seasonal changes in rainfall pattern may alter the hydrological cycle and environmental processes (Delitalia et al., 2000) as well as the vegetation and the entire ecosystem (Lazaro et al., 2001; Ni and Zhang, 2000). These areas have low production potential due to the restrictical rainfall (Zeynaddini and Banaei, 2001).

Iran's population increased dramatically during the later half of the 20th century, reaching about 72 million by 2008. Proper land resource ultilization for agriculture is therefore crucial. Part of the solution to the land-use problem can be solved through land evaluation in support of rational land use planning and sustainable use of natural and human resources (Rossiter, 1996). Several land evaluation studies for some important crops in Iran had been reported by Moghimi (2002), Garkani Negad et al. (2009. These authors agreed that for arid and semi-arid lands of Iran, the soil aridity, salinity, acidity and high carbonate content in soils as among the serious limiting factors. Calcareous soils covered vast areas of Iran. The soils in which a high amount of calcium carbonate dominates the problems related to agricultural land

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Figure 1. Location of studied area.

use. They are characterized by the presence of calcium carbonate in the parent material and by a calcic horizon, a layer of secondary accumulation of carbonates (usually Ca or Mg) in excess of 15% calcium carbonate equivalent and at least 5% more carbonate than an underlying layer. In some soils the calcium carbonate deposits are concentrated into layers that may be very hard and impermeable to water. These soils are generally very fertile, alkaline and saline. Due to alkalinity, they are proned to Zn, Fe, Mn and Cu deficiency (Cakmak et al., 1996) and experienced phosphorus (P) deficiency and low P-use efficiency (Korkmaz et al., 2009). Salinity affects plant growth by weakening the plant's ability to absorb water from the soil. Wheat, like many other crops show intraspecific variation in response to salinity (Kingsbury and Epstein, 1986; Parida and Das, 2004) and physical properties of soil (Bagherzadeh, 2013). The present study was to characterize some calcerous soils of the Ashkara plain and evaluate them for their potential in wheat production.

MATERIALS AND METHODS

Site description

The Ashkara plain occupied about 17600 ha of land and is located about 150 km north of Bandarabbas city in the north part of Hormozgan province of southeast Iran, from 28° 8´ to 28° 11´ North longtitude and 56° 7´ to 56° 11´ East latitudes (Figure 1). The climate is arid with an average annual precipitation and evaporation of about 162 (Figure 2) and 4243 mm, respectively. The moisture and temperature regimes are aridic ustic and hyperthermic (Banaei, 1998). The altitude of the region is 850 m a.s.l.

Sixteen soil profiles within the colluvial fan in different physiographic units were dug and studied. The morphological properties of the profiles were described in the field using the field book of USDA (2003). The four representative profiles were internationally classified using the criteria of soil taxonomy (Soil Taxonomy, 2010) and their approximate classes in the IUSS working group WRB (2007) world reference base for soil resources. Two famillies and four phases of soils were identified. Soil samples were taken from pedogenic horizons or layers of the profiles for various laboratory analysis.

Laboratory analysis and soil classification

Soil samples were air-dried in the laboratory ground and sieved through a 2 mm sieve. The percentage gravel content was calculated on the basis of subsamples (500 g each) of whole samples. Particle-size distribution was determined after the removal of $CaCO_3$ with 2N HCl and organic matter with 30% H_2O_2 by the pipette method (Day, 1965). Organic carbon was measured by Walkly and Black (1947) procedure and total N by the micro-kejeldal technique (Bremner and Mulvaney, 1982). The soil pH was determined in a saturated paste by a glass electrode (McLean, 1982). The electrical conductivity (EC) was measured in the saturated extract (Salinity Laboratory Staff, 1954). The calcium carbonate equivalent (lime) was measured by acid neutralization (Allison and Moodi, 1965). Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at pH 8.2 (Chapman, 1965). The complexometric titration method described by Chapman (1965) was used for the determination of calcium and magnesium. Potassium and sodium were determined from ammonium acetate leachate using the flame photometer. The sodium adsorption ratio (SAR) was calculated from soil solution data (Na^+, Ca^{2+}, Mg^{2+} given in $cmol_c kg^{-1}$): $SAR = Na^+[(Ca^{2+}+Mg^{2+})/2]^{-0.5}$. Available P was

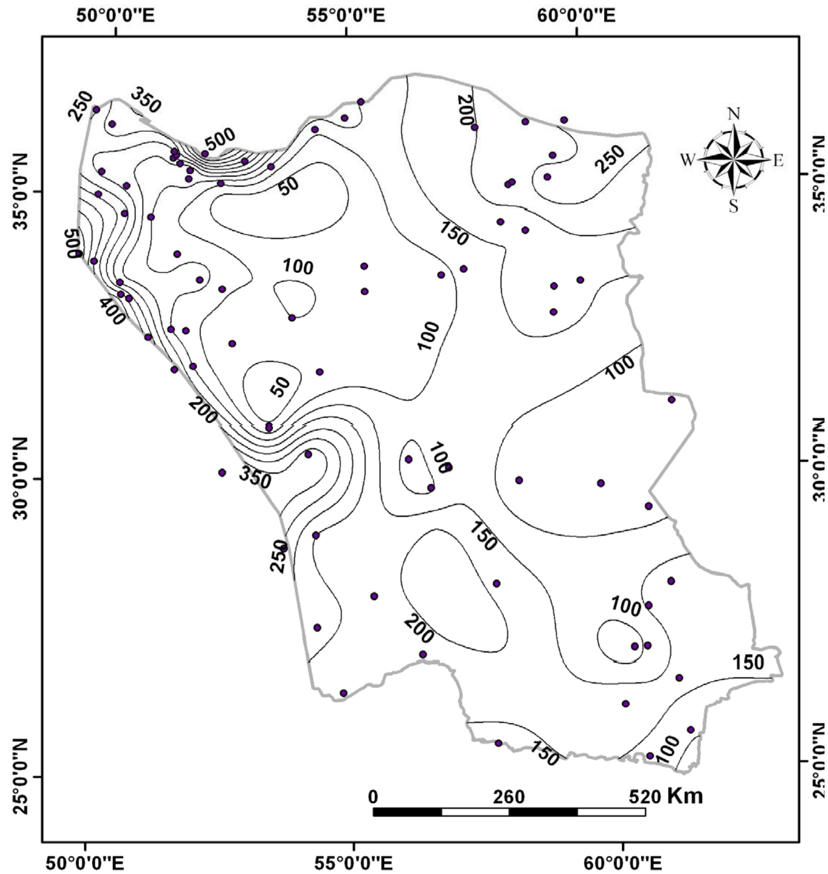

Figure 2. Mean annual precipitation over the study area during 1965-2000.

extracted by the Bray method and determined colorimetrically (Watanabe and Olsen, 1965). For the land evaluation suitability study, the soils were evaluated for wheat following the method of Sys et al. (1991a, b, 1993). Soils were placed in the suitability classes by matching their characteristics with the requirement of wheat (Table 1) using the simple limitation and parametric methods (square root method). In this analysis, the classes S1, S2, S3, N1 and N2 represent highly, moderately, marginally, actually notsuitable but potentially suitable and actually and potentially not suitable, respectively.

RESULTS AND DISCUSSION

Soil morphological properties

Four soil phases were identified, namely the Ashkara, Dareabad, Khalandi and the Sheikhabad soil. The soils were deep but the soil texture changes throughout the profile quite obvious in almost all soils. Since the plain is part of the colluvial fan, the deposition of materials from the alluvial wash vary from time to time creating different textural layers. This is observed in all soils studied where the soils textural changes were quite drastic, particularly for the silt and sand content. There were also variation in their structures and this is also associated to the amount of sand and silt in the soil. The soil tends to be massive when the silt content is high otherwise the structure would be singular when the sand content is high. Gravel was observed in the Ashkara soil but not in other soil types. The rounded nature of these gravels suggested that it was deposited along part of the plain. All soils were weakly developed with only weak profile horizon formation because of the slow chemical weathering inthese normally dry and hot soils.

The Ashkara soil had brown (10YR4/3) loamy sand to sandy texture and were gravelly throughout the profile (Table 2). The gravel were rounded and increased down the profile from 10% at topsoil to 60% at 85 cm depth. Similar trend was observed for the sand content (Table 3). The soil structure was somewhat massive at the top 30 cm but became singular down the profile as sand content increases. The soil was observed to be well drained. The Dareabad soil was characterized by dark brown (7.5YR4/4) loamy topsoil to more sandy subsoil. The sand content was 90% at 120 cm as compared to only 45% at the surface. The Khalandi soil had brown (10YR5/3) sand on top coming down to pale brown (10YR6/3) at the subsoil. Their textures were somewhat irregular changing from sandy to sandy loam, loamy

Table 1. Climate, soil and land requirements for wheat production (Sys et al., 1993).

Land, soil and climate characteristics	S1	S2	S3	N1	N2
Climate					
Mean tem. of the growing cycle (°C)	12-23	23-10	8-25	-	>30, <8
Mean tem. of the vegetation stage (°C)	6-18	6-4,18-24	4-2,24-28	-	<2, >28
Mean tem. of the flowering stage (°C)	18-12,18-26	12-10,26-32	10-8,32-36	-	<8, >36
Mean tem. of the ripening stage (°C)	20-16,20-24	14-12,30-36	12-10,36-24	-	<10, >42
Average daily min. tem. Coldest month (°C)	<8	>8	8-19	-	-
Average daily max. tem. Coldest month (°C)	<21	<21	>21	-	-
Physical soil characteristics (s)					
Texture	Si,SiC,SiL,CL,L	SCL	SL,LfS	-	Cm,fS,LcS
$CaCo_3$ (%)	3-30	30-40	40-60	-	>60
Soil fertility characteristics (f)					
Apparent CEC (cmol(+)/kg clay)	16-24, >24	<16 (-)	<16 (+)	-	-
pH H_2O	6-8.2	5.6-6,8.2-8.3	5.2-5.6,8.3-8.5	<5.2	>8.5
Salinity and alkalinity (n)					
ECe (ds/m)	0-3	3-5	5-6	6-10	>10
ESP (%)	0-20	20-35	35-45	-	>45

SL = Sandy loam, LS = loamy sand, L = loam, S = sand, SiL = silty loam, Si = silty, CL = clay loam, LfS = loamy fine sand, SCL = sandy clay loam, LcS = loamy coarse sand, SiC = silty clay, S1 = very suitable, S2 = suitable, S3 = marginally suitable, N1 = currently not suitable, N2 = permanently not suitable; tem., temperature.

Table 2. Field morphological description of representative pedons.

Groups of soils	Depth (cm)	Color	Clay	Silt	Sand	Texture ++	Structure *	Consistence +	Boundry **	Gravels (%)
				%						
Ashkara	0-12	10YR4/3	4.3	13.7	82	LS	Ma	VFi	-	10
	12-30	10YR4/3	4.2	11.8	84	LS	Ma	Fi	Cs	30
	30-60	10YR4/3	3.9	6.1	90	S	Ma-Sin	VFi	Cs	45
	60-85	10YR4/3	3.8	6.2	90	S	Sin	Lo	Cs	35
	85-150	10YR4/3	3.5	6.5	90	S	Sin	Lo	Cs	60
Dareabad	0-30	7.5YR4/4	12	40	48	L	Ma	Fi	-	-
	30-50	7.5YR4/4	14	36	50	L	Ma	Fi	Cs	-
	50-120	10YR4/4	8	22	70	SL	Ma	VFi	Cs	-
	120-150	10YR4/3	6	4	90	S	Ma-Sin	Lo	Cs	-
Khalandi	0-25	10YR5/3	4	8	88	S	Ma	VFi	-	-
	25-55	10YR5/3	6	44	50	SL	Ma	VFi	Cs	-
	55-85	10YR6/3	4	20	76	LS	Ma-Sin	VFi	Cs	-
	85-150	10YR6/3	4	8	88	S	Sin	Lo	Cs	-
Sheikhabad	0-12	10YR5/3	10	60	30	SiL	Ma	Fi	-	-
	12-35	10YR5/3	14	45	32	SiL	Ma	Fi	Cs	-
	35-60	7.5YR3/4	10	56	34	SiL	Pla	Fi	Cs	-
	60-100	7.5YR3/4	10	20	70	SL	Pla	VFi	Cs	-
	100-150	10YR5/3	2	2	96	S	Sin	Lo	Cs	-

Texture++: SL = sandy loam, LS = loamy sand, L = loam, S = sand, SiL = silty loam, Structure* :Ma = massive, Sin = singular, Pla = platy, consistence +: VFi = very firm, Fi = firm, Lo = loose, boundry **: Cs = clear smooth.

Table 3. Chemical properties of representative pedons.

Depth (cm)		Ave.P (ppm)	O.C (%)	SAR	EC (dSm^{-1})	pH H_2O	$CaCO_3$ (%)	HCO^{3-}	$SO_4^=$	Cl^-	CEC	K^+	$Ca^{2+}+Mg^{2+}$	Na^+
								$cmol_ckg^{-1}$						
A	0-12	6.7	0.39	1.3	1.3	8.25	25.8	2.2	1.2	2.0	6.5	0.15	3.8	1.9
	12-30	6.5	0.38	1.4	1.2	8.15	32.5	1.6	0.5	2.2	5.2	0.11	2.8	1.6
	30-60	6.3	0.21	2.8	0.9	8.30	25.3	2.6	0.0	1.6	5.0	0.10	1.6	2.6
	60-85	5.9	0.06	3.5	1.1	8.35	25.5	4.2	0.0	3.0	8.2	0.08	3.2	4.5
	85-150	5.5	0.02	4.5	1.1	8.4	27.5	2.2	1.9	2.0	6.9	0.07	1.8	4.3
B	0-30	10.2	0.52	5.9	3.6	7.7	24	6.4	10.5	21.2	42	0.45	17	21.5
	30-50	0.13	0.15	10.3	4.3	8.15	23.8	1.8	20	22.5	48	0.47	15.6	29
	50-120	0.05	0.06	9.4	1.9	8.17	25.8	2.0	8.9	8.8	24	0.24	5.0	15
	120-150	0.02	0.02	5.1	0.8	8.28	25.8	3.4	2.2	3.0	13	0.20	2.8	6.2
C	0-25	6.3	0.10	1.2	1.5	8.0	28	3.7	0.0	1.8	9.1	0.44	3.0	2.5
	25-55	4.6	0.13	2.5	1.2	8.4	30.3	2.3	2.4	1.6	10.4	0.25	3.4	3.3
	55-85	0.05	0.07	2.6	1.6	8.4	25	2.0	0.0	5.5	10.8	0.15	3.6	3.4
	85-150	0.04	0.11	0.8	1.4	8.3	25.3	0.6	0.8	5.4	11.4	0.16	6.6	1.5
D	0-12	13.1	0.4	10	9.4	8.4	24.0	3.2	24	26.4	64	2.52	21	32
	12-35	3.2	0.1	8.1	5.0	8.05	24.1	2.1	18	28.1	53	1.26	21	26
	35-60	0.04	0.17	2.4	3.6	8.1	24.2	1.8	9.5	12.6	30	1.22	8.8	16
	60-100	0.03	0.17	6.6	3.6	8.1	28.7	1.8	24	15.4	44	1.20	14.2	25
	100-150	0.01	0.07	6.4	1.7	8.0	33.0	1.2	2	9.0	13	1.05	2.4	7

A = Ashkara soil, B = Dareabad soil, C = Khalandi soil, D = Sheikhabad soil.

sand and finally became sandy at deeper depth.

These textures changes were due to the irregular changes of the silt and sand content. The Sheikhabad soil was characterised by grayish brown (10YR5/3) silty loam topsoil coming to dark yellowish brown (7.5YR3/4) sandy loam subsoil.

All the four soils were well drained. The Ashkara, Dareabad and Khalandi soils had massive to singular structure while the Sheikhabad soil was more platy down the profile (Table 2). In all soils, the sand content increases with depth resulting a more loose single structure. The consistency of all soils were also quite similar in their trend where soils were firm at the top but loose at the bottom layers. Soil structures were, however, very weak and unstable.

Soil chemical properties

All soils of the Ashkara plain exhibit some common properties with some variation (Table 3). They were all calcareous in nature containing 23 to 33% of $CaCO_3$ throughout the profile. The average electrical conductivity (EC) values were somewhat variable among the soils studied, placing these soils from slightly saline to saline level. The Ashkara and Dareabad soils were slightly saline with EC values less than 5.0 Ds/m, while some soil units of the Khalandi and Sheikhabad soils were slightly saline to saline with EC values ranging from 3 to 20 Ds/m. The sodium content showed slight variability among soils studied. The Ashkara and Khalandi soils contain less than 4.5 $cmol_ckg^{-1}$ of sodium as compared to Dareabab and Sheikhabad soils containing up to

Table 4. Soil classification and land suitability evaluation of representative pedons.

										Soil classification		
Soil No.	Soil unit	USDA	FAO	Flooding	Texture	$CaCO_3$ (%)	pH H_2O	ECe dSm^{-1}	SAR	Suitability SLM	Suitability PSR	Area (%)
A	1.1	Aridic Ustortents	Calcaric Regosols	F1	LS	27.6	8.3	0.3	2.2	S3s	S3s	7.8
B	2.1	Aridic Ustortents	Calcaric Regosols	F0	SL	24.3	7.7	3.3	7.7	S2s	S2s	12.15
	2.2	Aridic Ustortents	Calcaric Regosols	F0	SL	26.7	8.2	2.3	10	S2s	S2sf	2.55
C	3.1	Aridic Ustifluvent	Calcaric Arenosols	F0	SiL	29.1	8.0	9.4	15	S2n	S2n	3.0
	3.2	Aridic Ustifluvent	Calcaric Arenosols	F0	SL	28.5	8.6	1.2	4.6	S2sf	S3f	5.7
	3.3	Aridic Ustifluvent	Calcaric Arenosols	F0	SL	28.0	8.0	0.7	1.8	S2s	S2s	4.85
	3.4	Aridic Ustifluvent	Calcaric Arenosols	F0	SL	28.8	8.1	8.9	14.2	S2s	S3n	9.4
	3.5	Aridic Ustifluvent	Calcaric Arenosols	F0	L	27.4	8.0	8.8	14.7	S2n	S2n	6.8
D	4.1	Aridic Ustifluvent	Calcaric Fluvisols	F0	SiL	28.4	8.2	3.9	10.7	S1	S2f	3.95
	4.2	Aridic Ustifluvent	Calcaric Fluvisols	F0	L	24.8	8.1	5.2	9.4	S1	S1	4.35
	4.3	Aridic Ustifluvent	Calcaric Fluvisols	F0	SiL	29.1	7.6	12	14.9	S2n	S2n	9.65
	4.4	Aridic Ustifluvent	Calcaric Fluvisols	F0	L	28.6	8.2	3.5	4.4	S1	S1	5.7
	4.5	Aridic Ustifluvent	Calcaric Fluvisols	F0	L	27.6	8.0	17.3	18.9	S3n	S3n	11.75
	4.6	Aridic Ustifluvent	Calcaric Fluvisols	F0	L	27.4	8.3	3.1	4.1	S1	S1	7.5
	4.7	Aridic Ustifluvent	Calcaric Fluvisols	F0	SiL	27.1	8.4	20	19.3	N1n	N2n	1.15
	4.8	Aridic Ustifluvent	Calcaric Fluvisols	F0	L	30.6	8.2	18.2	9.9	S3n	S3n	3.7

SLM, Simple Limitation Method, PSR: Parametric Square Root Method, A = Ashkara soil, B = Dareabad soil, C = Khalandi soil, D = Sheikhabad soil.

6.2 cmolckg-1. The exchange capacity (CEC) content represented high variability among the soils. The CEC in The Ashkara and Khalandi soils less than 11.4 cmolckg-1 compared to Dareabab and Sheikhabad soils up to 13 cmolckg-1. All soils have pH values above 8.0 suggesting that they are alkaline and may induce deficiency problems for P and some micronutrients. Soil organic carbon were low in all soils, which is common for soils of these regions where vegetations are strongly influenced by the hask climatic condition.

Based on the soil morphological characteristics and chemical data analyzed, and following the Soil Taxonomy (2010), all soils were classified in the order of Entisol. The Ashkara and Dareabad soils were group as Aridic Ustortent while the Khalandi and Sheikhabad soils were classified as Aridic Ustifluvent. The soils of the Ashkara plain were basically young soils with little pedological development due to the sandy soil materials and little water available to promote weathering.

Suitability evaluation for wheat production

The morphological description and chemical date available suggested that soils of the Ashkara plain were rather sandy, calcerous, alkaline, slightly saline and received very little rainfall throughout the year. Based on these characteristics, these soils were evaluated of their potential for wheat production. Using the conversion table of Sys system (Table 1), the results of the land evaluation for wheat production is presented in Table 4.

The mean annual temperatures of the study site is within 23.7°C, hence they all fall within S1 (Highly suitable) class with reference to temprature requirement. All soils were not flooded and were well drained and therefore qualified for the S1 class when drainage and flooding were considered. Looking at the textural class as the evaluation criteria, Sheikhabad soils qualified into the S1 class, while the Ashkara, Dareabad and Khalandi soils into the S3 class. This is because of their loamy sand and sandy loam texture throughout the soil profiles that reduce the soil moisture availability when compared to the silty loam of the Sheikhabad soils. Considering the soil pH and the electerical conductivity values, the Ashkara soils were finally evaluated as S3 class while the Dareabad and Khalandi soils as S2 class. The Sheikhabad soil units, however, were very variable, finally evaluated as S1 (unit 4.1, 4.2, 4.4, 4.6), S2 (unit 4.3), S3 (unit 4.5, 4.8) and N1 (unit 4.7) classes. The evaluation suggested that aridity, alkalinity, high $CaCO_3$ and certain level of salinity as the major constraints to wheat productivity for the soils of the Ashkara plain. The Ashkara soils contain 10 to 30% gravels at top 30 cm depth and this would seriously affect the farm mechanization in the future.

Conclusions

The Ashkara plain soils were sandy, calcerous, high soil pH, saline and received little rainfall annually. These soils, however, were still potentially viable for wheat cultivation. The results of this study indicated that the largest parts of the study area were classified as suitable for wheat cultivation. These soils were evaluated as marginally (S3), moderately (S2) and highly suitable (S1) for wheat cultivation.The results of various methods demonstrated that the most important limiting factors are high $CaCO_3$ and sodium content, high pH and sandy texture. They were also low in organic matter and subsequently little nitrogen available. The high pH level results in unavailability of phosphate and sometimes reduced micronutrient availability such as zinc and iron. There may be also problems of potassium and magnesium nutrition as a result of the nutritional imbalance between these elements and calcium.

The salts or exchangeable sodium hinder crop growth. For efficient crop production salts must be therefore leached from the root zone which is in itself problematic because irrigation water is scarce in most regions where these soils occur. Plant growth is directly affected, as sodium in high concentrations is toxic for most crops, while the dense subsoil and unfavourable physical properties of these soils hinder downward water percolation and the growth of roots. Nutrients contents and nutrient retention are normally low, thus causing a low inherent fertility status for agricultural production. Nutrients are easily leached out of the solum. The poor soil structure also makes the soils very susceptible to wind erosion.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Allison LE, Moodi CD (1965). Carbonate. In Methods of soil analysis, pt. 1.C.A. Black et al. (eds). Part 2. Agronomy 9:1379-1396.

Banaei MH (1998). Soil moisture and temprature region map of Iran. Soil and water research Institute, Ministry of Agriculture, Tehran, Iran.

Bremner JM, Mulvaney CS (1982). Nitrogen-Total. In A.L. Page et al(ed.) Methods of soil analysis. Part 2. Agron. Monogr. No.9.ASA and SSSA, Madison, WI. pp. 595-624.

Cakmak I, Yilmaz A, Kalayci M, Ekiz H, Torun B, Erenoglu B, Braun HJ (1996). Zinc deficiency as a critical problem in wheat production in Central anatolia. Plant Soil. 180:165-172.

Chapman HD (1965). Total exchangeable bases. In Methods of soil analysis, pt. 1.C.A. Black et al. (eds). Agronomy 9:902-904.

Day PR (1965). Particle fractionation and particle size analysis. In Methods of soil analysis, pt. 1.C.A. Black et al. (eds). Agronomy 9:545-567.

Delitalia AMS, Cesari D, Chessa PA (2000). Precipitation regims over sardinia (Italy) during the 1946-1993 rainy season and associated large-scale climatic variation. Int. J. Climatol. 20:519-542.

Garkani Negad Mashizi S, Keshvarzi A, Ahmadi A, Hassan E (2009). Land suitability evaluation for important crop productions in gypsiferous soils of Bardsir area in Kerman Province, Iran. World Appl. Sci. J. 7:726-730.

IUSS Working Group WRB (2007). World Reference Base for Soil Resources 2006, first update 2007. World Soil Resources Reports, P. 103. FAO, Rome.

Kingsbury RW, Epstein E (1986). Salt sensivity in wheat‟ a case for specific ion toxicity˝. Plant Physiol. 80:651-654.

Korkmaz K, Ibrikci H, Karnez E, Buyuk G, Ryan J, Ulger AC, Oguz H (2009). Phosphorus use efficiency of wheat genotypes grown in calcareous soils. J. Plant Nutr. 32:2094–2106.

Lazaro R, Rodrigo FS, Gutierre ZL, Domingo F, Puigdefabregas J (2001). Analysis of a 30-years rainfall record (1967-1997) in semi-arid SE Spain for implications on vegetation. J. Arid Environ. 48:373-395.

McLean ED (1982). Soil pH and lime requirement. In Methods of soil analysis, pt. 1, 2nd ed. A. Klute (eds). Agronomy 9:199-244.

Moghimi AH (2002). Semi-detailed soil survey and classification in Ashkara plain, Iran. Soil and Water research institute, Ministry of Agriculture, Tehran, Iran.

Ni J, Zhang XS (2000). Climate variability, ecological gradient and the Northeast China Transect (NECT). J. Arid. Environ. 46:313–325.

Parida AK, Das AB (2004). Effects of salt on growth, ion accumulation photosynthesis and leaf anatomy of the mangrove, Bruguiera parifolora. Trees-struct. Funct.18:167-174.

Rossiter DG (1996). A theoritical framework for land evaluation (with discussion). Geoderma 72:165-190.

Salinity Laboratory Staff (1954). Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60. Washington, D.C.

Sys C, Van Ranst E, Debaveye J (1991a). Land evaluation. part 1: Principles in land evaluation and crop production calculation. General Administration for development cooperation. Agric. Publ. No : 7. Brussels, Belgium, P. 174.

Sys C, Van Ranst E, Debaveye J (1991b). Land evaluation. part 11 : Methods in land evaluation .General Administration for development cooperation. Agric. Publ. No: 7. Brussels, Belgium, P. 247.

Sys C, Van Ranst E Debaveye J (1993). Land evaluation. Part 111: Crop Requirements. International Training Center for Post Graduate Soil Scientists. Ghent University. Ghent. Belgium, P. 199.

USDA (2010). Keys to Soil Taxonomy. Soil Survey Staff, USDA, 11th Edition.

Walkly A, Black CA (1947). A critical examination of rapid method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-263.

Watanabe FS, Olsen SR (1965). Test of an ascorbic acid method for determining phosphorous in water and $NaHCO_3$ extracts from soil. Soil Sci. Soci. Am. Proc. 29:677-687.

Zeynaddini A, Banaei MH (2001). Qualitative and quantitative land suitability Classification for major crops in the Negar area, Kerman Province. Iranian J. Soil and Water, Special issue on soil survey and land evaluation.