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ORIGINAL PAPER

Modifications in selected soil attributes as influenced by long-term continuous cropping in a calcareous semiarid environment

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Abstract Intensified agriculture and irrigation practices over a long-term are an important factor in soil change phenomena that can appear some unwanted effects on soil attributes. To examine this hypothesis, physicochemical properties and clay mineralogy of four major soil types (Typic Haploxerepts, Typic Xerorthents, Typic Calcixerepts, and Fluventic Haploxerepts) under sunflower cultivation over five decades and adjoining virgin lands were investigated in order to monitor changes caused by long-term cropping. The comparison of cultivated soils and virgin lands indicated that cultivation resulted in an increase in clay (3–28 %) and silt (3–25 %) content, along with a decrease in sand content (2–17 %), resulting of the cultivation practices. For most of the examined soils, soil pH and calcium carbonate equivalent were marginally increased as 0.1–0.23 unit and 4–26 mg kg^{-1}, respectively, following intensive cropping. A relative depletion was manifested in mean value of soil organic carbon (4–18 %), soluble K (47–197 %), exchangeable K (21–34 %), available K (20–34 %), potassium absorption ratio (43–45 %), and exchangeable potassium percentage (26–54 %) due to continuous sunflower cropping. Comparing with the virgin lands, the cultivated soils showed a considerable rise in electrical conductivity (18–122 %), sodium absorption ratio (18–122 %), exchangeable Na (4–48 %), and exchangeable sodium percentage (10–47 %) likely due to the chemistry of the irrigation water used, as well as the chemical interaction between the irrigation water and its receiving soils. Over the five decades of cultivation, some changes in the X-ray diffraction pattern of illite and smectite were observed mainly as result of cropping and K depletion as well as alternating wet–dry periods induced by irrigation practices.

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Keywords Virgin land · Cultivation · Sunflower · Long-term · Irrigation

1 Introduction

In view of the fact that most of the world food and fiber supplies will continue to come from intensive agriculture, long-term continuous cultivations may result in some unwanted effects on soil heath or soil quality throughout over time (Brady and Weil 1999; Nunes et al. 2007). In the light of this, depending on external stimuli and internal change in soil processes or the internal chemical response to environmental forcing factor (Chadwick and Chorover 2001), both positive and negative effects can manifest in soil properties. Examples of attributes that change positively are the increase in soil inherent nutrients after transformation of primary minerals into secondary while those that affect negatively are exemplified as excess in solution salts, erosion, toxic metals, etc. For investigating both positive and negative aspects of soil quality, a complex integration of static or inherent quality (process contained soil natural ability to function) and dynamic quality (how soil changes depending on how it is managed) need to be considered (De la Rosa and Sobral 2008). Inherent and dynamic soil qualities are related largely to natural factors (such as climate, organism, parent material, and topography) and anthropogenic processes (such as management strategies and soil inputs), respectively. The pattern of changes in inherent soil aspect mainly occurs during long-term modifications [e.g., changes in soil mineralogical properties or large accumulations of secondary phase such as carbonates and opal (Chadwick and Chorover 2001)], and changes in dynamic soil aspects manifest during short-term modifications (e.g., changes in soil organic matter, electrical conductivity, and some nutrients). Nunes et al. (2007) observed a considerable increase in soil salinity along with a significant decrease in soil organic matter following 30 years of continuous irrigation under mediterranean conditions. Moebius-Clune et al. (2011) showed that continuous maize cultivation caused drastic soil degradation, with 25–93 % in soil quality after 77-years cultivation in western Kenya.

Overall, intensified agriculture and soil management often occur together, resulting in some modifications in soil processes such as erosion, soil contamination, leaching, salinization, and alkalization. (Wang et al. 2001). Such issues can be highlighted by decreasing plants yield and vegetation covers, declining soil fertility and productivity as well as increasing soil degradation. Accordingly, actions to protect soil heath necessitate (De la Rosa and Sobral 2008) assessing soil attributes following long-term intensive cultivation.

The objectives of this research were to: (a) evaluate the temporal variability of soil physicochemical properties and clay mineralogy in cropped soils and adjoining virgin lands, (b) assess the effects of continuous irrigation and agricultural practices on the value of relative depletion or enrichment in sunflower-growing calcareous soils, and (c) highlight the most sensitive soil attributes following long-term cropping.

1.1 Study area

The study region is very important in the western Azarbaijan province of northwest of Iran regarding with agricultural activities and crop productions. This area being mostly used for sunflower occupies approximately 53,000 ha. In the region, long-term continuous cultivation and irrigation are combined with removal of most crop residues after harvest for more than five decades. For instance, the soil is uncovered during intercropped periods, thereby can encourage changes in soil quality indicators including soil physicochemical and clay mineralogy attributes.

This research was undertaken at Khoy area (38°10′–38°40′N latitude and 44°15′–45°10′E longitude) as the northern part of western Azarbaijan province in the northwest of Iran (Fig. 1). The geology of the region is mainly underline by the combination of calcareous sandstone formations and the red to green shale which took place during the late Cretaceous to the Oli-Miocene. These formations are occupied by the alluvium and recent deposits belonging to the Quaternary period. Overall, the study area is an alluvial deposits system occurred in response to the different unstable phases of the Quaternary about 10,000 years BP. The Khoy area is characterized by a semi-arid climate (mean annual rainfall of 270 mm) linked with soil moisture and temperature regimes of xeric and mesic, respectively.

Agriculturally, the studied area is cropped continuously by sunflower-wheat or barley rotations for over five decades and has received irrigation water from rainfall, groundwater, or seasonal river water. Adjacent virgin lands with the cultivated soils were composed of shrubs and grassland (e.g., *Achillea millefolium*, *Gramineae* sp., *Centaurea* sp., *Althaea officinalis*, *Cynara cardunculus*, and other species).

2 Materials and methods

2.1 Soil samples and reference sites

Forty-eight surface soil samples (0–30 cm) in relation to ten pedons were described, classified (Soil Survey Staff 2010; FAO/ISRIC/ISSS 2006), and sampled from the main sunflower-growing soil and the adjacent virgin lands. Typic Haploxerepts [TH, more than

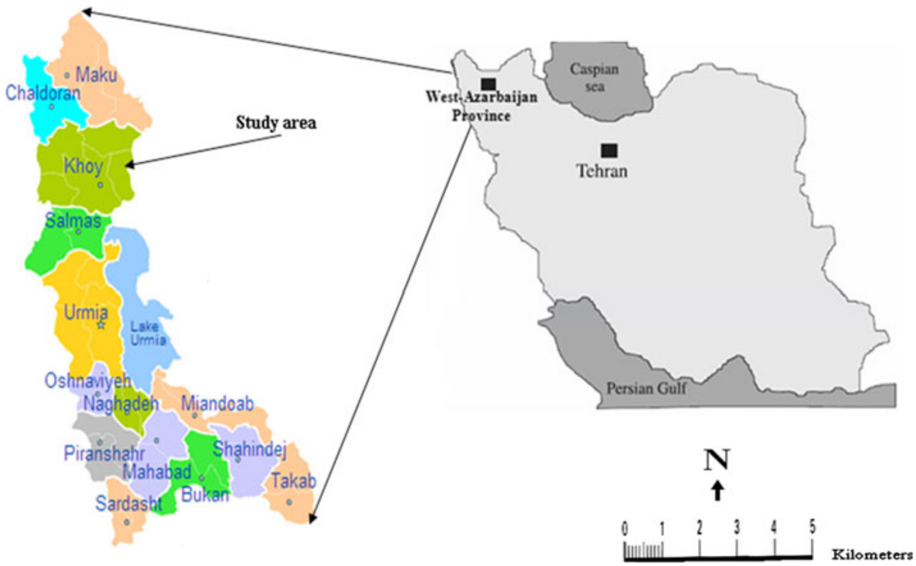

Fig. 1 Location of the studied region

Table 1 General properties for the soil studied

Classification		Longitude	Latitude	Physiographic position
Soil taxonomy[a]	WRB[b]			
Typic Xerorthents	Haplic Regosols (Calcaric)	44°52′E	38°36′N	Piedmont alluvial plain
Typic Haploxerepts	Haplic Cambisols (Calcaric)	44°55′E	38°31′N	Piedmont alluvial plain
Typic Haploxerepts	Haplic Cambisols (Calcaric)	44°38′E	38°35′N	Piedmont alluvial plain
Typic Calcixerepts	Haplic Calcisols (Arenic)	44°50′E	38°23′N	River alluvial plain
Fluventic Haploxerepts	Haplic Fluvisols (Calcaric)	44°01′E	37°50′N	River alluvial plain
Typic Xerorthents	Haplic Regosols (Calcaric)	44°56′E	38°23′N	River alluvial plain
Typic Haploxerepts	Haplic Cambisols (Calcaric)	44°51′E	38°26′N	River alluvial plain
Typic Calcixerepts	Haplic Calcisols (Arenic)	44°45′E	38°14′N	Piedmont alluvial plain
Fluventic Haploxerepts	Haplic Fluvisols (Calcaric)	44°13′E	38°45′N	River alluvial plain
Typic Haploxerepts	Haplic Cambisols (Calcaric)	44°59′E	38°36′N	River alluvial plain

[a] Soil Survey Staff (2010)

[b] World reference base for soil resources (FAO/ISRIC/ISSS 2006)

half of the cultivated soils (74 %), Typic Xerorthents (TX, 13.4 %), Typic Calcixerepts (TC, 7.05 %), and Fluventic Haploxerepts (FH, 5.4 %)] were determined as the major soil subgroups in the evaluated soils. In each soil type, the samples (cultivated soil and adjacent virgin land) were selected in similar slope, aspect, drainage condition, and parent materials. The main environmental properties of the examined soils are illustrated in Table 1. Soil samples were air-dried and passed through a 2-mm mesh sieve prior to any analysis.

2.2 Physical and chemical analysis

Particle-size distribution was determined using pipette methods after removing chemical cementing agents (Day 1966). Soil pH and electrical conductivity (EC) were determined in soil: 0.01 M $CaCl_2$ (1:5) suspension and in saturation extract, respectively. Total dissolved solids (TDS) of irrigation water was estimated based on the weight of the residue on evaporation after drying (Richards 1954). Soil organic carbon (SOC) was determined by wet oxidation technique (Nelson and Sommers 1982), calcium carbonate equivalent (CCE) was estimated by acid neutralization (Nelson 1982), and cation exchange capacity (CEC) was measured by 1 N sodium acetate (NaOAc) at a pH of 8.2 (Chapman 1965). Soluble cations were measured using saturation extract, and exchangeable cations were estimated using 1 M NH_4OAc at pH 7 (Thomas 1982). Sodium absorption ratio (SAR) was calculated using the content of solution Na, Ca, and Mg, and exchangeable sodium percentage (ESP) was calculated using exchangeable Na and CEC values (Richards 1954). Potassium absorption ratio (PAR) was calculated by the concentration of solution K, Ca, and Mg, and exchangeable potassium percentage (EPP) was calculated by exchangeable Na and CEC values. For soil different properties, a relative enrichment factor (REF) and a relative depletion factor (RDF) were calculated as value of each properties in the cultivated soil divided by value of that properties in the virgin land. Statistical analyses were performed using the SPSS software.

2.3 Mineralogical analysis

The mineralogy of silicate clay (<2 μm) was determined using the methods of Kunze (1965) and Mehra and Jackson (1960). After removal of soluble salts and carbonates by washing and using 1 N NaOAc at pH 5, subsamples were treated with 30 % H_2O_2 and citrate dithionite to remove organic matter and free iron oxides, respectively. Sand was isolated from silt and clay by wet sieving, and clay was separated from silt by centrifuge. X-ray diffraction (XRD) analysis for oriented clays was performed following some treatments as (a) Mg-saturation, (b) Mg-plus ethylene glycol salvation, (c) K-saturation, and (d) heat of K-saturation at 500 °C. The XRD patterns were obtained using a CuKα radiation, a step size of 0.02° 2θ at 1 s/step, and a scan from 3 to 30° 2θ. The semi-quantitative percentage of the clay mineral was calculated based on Biscaye (1965).

3 Results and discussion

3.1 The quality of irrigation waters

The quality of irrigation water used in the examined soils is given in Table 2. The qualities of the water used were in the well to moderate categories based on FAO (Ayers and Westcot 1994). However, based on Richards methods (1954), the irrigation waters were classified as medium and low (C2-S1) to high and low categories (C3-S1) based on the values of EC (C) and SAR (S) (Table 2).

3.2 Selected physicochemical properties

The selected soil physicochemical characteristics are given in Table 3. The cultivated soils were often associated with visible changes in particle-size distribution compared with the uncultivated soils under grassland. This trend was true for all soil types, but differences were not significant statistically for most of the examined soils. Long-term cultivation was produced an increase in clay content from 3 to 28 % and silt from 3 to 25 % along with a decrease in sand content from 2 to 17 % compared to those of the adjoining virgin lands. These differences can be explained by accelerated alteration in the cultivated field over the long periods of shrinking–swelling cycles induced by irrigation practices. However, clay content trend slightly to decrease in TC than the virgin land mainly as result of clay depletion cased by tillage operations. These results are comparable to the data found by De Clerck et al. (2003) in the California statewide and Golchin and Asgari (2008) in the north of Iran.

A minor fluctuation in soil pH was observed through long-term cultivation. Comparing to the virgin land, the mean soil pH was became more alkaline with a rise of 0.1–0.23 unit after cultivation except TC possibly due to the movement of salts and calcium carbonates into and out of different soil zones as soil moisture moves up and down through the soil

Table 2 Summary statistics of the chemical composition distribution of the irrigation water applied for the cropped soils

Parameters	pH	EC dS m^{-1}	TDS mg l^{-1}	SAR	Na/∑cations
Range	7.03–7.6	0.3–2.2	192–1,408	0.25–2.6	0.074–0.411
Mean ± standard deviation	7.28 ± 0.19	1.09 ± 0.80	694 ± 512	1.1 ± 0.98	0.233 ± 0.139
Median	7.3	0.70	448	0.54	0.164
Kurtosis	0.323	0.585	0.585	0.58	0.357
FAO standard level (Ayers and Westcot 1994)	7.0–8.0	0.75–2.0	1,000	3–9	–
Parameters	Ca^{+2} meq l^{-1}	Mg^{+2}	Na^{+1}	K^{+1}	∑Cations
Range	3.4–10.6	1.2–4.8	0.87–9.1	0.002–4.11	6.18–24.27
Mean ± standard deviation	6.8 ± 2.18	3.22 ± 1.32	3.98 ± 3.52	0.48 ± 1.28	14.48 ± 5.93
Median	0.371	1.85	1.85	0.05	13.04
Kurtosis	−0.278	0.529	0.529	3.14	0.334
FAO standard level (Ayers and Westcot 1994)	3.75	2.5	8–9	–	–
Parameters	CO_3^{-2} meq l^{-1}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}	∑Anions
Range	0.1–0.5	0.4–1.2	0.2–5.6	5.3–19.4	6.1–24.2
Mean ± standard deviation	0.29 ± 0.15	0.68 ± 0.38	1.64 ± 1.93	11.87 ± 4.46	14.4 ± 5.89
Median	0.3	0.4	0.6	11.05	12.95
Kurtosis	0.213	0.742	1.29	0.359	0.315
FAO standard level (Ayers and Westcot 1994)	0.1	2	7.0	3.0	–

EC electrical conductivity, *TDS* total dissolved solids, *SAR* sodium adsorption ration

Table 3 Mean ± standard deviation values of selected physicochemical properties for sunflower-growing soils and adjacent virgin lands

Parameter	Typic Haploxerepts			
	Cultivated soil	Virgin land	% Change	RDF or REF
Sand (%)	42.0 ± 17.89	47.87 ± 8.52	−14.3	0.88
Silt (%)	29.63 ± 6.32	29.37 ± 7.25	0.68	1.01
Clay (%)	28.37 ± 12.82	24.37 ± 10.5	16.4	1.16
Sp (%)	44.63 ± 10.34	40.50 ± 6.12	10.1	1.10
pH	7.94 ± 0.12	7.85 ± 0.20	1.2	1.01
OC (g kg^{-1})	6.99 ± 2.13	9.36 ± 4.07	−25.9*	0.75
CCE (g kg^{-1})	119.25 ± 27.27	112.75 ± 17.26	5.8	1.06
CEC (cmolc kg^{-1})	23.2 ± 3.32	22.86 ± 2.69	1.47	1.01
Soluble Ca (mmolc l^{-1})	4.57 ± 3.31	1.65 ± 0.6	179.2***	2.78
Soluble Mg (mmolc l^{-1})	0.80 ± 0.45	0.58 ± 0.20	38.0	1.38
Soluble Na (mmolc l^{-1})	5.04 ± 2.5	2.27 ± 0.23	120.2**	2.22
Soluble K (mmolc l^{-1})	0.42 ± 0.12	1.16 ± 0.89	−164.2***	0.36
Exchangeable K (mg kg^{-1})	207.88 ± 25.46	317.12 ± 61.7	−34.4**	0.65
Available K (mg kg^{-1})	211.5 ± 25.71	320.88 ± 60.87	−34.1**	0.66
PAR	0.27 ± 0.84	0.48 ± 0.27	−43.8**	0.56
EPP (%)	2.36 ± 0.19	3.5 ± 0.53	−32.6**	0.67
Parameter	Typic Xerorthents			
	Cultivated soil	Virgin land	% Change	RDF or REF
Sand (%)	56.5 ± 5.91	59.5 ± 9.33	−5.3	0.95
Silt (%)	27.75 ± 4.57	28.25 ± 9.33	−1.1	0.98
Clay (%)	15.75 ± 2.22	12.25 ± 0.96	27.6	1.28
Sp (%)	34.0 ± 2.16	28.0 ± 5.35	22	1.21
pH	8.03 ± 0.23	7.83 ± 0.22	2.9	1.03
OC (g kg^{-1})	5.1 ± 2.23	6.25 ± 2.49	−18.4	0.82
CCE (g kg^{-1})	115.75 ± 10.53	113.5 ± 17.62	2.2	1.02
CEC (cmolc kg^{-1})	17.1 ± 3.47	17.37 ± 3.75	2.4	0.98
Soluble Ca (mmolc l^{-1})	4.2 ± 3.1	1.61 ± 0.13	162***	2.63
Soluble Mg (mmolc l^{-1})	0.46 ± 0.21	0.39 ± 0.63	17.9*	1.18
Soluble Na (mmolc l^{-1})	4.63 ± 1.82	2.65 ± 0.95	75***	1.77
Soluble K (mmolc l^{-1})	0.30 ± 0.16	0.83 ± 0.46	−177***	0.36
Exchangeable K (mg kg^{-1})	164.0 ± 3.65	232.0 ± 1.63	−30*	0.71
Available K (mg kg^{-1})	168.75 ± 4.11	235.25 ± 1.71	−28*	0.72
PAR	0.21 ± 0.01	0.38 ± 0.09	−44.7**	0.55
EPP (%)	2.37 ± 0.38	3.5 ± 0.75	−54*	0.66
Parameter	Typic Calcixerepts			
	Cultivated soil	Virgin land	% Change	RDF or REF
Sand (%)	37.25 ± 4.43	40.0 ± 3.56	−8.1	0.93
Silt (%)	42.17 ± 6.32	34.0 ± 8.17	25	1.24

Table 3 continued

Parameter	Typic Calcixerepts			
	Cultivated soil	Virgin land	% Change	RDF or REF
Clay (%)	21.67 ± 2.25	23.33 ± 2.94	−7	0.94
Sp (%)	40.5 ± 1.29	41.25 ± 1.17	−2	0.99
pH	8.04 ± 0.15	8.09 ± 0.20	−0.62	0.99
OC (g kg^{-1})	5.6 ± 0.63	5.75 ± 0.99	−2.6	0.97
CCE (g kg^{-1})	141.67 ± 15.62	161.5 ± 14.5	−13.9*	0.88
CEC (cmolc kg^{-1})	20.2 ± 0.16	20.3 ± 0.24	−0.5	0.99
Soluble Ca (mmolc l^{-1})	2.9 ± 0.25	2.45 ± 0.24	17.5*	1.19
Soluble Mg (mmolc l^{-1})	0.5 ± 0.22	0.4 ± 0.55	25*	1.24
Soluble Na (mmolc l^{-1})	5.89 ± 2.25	4.45 ± 2.11	34*	1.32
Soluble K (mmolc l^{-1})	0.34 ± 0.0.43	0.65 ± 0.19	−47***	0.52
Exchangeable K (mg kg^{-1})	230.5 ± 24.89	287.0 ± 6.22	−21*	0.8
Available K (mg kg^{-1})	232.75 ± 24.62	291.0 ± 7.7	−20*	0.79
PAR	0.2 ± 0.33	0.35 ± 0.98	−43*	0.56
EPP (%)	2.85 ± 0.19	3.87 ± 0.53	−26*	0.73
Parameter	Typic Fluventic			
	Cultivated soil	Virgin land	% Change	RDF or REF
Sand (%)	44.0 ± 1.41	50.25 ± 3.1	−14	0.87
Silt (%)	31.75 ± 3.3	27.75 ± 3.3	15	1.14
Clay (%)	24.25 ± 2.06	21.5 ± 2.38	14	1.13
Sp (%)	39.75 ± 2.75	38.0 ± 1.63	5.3	1.05
pH	8.17 ± 0.64	8.0 ± 0.18	2.5	1.02
OC (g kg^{-1})	7.6 ± 3.38	8.55 ± 1.49	−13*	0.88
CCE (g kg^{-1})	162.5 ± 22.55	147.25 ± 25.73	11	1.10
CEC (cmolc kg^{-1})	19.7 ± 1.56	21.0 ± 1.27	−6.6	0.94
Soluble Ca (mmolc l^{-1})	2.87 ± 2.74	0.63 ± 0.202	360***	4.54
Soluble Mg (mmolc l^{-1})	1.62 ± 1.3	0.53 ± 0.08	206***	3.09
Soluble Na (mmolc l^{-1})	7.17 ± 1.64	2.88 ± 0.37	148***	2.49
Soluble K (mmolc l^{-1})	0.34 ± 0.21	1.04 ± 0.46	−197***	0.33
Exchangeable K (mg kg^{-1})	233.0 ± 23.24	335.25 ± 62.65	−31**	0.70
Available K (mg kg^{-1})	235.25 ± 23.48	338.5 ± 62.36	−32**	0.69
PAR	0.26 ± 0.06	0.47 ± 0.04	−43.7**	0.56
EPP (%)	2.97 ± 0.09	4.0 ± 0.52	−27.5**	0.74

Sp saturation percentage, *OC* organic carbon, *CCE* calcium carbonate equivalent, *CEC* cation exchangeable capacity, *PAR* potassium adsorption ratio, *EPR* exchangeable potassium ratio

RDF relative depletion factor, *RDF* relative enrichment factor

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ based on paired *t* test results

profile during cultivation practices. This pattern can be attributed as a negative aspect in soil quality because of any increase in soil pH is considered as negative change in the alkaline and calcareous soils (Smith and Doran 1996). Using this pathway, 75 % of the soils containing TH, TX, and FH showed negative effects in the soil pH, and 25 % of the soils containing TC indicated positive effects.

Effectively, long-term continuous sunflower cultivation led to a negative change in soil quality through degrading SOC. This pattern occurs for all soil types, but only became statistically significant ($P \leq 0.05$) in TH and FH (Table 3). The mean SOC declined in the order TH (a drop of 26 % with RDF of 0.75) > TX (a drop of 18 % with RDF of 0.82) > FH (a drop of 13 % with RDF of 0.88) > TC (a drop of 4 % with RDF of 0.97) through cropping, indicating that cultivation did not have the same effects on organic carbon in the different soil types. In this context, removal of most sunflower biomass after harvest can be considered as the most important subject for distributive pattern of SOC in the cultivated soils; however, effects of erosion and tillage in destruction of soil organic matter are not ruled out. A slight decline was manifested in soil CEC values for all of the examined soils except TH probably due to destruction of soil organic matter as reported by others (Rezapour and Samadi 2012). There was a significant relationship ($P \leq 0.01$) between CEC and SOC (Table 4).

There was a slight increase in CCE value for all of the studied soils (except TC) from 4 to 26 g kg^{-1} with cropping compared to the virgin land (Table 3). This may be caused by (1) tillage operation because of the calcareous parent material is tilled periodically by farmers to cultivate a certain depth of soil in the studied soils which can lead to an increasing pattern in CCE content and (2) the chemistry of the irrigation water used. The water quality was likely unfavorable for the dissolution and translocation of calcium carbonates due to the high Ca^{2+} content and pH of the irrigation water (Presley et al. 2004). On the other hand, calcium carbonates content trend to a significant loss ($P \leq 0.05$) in TC with cropping (a drop of 14 % RDF of 0.88) compared to those of the adjoining virgin land probably as a result of leaching process or plant root activities.

Compared to the virgin land, long-term cultivation caused an effective change in soluble K, exchangeable K, available K, as well as PAR and EPP (Table 3). There was a significant decline in soluble K ($P \leq 0.001$) from mean of 47 % (RDF of 0.52) to 197 % (RDF of 0.33) for all soil types, which can be explained by plant uptake and leaching. A pronounced significant decrease ($P \leq 0.01$) in exchangeable K (a drop from 31 to 34 % with RDF from 0.7 to 0.66), available K (a drop from 32 to 34 % with RDF from 0.69 to 0.66), and EPP (a drop from 32 to 33 % with RDF from 0.69 to 0.67) was recorded in TH along with FH, and a less significant decrease ($P \leq 0.05$) was observed in TX and TC. These patterns can be attributed to the content of clay and organic matter, nature and type of clay minerals (Table 4), and CEC as well described by other authors (Srinivasarao et al. 2006; Rezapour and Samadi 2012). The lowest content of exchangeable K, available K,

Table 4 Semi-quantitative percentage of clay minerals for the examined soils

Clay mineral	Soil			
	Typic Haploxerepts	Typic Xerorthents	Typic Calcixerepts	Fluventic Haploxerepts
Illite	+++	++++	++ to +++	+++
Smectite + mixed layered minerals	++ to +++	Trace to +	+ to ++	++
Kaolinite	++	++	+ to ++	++
Chlorite	++	+ to ++	++	+ to ++

Trace (<5 %); + (5–10 %); ++ (10–25 %); +++ (25–40 %); ++++ (40–60 %)

and EPP was associated with TX where the lowest clay content, organic matter, CEC, and smectite (Table 4) were observed. In general, the clay minerals that possess higher CEC-like smectite (due to native surface changes) have a greater affinity for potassium ions. In light of this, the lower clay content and organic matter, smectite nature, and corresponding low surface area and CEC contributed to at least some K pools (mainly exchangeable and available K) in TX compared with other soil types. There were positive significant relationships ($P \leq 0.05$) between CEC with clay and SOC as well as between CEC with exchangeable K, manifesting that as the amount exchangeable complex consistent clay and organic matter increase, exchangeable K content enhance, which is in line with the finding of other works (Samadi et al. 2008; Rezapour et al. 2009).

3.3 Soil salinity and alkalinity properties

With the exception of TH, the EC content of the examined soils was significantly influenced ($P \leq 0.05$) by the long-term agricultural practices (Fig. 2a). By the mean, a rise of 23 % (REF of 1.23) to 164 % (REF of 2.63) appeared in EC values as a result of cultivation compared with the virgin lands. Such patterns can be attributed to (1) the considerable content of soluble salts in the irrigation water used as recorded by its EC and TDS (Table 1), and (2) the weathering of basic-bearing minerals under sunflower roots activity as was evidenced by a significant increase in soluble cations (Ca, Mg, and Na) with

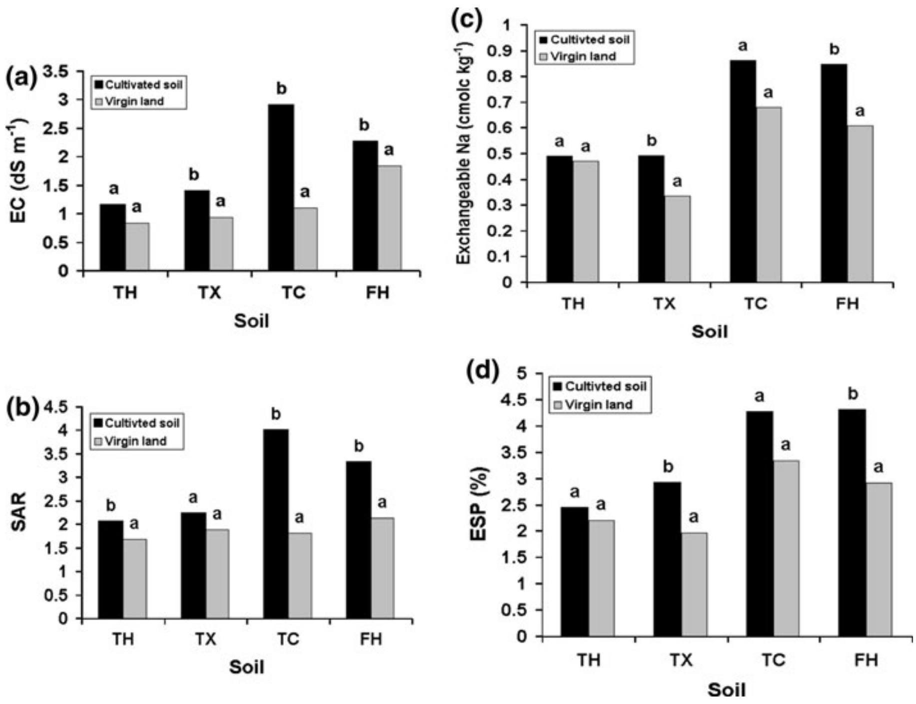

Fig. 2 The mean of the distribution of EC (**a**), SAR (**b**), exchangeable Na (**c**), and ESP (**d**) in the cultivated soil and the adjacent virgin land for different soil types (*TH* Typic Haploxerepts, *TX* Typic Xerorthents, *TC* Typic Calcixerepts, *FH* Fluventic Haploxerepts). *Values followed by the same latter* are not significantly different ($P \leq 0.05$)

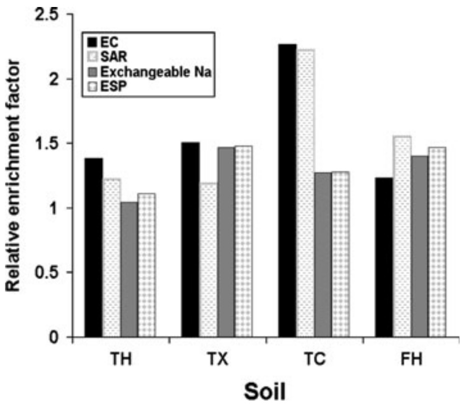

Fig. 3 Relative enrichment for EC, SAR, exchangeable Na, and ESP in different soil types (*TH* Typic Haploxerepts, *TX* Typic Xerorthents, *TC* Typic Calcixerepts, *FH* Fluventic Haploxerepts)

cropping than those of virgin lands (Table 3). For instance, the general spatial patterns of salinity (EC) tend to be associated with the soil chemical compounds as is reflected by correlation coefficients recorded for EC and soluble Na ($r = 0.57$, $P \leq 0.05$), EC and SAR ($r = 0.95$, $P \leq 0.001$), and EC and ESP ($r = 0.56$, $P \leq 0.05$) which is in match with the finding of Corwing et al. (2003). In general, variability of EC was in the order of TC > FH > TX > TH for the cultivated soils, indicating the great diversity of different soil types in responsibility to EC as showed other investigators (Nunes et al. 2007).

The SAR values, like EC, tend to increase with cropping the order of TC > FH > TH > TX (Fig. 2b). A pronounced significant increase in SAR levels was specified in TC (a rise of 122 % with REF of 2.2) along with FH (a rise of 57 % with REF of 1.55) and a less increase in TH (a rise of 23 % with RDF of 1.22) and TX (a rise of 18 % with RDF of 1.19). This pathway is consistent with the observations of Rezapour and Samadi (2012) who found that soils under long-term continuous sugar beet cultivation resulted in a significant rise ($P \leq 0.05$) in SAR values compared with soils under grass land.

Long-term cropping resulted in remarkable changes in exchangeable Na and ESP (Fig. 2a, b). By the mean, a rise from 4 % (REF of 1.05) to 48 % (REF of 1.47) and from 10 % (REF of 1.11) to 47 % (REF of 1.48) was appeared in exchangeable Na and ESP, respectively, with cultivation. Both exchangeable Na and ESP increased in the order of TX > FH > TC > TH, indicating that the general spatial Na and ESP were in matching for different soil types. These results are in line with the observations of Nunes et al. (2007) who reported an increased pattern in exchangeable Na from 16 to 40 % and in ESP from 20 to 68 % following 30 years of continuous irrigation in a border zone between Portugal and Spain. High values of exchangeable Na and ESP could be associated with the chemistry of the irrigation water. Conditions were likely favorable (Presley et al. 2004) for the accumulation of sodium on the exchange complex due to the high Na^+ content and HCO_3^- of the irrigation water (Table 1). In this cause, it is possible that the combined effect of increased evapotranspiration or decreased the partial pressure of CO_2 and increased bicarbonate from irrigation led to depletion of Ca^{2+} and Mg^{2+} ions from the soil solution as insoluble carbonates. Consequently, the soil solution becomes impoverished in Ca^{2+} and Mg^{2+} ions (Pal et al. 2003), causing an excess of exchangeable sodium as well as an increase in ESP and SAR. There was a liner behavior between exchangeable Na and ESP ($r = 0.97$, $P \leq 0.001$), exchangeable Na and SAR ($r = 0.73$, $P \leq 0.001$), and ESP with SAR ($r = 0.98$, $P \leq 0.001$), suggesting that the general spatial pattern of SAR and mainly

ESP tends to be associated with exchangeable Na. In spite of the fact that soil alkalinity enhanced significantly through cultivation, the values of SAR and ESP were far below the values considered as the certain threshold [(13 for SAR and 15 % for ESP) (Ayers and Westcot 1994; Soil Survey Staff 2010)]. According to the Iranian soil interpretation classes for salinity and alkalinity (Barzegar 2001), all the studied soils are grouped as well category for agricultural activities. In this interpretation, the well category involves a range from 0 to 8 for soil SAR and 0–10 % for soil ESP. However, the increased SAR and ESP exhibited in our study must be considered as a negative aspect in soil quality which needs to be monitored periodically to maintain the overall heath of the soils. As a sequence, it can said that long-term cultivation and irrigation have been associated with an increasing pattern in soil salinity and alkalinity mainly as a result of the combination of their addition through irrigation water along with interaction between the used water and its receiving soils in the studied region where rainfall is insufficient to leach the base-forming cations (Brady and Weil 1999) and the irrigation water carries a significant quantity of alkaline compounds. In Fig. 3, REF for EC, SAR, exchangeable Na, and ESP in different soil types is illustrates.

3.4 Clay mineralogy

The X-ray patterns indicate the presence of illite, smectite, mixed layered clay minerals, chlorite, and kaolinite in within clay fraction for both the cultivated soils and the adjoining virgin lands (Fig. 3). Relative amounts, semi-quantitatively, of chlorite and kaolinite and their XRD patterns were found in a similar pathway for both the cultivated and uncultivated soils among different soil types (Fig. 3; Table 4). This means that chlorite and kaolinite remained relatively unchanged irrespective of long-term continuous sunflower cultivation and soil type. Such results are comparable with the finding of Chorom et al. (2009) and Rezapour and Samadi (2012) who observed that chlorite and kaolinite under semi-arid condition were relatively unaffected by long-term continuous sugarcane and sugar beet cultivation. Additionally, the soil solution chemistry was not favorable for chemical weathering of chlorite in these soils, where water-extractable Mg concentration ranged from 0.45 to 2.5 mmol l^{-1} for the cultivated soils and from 0.3 to 0.9 mmol l^{-1} for the virgin lands. These amounts of Mg are greater than the threshold values for preserving chlorite (Timpson et al. 1996).

Illite and smectite were conditioned, relatively, to the long-term cultivation regarding to intensity, position, and peak figure of them (Fig. 3). Considerably, sharp diffractogram of the 1.0 nm peaks (well-crystallized illite) in the virgin lands shifted toward border peaks of 1.02–1.04 nm (poorly crystallized illite) along with some decrease in the intensity of the peak in the cultivated soils. These patterns may be because of the different aspect affecting the long-term agricultural operations such as (1) the longer periods of moisture availability along with activity of sunflower roots in the cultivated soils which may have provided favorable condition for instability in illite layer through chemical weathering (Khormali and Abtahi 2003; Rezapour et al. 2009), (2) sunflower, as a great K-demanding crop, might promote the release of non-exchangeable K from interlayer positions which could correspond to dissolution of some illite layers and relative increase in the d_{oo1} of illite from 1.0 to 1.04 nm. This is in agreement with the observations of other researchers. Barre et al. (2009) found, for instance, that plants can promote the release of K from illitic layers and the associated expansion of 1.0 nm illitic layers to 1.4 nm vermiculite layers or 1.8 nm smectite layers through laboratory and field observations in temperate environments. For the release of interspaces K from illitic layers to process, a significant decrease in K

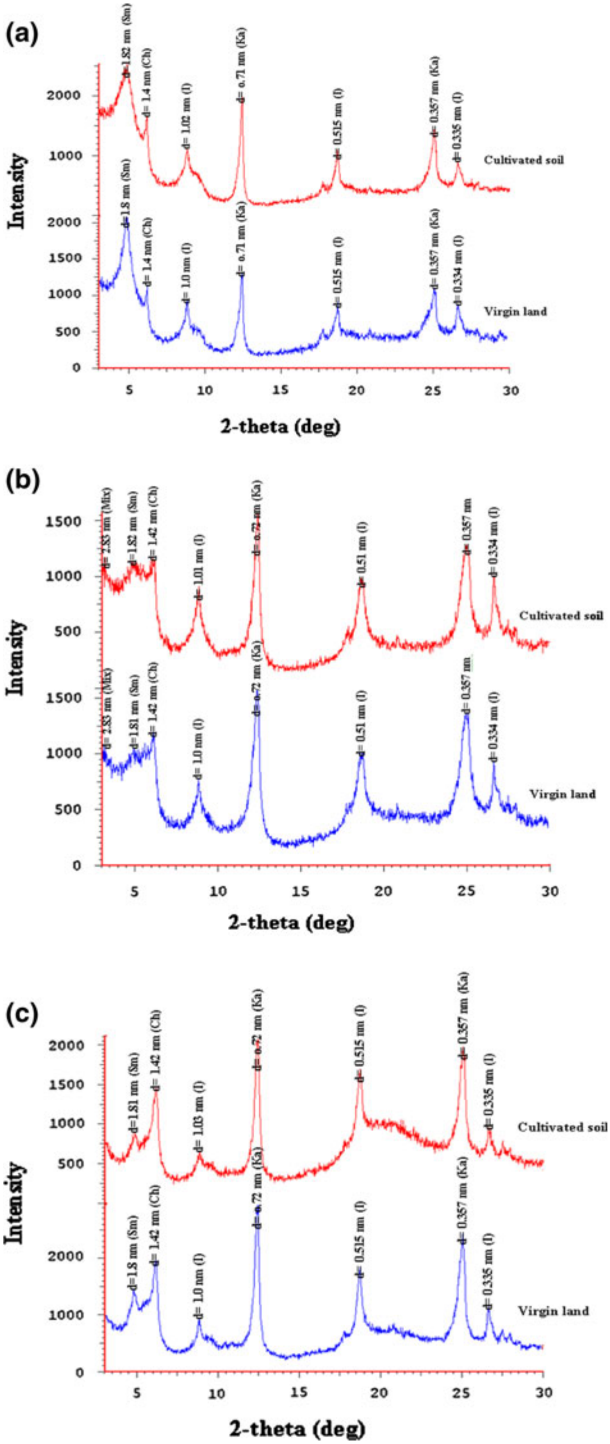

Fig. 4 XRD patterns of Mg-plus EG treatments in the cultivated soil and the adjacent virgin land for Typic Haploxerepts (**a**), Typic Xerorthents (**b**), Typic Calcixerepts (**c**), and Fluventic Haploxerepts (**d**). *Sm* smectite, *Ch* chlorite, *I* illite, *K* kaolinite, *Mix* mixed layered clay mineral

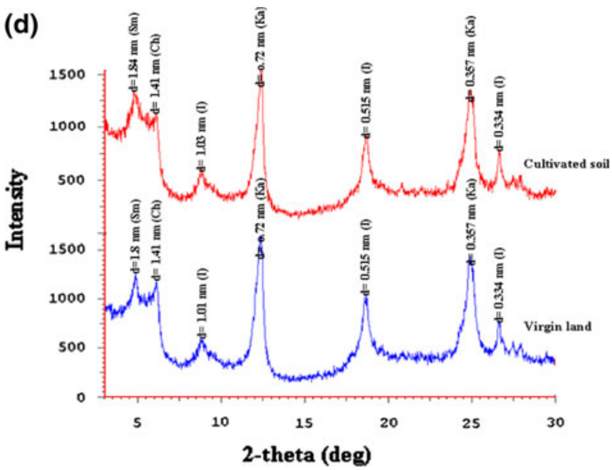

Fig. 4 continued

concentration to below a critical level is necessary in the surrounding solution. Mengel and Kirkby (2001) showed that the threshold K level necessary for preserving illite and muscovite is 2.5 mmol l^{-1}. In the study region, solution K ranged from 0.3 to 0.6 mmol l^{-1} for the cultivated soils and from 0.3 to 2.5 mmol l^{-1} for the adjoining virgin lands (Table 3); consequently, the chemical weathering of illite identified in these soils to expandable minerals should be favored (Timpson et al. 1996) mainly in the cultivated soils, (3) daily and seasonal fluctuations in temperature and moisture (Boettinger and Southard 1995) or wetting–drying cycle (by flooding irrigation) in Khoy area may be accelerated illite weathering in the soil surface, (4) compared with the virgin land, soluble Na and Mg were higher effectively in the cropland (Table 3) which may promote release more K from illite interspaces (Rahmatullah et al. 1994), thereby decreasing the number of layers at 1.0 nm and favoring illite transformation to smectite. Overall, it was found that long-term continuous sunflower cultivation along with strong irrigation had altered illitic layers, relatively, based on X-ray patterns mainly as result of some changes in soil solution chemistry (Fig. 4).

Comparing to the virgin land, the XRD patterns of smectite appeared to be broader and bigger in d_{oo1} (peak of 1.7–1.8 nm) by long-term cropping (Fig. 3), suggesting that smectite tend to be more instability and more variability (such as decrease in particle size) in the soils cropped. It was observed that the broad peaks belonging to smectite and illite linked to an increasing pattern in clay content after long-term cultivation (Table 3). This confirmed that the XRD peaks broaden of smectite and illite were in matching with decreasing particle size. Based on Schulze (2002), the width of XRD peaks is as a function of decreasing particle size.

4 Conclusions

This study illustrates that long-term continuous sunflower cropping had considerable effects on some soil attributes. Over five decades of cultivation, a depletion face was observed in SOC, CCE, some K forms (solution, exchangeable, available K), PAR, and

EPP for most of the studied soils. In contrast, an enrichment aspect was manifested in the salinity and alkalinity parameters (EC, SAR, exchangeable Na, and ESP) following intensive cultivation, possibly due to the combination of (1) the extensive addition of solution salts in the irrigation water used, and (2) interaction between the irrigation water and its receiving soils. It appear that continuous cropping and K depletion by sunflower, as a great K-demanding crop, over a long-time promoted some changes in the XRD pattern of illite and smectite regarding to the intensity and position of XRD peaks. Overall, soluble and exchangeable K along with EC, SAR, exchangeable Na, and ESP were known to be the most sensitive indicators following long-term continuous sunflower cropping and irrigation practices. It seems that monitoring the chemical characteristics of both the irrigation water and the soil must be considered in order to establish the water–soil–plant management strategies that will help to prevent environmental degradation and to maintain the overall heath of the studied soils.

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References

Ayers RS, Westcot DW (1994) Water quality for agriculture irrigation and drainage. FAO, Rome, Paper no. 29

Barre P, Berger G, Velde B (2009) How element translocation by plants may stabilize illitic clays in the surface of temperate soils. Geoderma 151:22–30

Barzegar AR (2001) Salt-affected soils: diagnosis and productivity. Shahid Chamran University, Ahvaz (in Persian)

Biscaye PE (1965) Mineralogy and sedimentation of recent deep sea clay in the Atlantic Ocean and adjacent seas and oceans. Geo Soc Am Bull 76:803–832

Boettinger JL, Southard RJ (1995) Phyllosilicate distribution and origin in Aridisols on a granitic pediment, Western Mojave Desert. Soil Sci Soc Am J 59:1189–1198

Brady NC, Weil RR (1999) The nature and properties of soils. Prentice-Hall, Inc., Englewood Cliffs

Chadwick OA, Chorover J (2001) The chemistry of pedogenic thresholds. Geoderma 100:321–353

Chapman HD (1965) Cation exchange capacity. In: Black CA (ed) Methods of soil analysis. Part 2. American Society of Agronomy, Madison, pp 891–900

Chorom M, Baghernejad M, Jafari S (2009) Influence of rotation cropping and sugarcane production on the clay mineral assemblage. Appl Clay Sci 46:385–395

Corwing DL, Kaffka SR, Hopmans JW, Mori Y, Van Groenigen JW, Van Kessel C, Lesch SM, Oster JD (2003) Assessment and field-scale mapping of soil quality properties of a saline-sodic soil. Geoderma 114:231–259

Day PR (1966) Particle fractionation and particle-size analysis. In: Black CA (ed) Methods of soil analysis. Part I. American Society of Agronomy, Madison, pp 545–566

De Clerck F, Singer MJ, Lindert P (2003) A 60-year history of California soil quality using paired samples. Geoderma 114:215–230

De la Rosa D, Sobral R (2008) Soil quality and methods for its assessment. In: Braimoh AK, Vlek PLG (eds) Land use and soil resources. Springer Science+Business Media B.V., Berlin, pp 167–200

FAO/ISRIC/ISSS (2006) World reference base for soil resources (WRB). Food and agriculture organization of the United Nations. World Soil Resources reports no. 103. ISRIC and ISSS, Rome, Italy

Golchin A, Asgari H (2008) Land use effects on soil quality indicators in northeastern Iran. Aust J Soil Res 46:27–36

Khormali F, Abtahi A (2003) Origin and distribution of clay minerals in calcareous arid and semi-arid soils of Fars province, south Iran. Clay Min 38:511–527

Kunze GW (1965) Pretreatment for mineralogical analysis. In: Klute A (ed) Methods of soil analysis. Part 1. America Society of Agronomy, Madison, pp 210–221

Mengel K, Kirkby EA (2001) Potassium in crop production. Adv Agron 33:59–110

Mehra OP, Jackson ML (1960) Iron oxide removal from soils and clays by a dithionite citrate system with sodium bicarbonate. Clays Clay Min 7:317–327

Moebius-Clune BN, Van Es HM, Idowu OJ, Schindelbeck RR, Kimetu JM, Ngoze S, Lehmann J, Kinyangi JM (2011) Long-term soil quality degradation along a cultivation chronosequence in western Kenya. Agric Ecosyst Environ 141:86–99

Nelson RE (1982) Carbonate and gypsum. In: Page AL (ed) Methods of soil analysis. Part 2. American Society of Agronomy, Madison, pp 181–199

Nelson DW, Sommers LE (1982) Total carbon, organic carbon, and organic matter. In: Page AL (ed) Methods of soil analysis. Part 2. American Society of Agronomy, Madison, pp 539–580

Nunes JM, Lopez-Pineiro A, Albarran A, Munoz A, Coelho J (2007) Changes in selected soil properties caused by 30 years of continuous irrigation under Mediterranean conditions. Geoderma 139:321–328

Pal DK, Srivastava P, Bhattacharyya T (2003) Clay illuviation in calcareous soils of the semi-arid part of the Indo-Gangetic Plains, India. Geoderma 115:177–192

Presley DR, Ransom MD, Kluitenberg GJ, Finnell PR (2004) Effects of thirty years of irrigation on the genesis and morphology of two semi-arid soils in Kansas. Soil Sci Soc Am J 68:1916–1926

Rahmatullah B, Shaikh Z, Gill MA, Salim M (1994) Bioavailable potassium in riverbed sediments and release of interlayer potassium in irrigated arid soils. Soil Use Manag 10:43–46

Rezapour S, Samadi A (2012) Assessment of inceptisols soil quality following long-term cropping in a calcareous environment. Environ Monit Assess 184:1311–1323

Rezapour S, Jafarzadeh AA, Samadi A, Oustan Sh (2009) Impacts of clay mineralogy and physiographic units on the distribution of potassium forms in calcareous soils in Iran. Clay Min 44:329–339

Richards LA (1954) Diagnosis and improvement of saline and alkali soils. US Salinity Lab., US Department of Agriculture Handbook 60, California

Samadi A, Dovlati A, Barin M (2008) Effect of continuous cropping on potassium forms and potassium adsorption characteristics in calcareous soils of Iran. Aust J Soil Res 46:265–272

Schulze DG (2002) An introduction to soil mineralogy. In: Dixon JB, Schulz DJ (eds) Soil mineralogy with environmental applications soil science. American Society, Madison, pp 1–34

Smith JL, Doran JW (1996) Measurements and use of pH and electrical conductivity for soil quality analysis. In: Doran JW, Jones AJ (eds) Methods for assessing soil quality. SSSA Special Publication 49, Soil Science Society of America, Madison, Wisconsin, USA, pp 169–185

Soil Survey Staff (2010) Keys to soil taxonomy. U. S. Department of Agriculture, Natural Resources Conservation Service, Washington

Srinivasarao CH, Rupa TR, Subba Rao A, Ramesh G, Bansal SK (2006) Release kinetics of nonexchangeable potassium by different extractants from soils of varying mineralogy and depth. Commun Soils Sci Plant Anal 37:473–491

Timpson ME, Lee SY, Ammons JT, Foss JE (1996) Mineralogical investigation of soils formed in calcareous gravelly alluvial, eastern Crete, Greece. Soil Sci Soc Am J 60:299–308

Thomas GW (1982) Exchangeable cations. In: Page AL et al (eds) Methods of soil analysis. Part 2. Soil Science Society of American, Madison, pp 159–166

Wang J, Fu B, Qiu Y, Chen L (2001) Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. J Arid Environ 48:537–550