Environ Earth Sci (2014) 71:375–381
DOI 10.1007/s12665-013-2440-x

ORIGINAL ARTICLE

Pasture degradation effects on soil quality indicators at different hillslope positions in a semiarid region of western Iran

Shamsollah Ayoubi · Nazanin Emami ·
Nasrin Ghaffari · Naser Honarjoo ·
Kanwar L. Sahrawat

Received: 10 August 2012 / Accepted: 21 March 2013 / Published online: 3 April 2013

Abstract A study was made to determine the influence of pasture degradation on soil quality indicators that included physical, chemical, biological and micromorphological attributes, along the hillslope positions in Chaharmahal and Bakhtiari province, western Iran. Soil samples from different slope positions were collected from 0 to 30 cm depth for physical and chemical properties and from 0 to 15 cm depth for biological properties at two adjacent sites in the two ecosystems: natural pasture and cultivated land. Soil quality indicators including bulk density, mean weight diameter, soil organic carbon (SOC), particulate organic material (POM) in aggregate fractions, total nitrogen, available potassium, available phosphorus, cation exchange capacity, soil microbial respiration (SMR) and microbial biomass C and N were determined. The results showed that SOC decreased cultivation from 1.09 to 0.77 % following pasture degradation. The POM decreased by about 19.35 % in cultivated soils when compared to natural pasture; also, SMR and microbial biomass C and N decreased significantly following pasture degradation. Furthermore, aggregate stability and pore spaces decreased, and bulk density increased in the cultivated soils. Overall, our results showed that long-term cultivation following pasture degradation led to a decline in soil quality in all selected slope positions at the site studied in the semiarid region.

Keywords Hillslope · Land use change · Pasture · Slope position · Soil quality

Introduction

Degradation of environment caused by improper land use is a worldwide problem that has attracted attention, especially for developing sustainable agricultural production systems (Vagen et al. 2006; Khormali and Nabiallahy 2009; Ayoubi et al. 2012; Karchegani et al. 2012). Deforestation, overgrazing and conversion of pasture and forests are leading to decline in physical, chemical and biological quality of soil resources in Iran and elsewhere in the world (Nael et al. 2004). Land use/land cover changes are influenced by human activity and growth, socioeconomic factors, expansion of the forests, grazing, agricultural activities, government policies and environmental factors such as drought (Kamusoko and Aniya 2007).

Soil quality, for example, means "capacity of the soil to function, within the ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health"; therefore, it is one of the most important considerations in developing sustainable land management (Nael et al. 2004; Blecker et al. 2013). Soil quality is a concept that integrates soil biological, chemical and physical aspects into a framework for soil resource evaluation (Khormali et al. 2009). Land use changes resulting in decline of the soil quality as

---

S. Ayoubi (✉)
Department of Soil Science, College of Agriculture, Isfahan University of Technology, 84156-83111 Isfahan, Iran
e-mail: ayoubi@cc.iut.ac.ir

N. Emami · N. Ghaffari
Department of Soil and Water Science, Tabriz Branch, Islamic Azad University, Tabriz, Iran

N. Honarjoo
Department of Soil Science, Khorasgan Branch, College of Agriculture, Islamic Azad University, Isfahan, Iran

K. L. Sahrawat
International Crop Research Institute for the Semi Arid Tropic (ICRISAT), Patancheru 502 324, Andhra Pradesh, India

ecologically sensitive component of the pasture ecosystem are not able to buffer the effects of agricultural practices (Khormali et al. 2009; Karchegani et al. 2012). Diminish in soil quality may lead to a permanent loss of land productivity (Islam and Weil 2000).

Celik (2005) reported that the mean weight diameter (MWD) of soil aggregates in cultivated soils as an indicator of physical quality was lower than that in pasture soils, and they further showed that soil cultivation decreased MWD, especially in the 0- to 10-cm layer of soil. Soil bulk density was lower under pasture than under cultivated plots (Puget and Lal 2005). Soil porosity and aggregate stability have been proposed by international groups as the major soil quality indicators in forest soils (Khormali et al. 2009). Soil aggregate structure and stability are important factors contributing to sustainable soil quality (Shepherd et al. 2002).

Soil organic matter (SOM) is one of the important indicators of soil quality; and it is also a main source of atmospheric CO_2 and other greenhouse gases (Lal 2004). Vagen et al. (2006) indicated that the lowest soil organic carbon (SOC) and total nitrogen (TN) contents were observed in areas that have been under cultivation for more than 50 years. Land use practices affect the distribution and supply of soil nutrients directly by altering soil properties and indirectly by influencing microbial transformations in the rooting zone. For instance, cultivation of pastures decreased SOC within a few years of initial conversion; and cultivation substantially decreased N mineralization capacity (Majaliwa et al. 2010). Cambardella et al. (2001) reported that SOC and TN were greater for the footslope, toeslope and summit than for backslope and shoulder elements. Land use change–induced decrease in SOM influenced SMR, an important soil biological indicator; and with increasing SOC content, microbial activity was stimulated (Nael et al. 2004).

Although a number of studies have been conducted to study the effects of land use changes on soil quality attributes, little efforts have been made to study the effects of pasture degradation on different slope positions in the semiarid regions. Therefore, this study was conducted to introduce and evaluate selected soil quality indicators potentially sensitive to land degradation in the hillslopes of Sooreshjan in Chaharmahal and Bakhtiari province, west of Iran.

Materials and methods

Description of the study area

The study area is situated at 32°18′ and 32°25′N and 50°19′ and 50°42′E in Sooreshjan area, Chaharmahal and Bakhtiari province, western Iran (Fig. 1). The area is located at 2,025 m a.s.l. The mean annual temperature and precipitation in the selected site are 15.4 °C and 467 mm, respectively. The hillslopes of the study area are generally covered with *Lunea astragalus* and *Lunea alhaji*. A major part of natural pasture in the study area has been degraded and overgrazed for the last 40 years.

Soil sampling and laboratory analyses

Surface (0–30 cm) soil samples were collected for determining chemical and physical characteristics; and surface (0–15 cm) soil samples were collected for measuring biological properties from five slope positions: summit (SU), shoulder (SH), backslope (BS), footslope (FS) and toeslope (TS) of pasture and adjacent cultivated land site. The transaction of the studied hillslope in the selected site is illustrated in Fig. 2. The experiment was conducted using a randomized complete block design. Three samples were randomly collected from each slope position of both land uses from surface soils. In total, 30 surface soil samples were collected from the various positions under two land uses. Intact soil samples from the surface layer (0–30 cm) were collected for the determination of micromorphological properties.

After air drying, soil samples were sieved through 2-mm sieve for chemical and physical analyses. The MWD was determined using the wet-sieving method with the sieves set of 2.0, 1.0, 0.5, 0.25 and 0.1 mm (Angers and Mehuys

Fig. 1 Location of the study area in western Iran

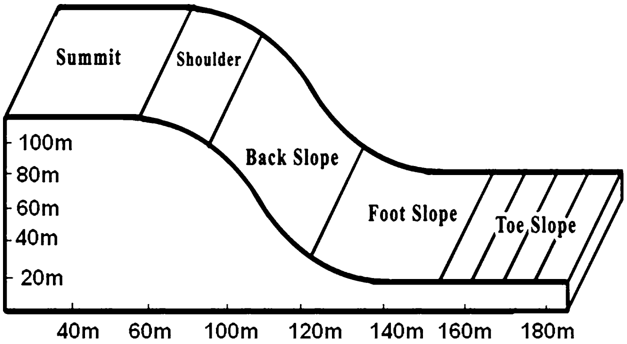

Fig. 2 Transaction of the studied hillslope in the selected site in west of Iran

1993). Soil bulk density (BD) was measured in the laboratory on undisturbed core samples. The separation of particulate organic matter (POM) was done by the following procedure of Cambardella et al. (2001). The SOC was determined by the wet-oxidation method (Nelson and Sommers 1982), and calcium carbonate percentage was determined using the back-titration method. The TN, available potassium (K_{ava}) and available phosphorous (P_{ava}) were determined by procedures described in Baruah and Barthakur (1997). Cation exchange capacity (CEC) was measured by the sodium acetate method. Soil microbial respiration (SMR) was measured by the closed bottle method of Stotzky (1965). Microbial biomass N was measured by chloroform fumigation and incubation method (CFIM) (Anderson and Domsoh 1978).

Thin sections of about 80 and 40 cm^2 were prepared from surface samples collected from the two land use systems using standard techniques. Micromorphological description was made according to Stoops (2003). A Zeiss polarizing microscope was used to study thin sections under both plane- and cross-polarized lights. The main features studied were those important for soil quality interpretation such as microstructure, voids and bio-related pedo-features.

The analysis of variance (ANOVA) was made by using SPSS software; and the mean comparisons were done using the Duncan's test at the $P < 0.05$ probability level.

Results and discussion

Soil physical attributes

The results on the effects of land use change on selected chemical, physical and biological characteristics are summarized in Table 1. Particle size distribution analysis showed that the clay content in surface layer of the cultivated soils was significantly decreased (Table 1). The clay content decreased from 38 % in the pasture to 33 % in the cultivated soils (Table 1), and silt content increased from 40 % in the pasture to 44 % in the cultivated soils. The parent material of the studied site seems uniform in terms of particle size distribution. Ghaffari (2011) who studied the hillslopes reported no significant difference in particle size distribution in the C horizons (i.e., parent material) at all the positions in the two ecosystems. Therefore, changes in texture in the surface layers are attributed to the land use change and slope gradient effects. The results showed that clay content decreased in the SU and BS positions in the cultivated soils from 40 to 34 % and from 38 to 33 %, respectively. This conclusion is supported by the results reported by Dengiz et al. (2007) who studied the effects of different topographic positions on selected soil properties such as texture in Cankiri-Acicay, Turkey.

The highest values of silt and clay contents were found in the cultivated land at lower slope positions, whereas the highest value of sand content was observed in the steep slopes of cultivated land (Table 1), presumably because of accelerated detachment of finer particles during soil erosion from the bare and disturbed soils. Hajabbasi et al. (1997) found that tillage practices and soil degradation in Lordegan, Iran, resulted in decreased clay % and the silt increased in cultivated land. Also, Khormali et al. (2009) reported 32 % clay in the surface layer of the forest and 22 % in the cultivated soils; and the difference in clay content was significant ($P < 0.05$). They stated that the soils of toeslopes had finer soil texture than the other landscape positions.

Soil bulk density (BD) was significantly lower ($P < 0.05$) under pasture (1.30 g cm^{-3}) than under cultivation (1.45 g cm^{-3}). The highest BD in the two land uses was observed at SH position and the lowest at BS position. High BD is related to weak soil structure and loss of organic carbon. Lemenih (2004) and Kizilkaya and Dengiz (2010) showed that BD increased due to loss of SOC and soil compaction following soil plowing and manipulation.

Soil chemical attributes

The SOC was significantly higher in different slope positions under pasture than under cultivation. The decrease in SOC following land use change was 46.15, 27.05, 9.58, 11.84 and 30 % for SU, SH, BS, FT and TS positions, respectively (Table 1). The highest SOC was observed in SU position in pasture soils (1.3 %) and the lowest (0.62 %) in cultivated soils in SH position. Kizilkaya and Dengiz (2010), Ayoubi et al. (2011), Fallahzadeh and Hajabbasi (2011), Shahriari et al. (2011) and Ayoubi et al. (2012) reported that land use change led to decrease in SOC; and cultivation was identified as one of the most important factors that caused reduction in organic carbon. These results are in agreement with the results of Nardi

Table 1 Effects of land use change on soil properties in different hillslope positions in the selected site

Slope position	Land use	Clay (%)	Silt (%)	BD (g/cm3)	MWD (mm)	K_{ava} (mg Kg)	P_{ava} (mg Kg)	TN	POM (%)	SOC	CEC (cmol +/Kg)	SMR (mg C g^{-1} day)	MBC (mg kg^{-1})	MBN (mg kg^{-1})
SU	Pasture	34b	40b	1.3b	0.22a	265a	23.1a	0.08a	0.36a	1.30a	29.0a	110a	0.14a	0.02a
	Cultivated	40a	44a	1.4a	0.16b	217b	15.5b	0.05b	0.19b	0.70b	25.4b	80b	0.13b	0.014b
SH	Pasture	35b	44b	1.3b	0.18a	240a	21.1a	0.06a	0.28a	0.85a	26.0a	48a	0.09a	0.019a
	Cultivated	30a	39a	1.5a	0.13b	220b	16.9b	0.04b	0.20b	0.62b	24.0b	39b	0.06b	0.009b
BS	Pasture	33b	41b	1.3a	0.19a	250a	17.a	0.05a	0.24a	0.73a	26.0a	38a	0.08a	0.01a
	Cultivated	38a	43a	1.3a	0.13b	225b	14.6b	0.03b	0.18b	0.66b	24.0b	25b	0.07b	0.008b
FS	Pasture	33b	38b	1.2b	0.13a	270a	22.1a	0.05a	0.24a	0.76a	27.8a	65a	0.14a	0.01a
	Cultivated	37a	45a	1.4a	0.08b	233b	17b	0.04b	0.20b	0.67b	26.0b	51b	0.11b	0.008b
TS	Pasture	32b	32b	1.2b	0.20a	326a	24.9a	0.06a	0.36a	1.0a	31.7a	162a	0.14a	0.025a
	Cultivated	37a	38a	1.4a	0.12b	320b	22.2b	0.05b	0.29a	0.70b	28.0b	91b	0.12b	0.023b
Pasture		34.1b	40.2a	1.2b	0.18a	277a	20.3a	0.06a	0.31a	1.09a	27.3a	89.4a	0.11a	0.016a
Cultivated		37.3a	39.6a	1.4a	0.14b	227b	18.6b	0.04b	0.25b	0.77b	25.6b	64.8b	0.09b	0.012b

Numbers with the similar letters are not significantly ($P < 0.05$) different in two land uses

SU summit, *SH* shoulder, *BS* backslope, *FS* footslope, *TS* toeslope, *BD* bulk density, *MWD* mean weight diameter, K_{ava} available potassium, P_{ava} available phosphorus, *TN* total nitrogen, *POM* particulate organic matter, *SOC* soil organic carbon, *CEC* cation exchange capacity, *SMR* soil microbial respiration, *MBC* microbial biomass carbon, *MBN* microbial biomass nitrogen

et al. (1996) who suggested that the rupture of the larger aggregates into the smaller ones following deforestation aggravates the loss of SOM. Li et al. (2012) in a study in Inner Mongolia showed that degradation of grasslands had the influential effect on decreasing soil organic carbon density. Physically protected organic materials are exposed to microbial decomposition following aggregate breakdown.

Several studies on variability of the organic carbon due to slope gradient showed that the down slope positions are mostly high in SOC compared to the upper positions. Wilding et al. (1983) suggested that the higher SOC of the lower slope positions (with finer soil texture) are mainly due to greater soil water storage promoting vegetation growth and slower decomposition of organic matter under anaerobic conditions. Another reason for higher SOC in the lower slope positions is the bulk (massive) transport of soil materials from the upper positions.

The POM is the first product in the decomposition process of plant residues and consists of relatively young plant debris primarily from plant roots (Karchegani et al. 2012). The difference in POM content between the soils under two land uses was mainly due to larger proportion of micro- and macroaggregate fractions in the pasture soils. In contrast, no plowing was done in pasture, and plant residues were mainly added to the soil surface. The POM in pasture soils was considerably more than that in the cultivated lands (Table 1).

The higher amount of POM in pasture soils implies high input and coarser nature of organic debris under pasture compared to that under cultivated land. Generally, soils under permanent vegetation with large annual return of litter (pasture and grassland) indicate the highest proportion of SOM recovered as POM (Mendham et al. 2004). On the other hand, in cultivated lands, coarse organic residues get disintegrated and oxidized due to aggregate destruction, exposing the physically protected SOM. This conclusion is in accordance with findings reported by Karchegani et al. (2012) and Ayoubi et al. (2012) in deforested land in western Iran. Pasture degradation and land use changes showed significant differences in TN between the pasture and cultivated soils in different slope positions (Table 1).

Pasture degradation and land use change in different slope positions showed that mean weight diameter (MWD) was significantly ($P < 0.05$) lower. The mean MWD values for natural pasture and cultivated soils were 0.18 and 0.14 mm, respectively (Table 1). The highest value of MWD (0.22 mm) was determined for SU position in pasture soils and the lowest (0.08 mm) for FS position in cultivated soils. Soil tillage resulted in the breakdown of the macroaggregate into primary particles and aggregate stability decreased (Shepherd et al. 2002). This is in accord with observations of Kizilkaya and Dengiz (2010) and Ayoubi et al. (2011). Khormali et al. (2009) and Ayoubi et al. (2012) observed a greater MWD in forest soils when compared to the cultivated soils in northern and western Iran, respectively. Alvarez et al. (2012) studied in comparison with different land uses in Typical Argiudolls of the Buenos Aires southeastern area and found that substantial decrease in humic substances in cultivated plots translates into a lower biological activity; this influences the reduction in aggregation and thus lowering the structural stability of these plaits compared to other land uses including native pastures and forests. Loss of SOC, plowing of soil and decline in microbial activity together might have influenced aggregate stability; and the situation would have gone worse as a result of continuous use of machinery for cultivation.

The highest value of K_{ava} was observed in toeslope position and the lowest was attributed to shoulder position in the two selected land uses (Table 1). The K_{ava} in cultivated land significantly decreased compared to the pasture land ($P < 0.05$) (Table 1). Lemenih (2004) and Hajabbasi et al. (1997) reported similar results on the effects of land use change on available K. Coarser soil texture, lower CEC, lack of permanent vegetation cover and water erosion in cultivated soils are the main reasons for the loss of available potassium (Khormali et al. 2009). We also observed similar results in the present study for available *P* (P_{ava}) in different slope positions under the two ecosystems (Table 1).

Land use change resulted in significant change in CEC for all hillslope positions (Table 1). The highest value of CEC was observed for the toeslope position in the two ecosystems. This could be attributed to the transportation of fine clay particles and SOM with higher CEC from upper parts of hillslope to down the slope (toeslope) by preferential soil water erosion. Similar results were reported by Khormali et al. (2009), Ayoubi et al. (2011), Ayoubi et al. (2012) and Karchegani et al. (2012).

Soil biological attributes

The result of our study showed that SMR significantly decreased from 101.40 mg C day^{-1} kg^{-1} for pasture soils to 88.40 mg C day^{-1} kg^{-1} for cultivated soils. In different positions of hillslope, decrease in SMR was consistent with the decrease in SOC. The highest SMR was observed in TS position and the lowest in BS position. Islam and Weil (2000) reported the highest value of SMR in pasture and forest soils; and it was related to high SOC. Increase in foliage of trees and vegetation cover increases SMR value in pasture compared to disturbed ecosystem (Kiani et al. 2004).

Soil microbial biomass is defined as the living part of the SOM excluding soil animals larger than 5×10^3 μm^3 and plant roots (Jenkinson 1988). In this study, microbial biomass C and N in natural pasture soils was higher than that in the cultivated soils in all selected slope positions (Table 1). It appears that the change in land use from natural pastures to cultivated soils results in lower microbial biomass C, probably due to the contribution of plant roots to provide easily decomposable C source for microbes in pasture soils.

Soils with high inputs of easily decomposable organic matter tend to have higher microbial activity and biomass. Relatively greater inputs of residues from natural pasture could have accounted for the higher microbial biomass C and N in natural pasture soils relative to cultivated soils. These results are consistent with those reported by Khormali et al. (2009) in northern Iran.

Micromorphological attributes

Micromorphological and microscopic studies are used as the reliable techniques for investigating the effects of faunal activity on soils (Khormali et al. 2009; Ayoubi et al. 2012). Micromorphological properties of selected sections of surface layer of two land uses are given in Table 2. The micromorphological studies indicated that land use change led to changes in microstructure and micropores (Table 2). Compound packing voids which are associated with crumb and granular microstructure in pasture soils (Fig. 3a) changed to planar voids with blocky microstructure (Fig. 3c). No differences were found between b-fabric and calcitic pedo-features in the two land uses.

The high microbial activity could be deduced from the presence of high amount of excremental pedo-features or passage features as discussed by Adesodun et al. (2005) (Fig. 3b). In contrast, topsoil from the cultivated soil treatment lacked sufficient organic matter and consequently microbial activity for the improvement in soil microstructure and porosity. As seen in Fig. 3c, the topsoil microstructure of cultivated treatment is mainly massive or weakly developed with low porosity. Cultivation practices have led to soil loss and compaction, deteriorating soil quality attributes such as microbial activity, porosity and microstructure. Our finding are consistent with the results of Khormali et al. (2009) and Khormali and Shamsi (2009)

Table 2 Micromorphological attributes of surface soils samples in two selected ecosystems

Land use	C/F	Void	Microstructure	b-Fabric	Nodules
Pasture soils	Double-spaced coarse enaulic	Compound packing void and channel	Highly separated crumb	Crystalitic	Typic calcite nodules
			Microstructure	b-Fabric	
Cultivated soils	Coarse enaulic	Planar	Weakly separated	Crystalitic	Typic calcite nodules
			Blocky microstructure	b-Fabric	

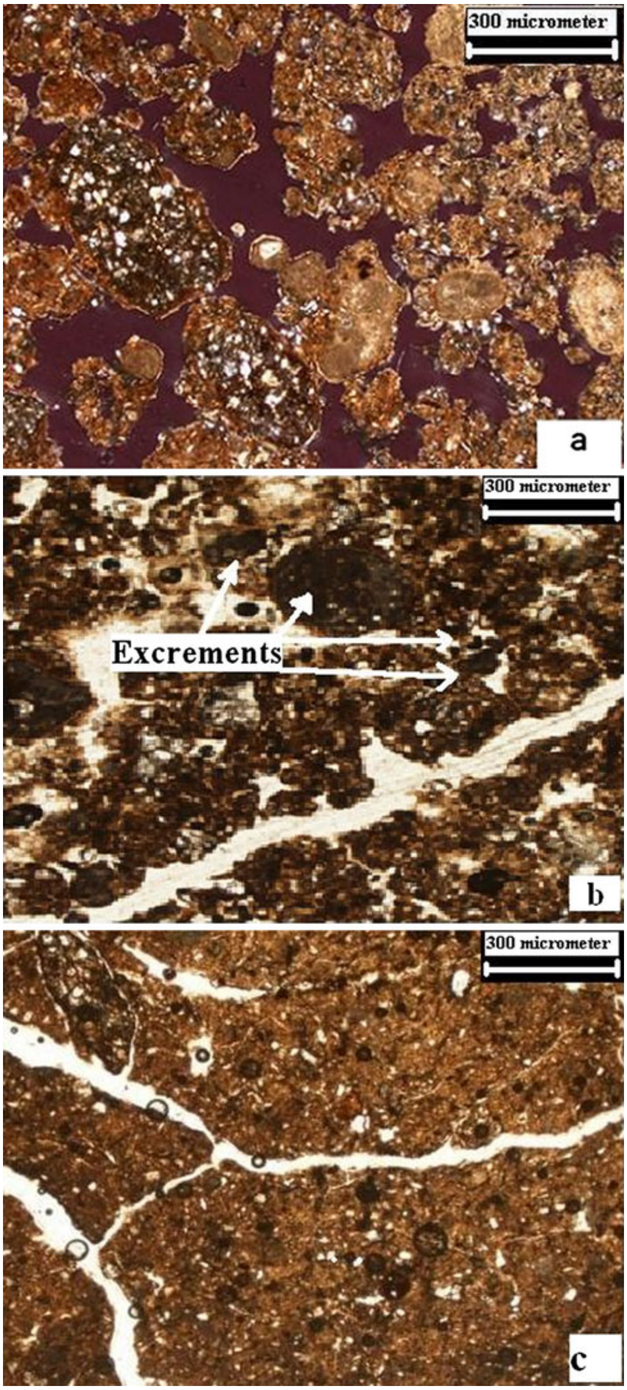

Fig. 3 **a** Crumb and granular microstructure in the topsoil under natural pasture soils (XPL). **b** Excremental pedo-features (e.g., passage features, biological activity) in the topsoil under pasture soils. **c** Planar voids with blocky structure in the topsoil under cultivated soils (PPL)

who used the micromorphological pedo-features to determine the effects of land use change on soil microstructure and porosity in loess soils of hillslopes of Golestan province, northern Iran, and Ayoubi et al. (2012) in hilly region of western Iran.

Conclusions

The effects of long-term land use on selected soil chemical, physical, biological and micromorphological attributes at various hillslope positions were studied. The effects of land use on SOC, TN, POM, MWD, SMR, microbial biomass C and N, soil texture, soil porosity and microstructure were highly significant in the steep slope positions (i.e., shoulder and backslope) and down slope positions (i.e., toeslope and footslope). We concluded that degradation of natural pasture followed by extensive cultivation with little attention to conservation practices has led to decline in soil quality. The above-mentioned soil attributes were significantly reduced by overgrazing and cultivation. Overall, the results showed that native pasture improves soil organic carbon storage and reduces soil erosion, especially in the hilly regions with high rainfall in west of Iran. Further studies are required to fully understand the implications of sustainable land management on sustainable development of agricultural production systems by taking leads from the findings reported in this paper in the semiarid region of Iran.

References

Adesodun JK, Davidson DA, Hopkins DW (2005) Micromorphological evidence for faunal activity following application of sewage and biocide. Soil Ecol 29:39–45

Alvarez MF, Osterrieth ML, del Río JL (2012) Organic matter fractionation in aggregates typical Argiudolls southeastern Buenos Aires and its relation to different soil uses: a preliminary study. Environ Earth Sci 65:505–515

Anderson JPE, Domsoh KH (1978) Mineralization of bacteria and fungi in chloroform-fumigated soils. Soil Biol Biochem 10:207–213

Angers DA, Mehuys GR (1993) Aggregate stability to water. In: Carter MR (ed) Soil sampling and methods of analysis. Lewis, Boca Raton

Ayoubi S, Khormali F, Sahrawat KL, Rodrigues de Lima AC (2011) Assessing impact of land use change on soil quality indicators in a loessial soil in Golestan province. Iran J Agric Sci Technol 13:727–742

Ayoubi S, Mokhtari Karchegani P, Mosaddeghi MR, Honarjoo N (2012) Soil aggregation and organic carbon as affected by topography and land use change in western Iran. Soil Till Res 121:18–26

Baruah TC, Barthakur HP (1997) A textbook of soil analysis. Vikas, New Delhi

Blecker SW, Stillings LL, Amacher MC, Ippolito JA, DeCrappeo NM (2013) Development and application of a soil organic matter-based soil quality index in mineralized terrane of the Western US. Environ Earth Sci 68:1887–1901

Cambardella CA, Gajda AM, Doran JW, Wienhold BJ, Kettler TA (2001) Estimation of particulate and total organic matter by weight loss-on-ignition. In: Lal R, Kimble J, Follett R, Stewart B (eds) Assessment methods for soil carbon. CRC, Boca Raton

Celik I (2005) Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil Till Res 83:270–277

Dengiz O, Kızılkaya R, Göl C, Hepşen Ş (2007) The Effects of different topographic positions on soil properties and soil enzymes activities. Asian J Chem 19:2295–2306

Fallahzadeh J, Hajabbasi MA (2011) The effects of irrigation and cultivation on the quality of desert soil in central Iran. Land Degrad Dev 10:114–123

Ghaffari N (2011) Soil micromorphology and mineralogy attributes in soils developed on different slope positions of hilly regions of western Iran. M.Sc Thesis. Islamic Azad University, Tabriz Branch, Tabriz

Hajabbasi MA, Jalalain A, Karimzadeh H (1997) Deforestation Effects on soil physical and chemical properties. Lordegan, Iran. Plant Soil 190:301–308

Islam KR, Weil RR (2000) Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric Ecosyst Environ 79:9–16

Jenkinson DS (1988) Determination of microbial biomass carbon and nitrogen in soil. In: Wilsom JR (ed) Advances in Nitrogen Cycling in Agricultural Ecosystems. CAB International, Wallingford, pp 368–386

Kamusoko C, Aniya M (2007) Land use/cover change and landscape fragmentation analysis in the Bindura District, Zimbabwe. Land Degrad Dev 18:221–233

Karchegani P, Ayoubi S, Mosaddeghi MR, Honarjoo N (2012) Soil organic carbon pools in particle-size fractions as affected by slope gradient and land use change in hilly regions, western Iran. J Mountain Sci 9:87–95

Khormali F, Nabiallahy K (2009) Degradation of Mollisols as affected by land use change. J Agric Sci Technol 11:363–374

Khormali F, Shamsi S (2009) Micromorphology and quality attributes of the loess derived soils affected by land use change: a case study in Ghapan watershed, Northern Iran. J Mountain Sci 6:197–204

Khormali F, Ajami M, Ayoubi S, Srinivasarao C, Wani SP (2009) Role of deforestation and hillslope position on soil quality attributes of loess-derived soils in Golestan province. Iran. Agric Ecosyst Environ 134:178–189

Kiani F, Jalalian A, Pashaee A, Khademi H (2004) Effect of deforestation on selected soil quality attributes in loess-derived landforms of Golestan province, northern Iran. Proceeding of International Iran and Russia Conference, 546–550

Kızılkaya R, Dengiz O (2010) Variation of land use and land cover effects on some soil physico-chemical characteristics and soil enzyme activity. Zemdirbyste-Agric 97:15–24

Lal R (2004) Carbon sequestration in soils of central Asia. Land Degrad Dev 15:563–572

Lemenih M (2004) Effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia, Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala

Li B, Tang H, Wu L, LI Q, Zhou C (2012) Relationships between the soil organic carbon density of surface soils and the influencing factors in differing land uses in Inner Mongolia. Environ Earth Sci 65:195–202

Majaliwa JG, Twongyirwe R, Nyenje R, Oluka M, Ongom B, Sirike J, Mfitumukiza D, Azanga E, Natumanya R, Mwerera R, Barasa B (2010) The effect of land cover change on soil properties around Kibale national park in southwestern Uganda. Appl Environ Soil Sci 10:1–7

Mendham DS, Heagney EC, Corbeels M (2004) Soil particulate organic matter effects on nitrogen availability after afforestation with Eucalyptus globulus. Soil Biol Biochem 36:1067–1074

Nael M, Khademi H, Hajabbasi MA (2004) Response of soil quality indicators and their spatial variability to land degradation in central Iran. Appl Soil Ecol 27:221–232

Nardi S, Cocheri G, Dell Agnola G (1996) Biological activity of humus. In: Piccolo A (ed) Humic substances in terrestrial ecosystems. Elsevier, Amsterdam

Nelson DW, Sommers LE (1982) Total carbon, organic carbon, and organic matter. In: Page AL, Miller RH, Keeney DR (eds) Methods of soil analysis. Part 2, chemical and microbiological properties, vol 9, 2nd edn. Agron, Madison, pp 539–579

Puget P, Lal R (2005) Soil organic carbon and nitrogen in a Mollisol in central Ohio as affected by tillage and land use. Soil Till Res 80:201–213

Shahriari A, Khormali F, Kehl M, Ayoubi S, Welp G (2011) Effect of a long-term cultivation and crop rotations on organic carbon in loess derived soils of Golestan Province, Northern Iran. Int J Plant Prod 5(2):147–152

Shepherd MA, Harrison R, Webb J (2002) Managing soil organic matter: implications for soil structure on organic farms. Soil Use Manag 18:284–292

Stoops G (2003) Guidelines for analysis and description of soil and regolith thin sections. SSSA, Madison

Stotzky G (1965) Microbial respiration. In: Black CA (ed) Methods of soil analysis, part 2. ASA, Madison, pp 1500–1572

Vagen TG, Lal R, Singh BR (2006) Soil carbon sequestration in sub-Saharan Africa: a review. Land Degrad Dev 16:53–71

Wilding NE, Smeck A, Hall GF (1983) Pedogenesis and soil taxonomy. II. The soil orders. Dev Soil Science 11:iii–x