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Soil properties and carbon sequestration in Persian oak (*Quercus brantii* var. *persica*) forests, Iran

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Abstract: One of the important issues both in the political discussion about climate change and in forest ecosystem research is carbon sequestration. In this paper, we estimated soil carbon sequestration (SCS) in two Persian oak forest stands of different origin (seed and coppice). Soil samples were taken at two soil depths (0–15 and 15–30 cm) and locations (under the tree crown and open area) in each oak stand. Results showed that surface layers (0–15 cm) had the highest soil carbon sequestration ranging from 41.2 $t \cdot ha^{-1}$ to 47.9 $t \cdot ha^{-1}$ for both oak forests. The total SCS was higher (between 79.5 and 89.07 $t \cdot ha^{-1}$) in open areas of the two forest stands than under the crowns of oak trees. Finally, the amount of total SCS in seed originated forest (SOF) (86.52 $t \cdot ha^{-1}$) was significantly greater ($P < 0.05$) than in coppice forest (CF) (77.70 $t \cdot ha^{-1}$). The results indicate that a relatively large proportion of C loss in CF is due to overgrazing, forest degradation and conversion to coppice forests in the study area.

Keywords: carbon pool; soil characteristics; coppice forest; Zagros forest

Anthropogenic growth in the atmospheric CO_2 plenitude is increasing, and main drivers have been identified as the dominant contributors (Raupach et al. 2008). Particularly, the CO_2 emission increase rate from fossil fuel emissions rose from 1.3% per year in the 1990's to 3.3% per year in 2000–2006 (Canadell et al. 2007). The rate of increase in the atmospheric CO_2 concentration can be reduced through the process of carbon sequestration (CS). Carbon sequestration is defined as the uptake of C-containing substances, in particular CO_2, into a long-lived pool that would otherwise be emitted or remain in the atmosphere (IPCC 2007; Lal 2008). These pools are located in the ocean, biosphere, pedosphere and geosphere (Lorenz, Lal 2010). Carbon sequestration in forest ecosystems has become a significant topic both in the political discussion and forest ecosystem research about abrupt climate change (ACC) (Lorenz, Lal 2010). Forests are major terrestrial C sinks (about half of the terrestrial C sink), have large C densities and sequester large amounts of atmospheric carbon dioxide (CO_2) (Canadell et al. 2007). Based on FAO statistics, about 234 Pg (petagrams) C are stored by/in aboveground biomass, 62 Pg C in belowground biomass, 41 Pg C in dead wood, 23 Pg C in litter, and 398 Pg C in soils of forest ecosystems (Kindermann et al. 2008). As can be seen, carbon stored in soils is notable and soil organic matter (SOM) may act as a powerful sink for atmospheric C in the long term (Lorenz,

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Lal 2010). All source-sink duties of forest ecosystem soils relate to biotic processes because litter production, decomposition, and humus synthesis are controlled by a large number of organisms that interact in forest ecosystems (Lorenz, Lal 2010).

In general, the annual C storage in forest ecosystems depends on disturbances, forest succession, and climate variations (Gough et al. 2008). Disturbance is any factor (biotic and abiotic factors) that meaningfully reduces the overstorey leaf area index (LAI) for more than one year or an incident that makes growing space available for surviving trees (Oliver, Larson 1996; Waring, Running 2007). Globally, disturbances affected more than 104 million ha or 3.2% of the total forest area in 2000 (FAO 2006). Approximately half of the soil C in managed ecosystems has been lost to the atmosphere during the past two centuries due to land-use changes and degradation of forests because of cultivation practices (Kooch et al. 2012). Land-use changes and degradation of forests and soils in developing countries are related to socio-economic factors, human population and livestock growth, technological changes, and location specific biophysical conditions (Upadhyay et al. 2013). Land-use changes in Iran have been more rapid in the last 50 years than at any time in Iran's history and are expected to continue at this rate or accelerate in the future (Haghdoost et al. 2013).

Zagros forests of Iran with about six-million-hectare area have been classified as semi-arid forests and are most important with respect to water supply, soil conservation, climate change and socio-economic balance of the entire country (Sagheb-Talebi et al. 2014). These forests have been considered as pastoral ecosystems since 10,000 years ago (Zeder, Hesse 2000). Therefore, large numbers of livestock, mainly goats and to some extent sheep, have had a significant impact on Zagros forests and influenced their structure and function (Hoekstra, Shachak 1999; Soltani et al. 2014). Forest clearance for cultivation and forest degradation due to overharvesting and overgrazing have led to soil erosion rates in the range of 2–10 ton per hectare per year in Zagros regions (Sagheb-Talebi et al. 2014; Soltani et al. 2014). In addition to the above-mentioned practices, other practices like litter raking and fuel-wood coppicing have led to soils severely depleted of SOM and nutrient reserves. Thus, forests in many Zagros regions suffer from those extractive practices. In the last decade, efforts have been made to assess soil carbon in forests of Iran, but most studies have been focused on Hyrcanian forests in the north of Iran and less attention was paid to the Zagros forests. The present study is an attempt to estimate the potential of soil carbon sequestration and to assess the soil chemical properties in two natural Persian oak stands of different origin in Dalab valley in Ilam province. Certainly, the results of the study will contribute to understanding the effects of natural Persian oak forests on soil C stocks and will help the natural resource managers in Iran to do sustainable forest management practices.

MATERIAL AND METHODS

Study area

The protected Dalab valley forest with 3,000 ha area is located 8 km northwest of Ilam county, in the west of Iran, between 33°41'01" to 33°43'13" north latitude and 46°22'15" to 46°25'27" east longitude (Fig. 1). The elevation of the forest area ranges between 1,200 and 2,000 m a.s.l. Ac cording to data of the Ilam Meteorological Station, the mean annual precipitation and temperature are 525 mm (it occurs mainly in winter) and 16.9°C, respectively. According to Emberger, the study area has a cold semi-arid climate and dry months extend from May to November. There are no significant climatic differences in the study area to such an extent that the climate alone could have an effect on changing soil properties regardless of the forest type origin (seed and coppice). However, we tried to select two Persian oak forest stands of different origin but in similar topographic (in terms of the slope – 20%), aspect (northern) and elevation (average elevation of 1,533 m a.s.l.) conditions. The soil order (based on FAO orders) in the study area is Lithosols on the limestone bedrock, characterized by sandy-loamy texture in both forest stands (originating from seeds and coppice). The dominant vegetation in the study area consists of Persian oak trees (*Quercus brantii* var. *persica*) of seed and coppice origin. Some other tree species in the study area are pistachio (*Pistacia atlantica*), hawthorn (*Crataegus sp.*), maple (*Acer monspessulanum*) and almond (*Amygdalus eleagnifolia*). Regressive succession stages of oak forests in the study area (in particular in coppice stand) like in other Zagros regions have taken place under drastic human induced disturbances such as overgrazing, fuel

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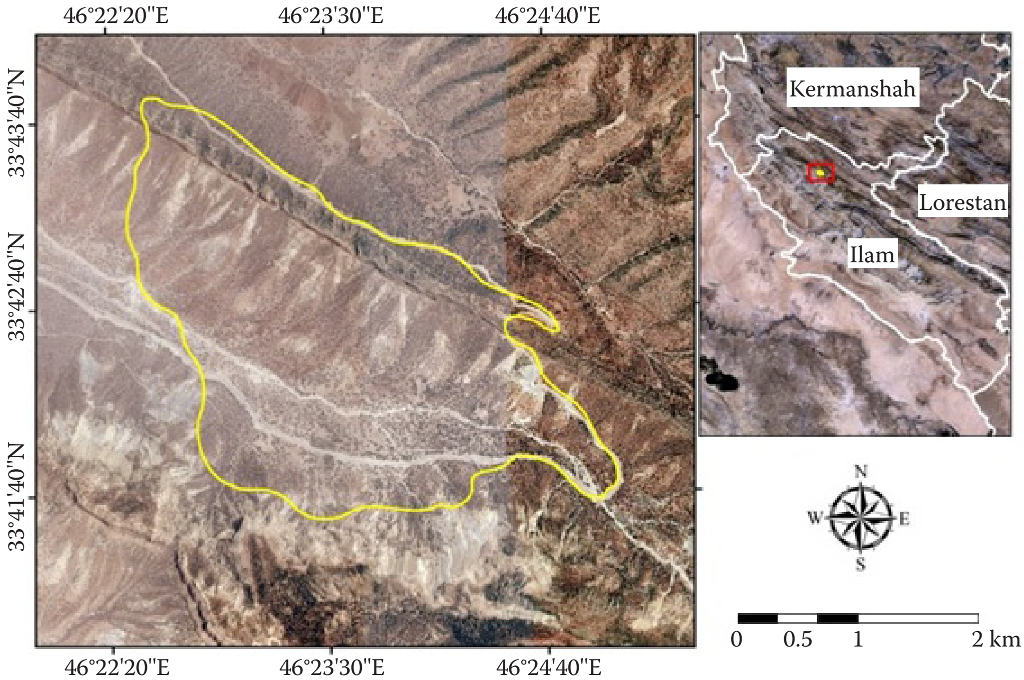

Fig. 1. The study area location in Iran and Ilam province

wood uses, clearance for cultivation and understorey cultivation. We tried to select 5 ha of less degraded stands from both origins of the oak forests. However, the seed originated oak forest in the study area has been conserved for 25 years and had less human disturbances in comparison with the coppice forest. Coppice stands of Zagros are usually single-layered and have a low average height (Sagheb-Talebi et al. 2014). The average canopy cover density and species density of the study area are about 45% and 55 (trees per ha), respectively (Maleki 2014).

Experimental design and soil sampling

Ten trees were selected based on a randomized transect design in each oak stand. In total, 40 soil samples at two depths (0–15 cm and 15–30 cm) were collected from under and outside the tree crown for each oak stand. The soil samples under the tree crown were collected using a bucket auger from four points around each tree at a 50-cm distance from the trunk, mixed into a single soil sample for each depth separately. The soil samples from outside the tree crown were also a mix of four randomly selected points in open space near the selected tree. Thus, 20 soil samples at two depths from under the tree crown and 20 soil samples from outside the tree crown were collected for each studied oak stand.

Soil analysis

In each soil sample litter materials (roots, shoots and leaves) were removed. Then, all of the samples were air-dried for 48 hours and sieved (< 2 mm mesh size) after powdering. Each soil sample was characterized with respect to electrical conductivity (EC) (in saturated mud essence with an EC meter), soil texture (hydrometer method), bulk density (BD) (core method, a double-cylinder, drop-hammer sampler with a core is designed to remove a cylindrical core of soil), soil reaction (in saturated mud through a pH meter), total organic C (Walkley-Black method), total N (Kjeldahl method), exchangeable K (ammonium acetate and flame photometer) and absorbable P (Olsen method and spectrophotometer). Finally, the total soil carbon sequestration (SCS) was determined by the following Equation 1 (Nizami 2012; Haghdoost et al. 2013):

$$\mathrm{SCS} = C \times \mathrm{SB}_d \times d \quad (1)$$

where:

SCS – organic C sequestration at each soil layer ($t \cdot ha^{-1}$);

C – carbon content (%);

SB_d – soil bulk density ($g \cdot cm^{-3}$);

d – total depth at which the sample was taken (cm).

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Statistical analysis

The normality of variables and homogeneity of variances were controlled by the Kolmogorov-Smirnov test and Levene's test, respectively. To assess the differences in soil characteristics between two oak stands (seed originated and coppice) as well as different depths (0–15 and 15–30 cm) two-way analysis of variance (ANOVA) was tested. Duncan's test was used to separate the averages of the dependent variables which were significantly affected by the treatments. Significant differences between treatment averages for different parameters were tested at $P < 0.05$.

RESULTS

Soil properties

Soils in the study area were alkaline soils regardless of forest origin types. Table 1 shows summary statistics of physical and chemical soil properties for two different Persian oak forests at two different sampling depths and locations.

Statistical analysis

Table 2 shows two-way ANOVA to compare the effects of forest stand types, soil depths and soil sample locations on different soil properties. The results showed that except two soil properties, namely P and pH, there are no significant interactive effects of forest origin and soil depths on electrical conductivity (EC), organic matter (OM), organic carbon (OC), soil carbon sequestration (SCS), N and K ($P < 0.05$, Table 2). Two-way ANOVA also showed that except the soil phosphorus characteristic the source of variation in depth had a significant effect on all other soil properties ($P < 0.01$). In addition, the forest origin source of variation had a significant effect on EC, pH, SCS and K soil properties ($P < 0.01$ and 0.05, Table 2).

The results of Duncan's test to find significant differences between the means of dependent variables in different forest types, soil depths and locations are shown in Table 3.

Average pH ranged from 7.06 to 7.41 and increased with soil depth (Table 3). Soil pH was significantly higher in the coppice forest (CF) stand than in the seed originated forest (SOF) stand (Fig. 2), whereas no significant difference ($P < 0.05$) was observed between the surface depths in soil samples of the two stands taken under the crown (Table 3).

In general, EC at top soil depths was higher than in the subsoil in all locations (under the crown and outside the crown in both stands). The first depth of samples collected outside the crown had the highest EC (0.98 ± 0.13 and 0.81 ± 0.27) in SOF and CF, respectively (Table 3). The total average EC in SOF was significantly greater than in CF ($P < 0.05$) (Fig. 2).

The average bulk density in SOF was significantly higher than in CF ($P < 0.05$) (Fig. 2), whereas there was no significant difference ($P < 0.05$) between the same depths in two oak forests. The bulk density tended to increase as the soil depth increased in both stands. This is possibly due to more organic matter in the top soil than in subsoil (Table 3).

Table 1. Summary statistics of soil properties (means of two depths ± SD) for two different Persian oak forests at two different sampling depths and locations

Soil content	Means ± SD (0–30 cm depth)			
	SOF (under crown)	SOF (outside of crown)	CF (under crown)	CF (outside of crown)
OC (%)	2.70 ± 0.07	3.00 ± 0.15	2.99 ± 0.06	2.76 ± 0.08
BD (g·cm^{-3})	0.89 ± 0.03	1 ± 0.02	0.85 ± 0.01	0.96 ± 0.02
pH	7.38 ± 0.04	7.06 ± 0.06	7.41 ± 0.05	7.31 ± 0.04
EC (ds·m^{-1})	0.64 ± 0.04	0.74 ± 0.05	0.48 ± 0.02	0.54 ± 0.04
N (%)	0.27 ± 0.02	0.26 ± 0.03	0.25 ± 0.03	0.23 ± 0.03
Clay (%)	12.98 ± 0.8		13.65 ± 0.6	
Silt (%)	25.81 ± 0.6		22.48 ± 0.5	
Sand (%)	61.21 ± 0.9		63.87 ± 1.2	

SOF – seed originated forest, CF – coppice forest, OC – organic carbon, BD – bulk density, EC – electrical conductivity

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Table 2. Two-way ANOVA to assess the differences in soil characteristics in two oak stands as well as at different depths

Source of variation	Mean square								
	df	EC	pH	OM	OC	SCS	N	P	K
ForOrgin	1	0.44**	0.17*	0.02	0.05	1,296.69*	0.00	2,747.8	333,015**
Location	1	0.08*	0.60**	3.26**	0.31	1.43	0.00**	3,677.6	174,803**
ForOrgin × Location	1	0.003	0.15*	0.83	0.18	527.89	0.00	1,500.1	23,520
Depth	1	1.95**	1.56**	30.06**	1.25**	19,775.87**	0.07**	1,778.2	524,535**
ForOrgin × Depth	1	0.02	0.10*	0.14	0.01	920.80	0.00	11,747.6**	13,201
Location × Depth	1	0.12**	0.002	0.71	0.000	311.40	0.00	55.65	13,230
ForOrgin × Location × Depth	1	0.00**	0.05	0.04	0.000	67.99	0.00	2,623.04	18,253
Error	52	0.01	0.02	0.26	0.14	270.07	0.000	1,526.7	7,106.5
CV		20.67	2.18	10.65	12.35	20.04	8.24	25.26	16.96

ForOrgin – Forest Origin (seed or coppice originated forests), Location – under or outside the tree crown, Depth – $D_{1,}D_2$; OM – organic matter, OC – organic carbon, SCS – soil carbon sequestration, CV – coeficient of variation; **and* represent significant at the 0.01 and 0.05 levels

Nitrogen content was generally highest in the top soils in comparison with the second depth samples of two oak stands (Table 3). There were no significant differences in N and total mean soil organic matter percentages between the two forest stands (Fig. 2).

Phosphorus and potassium contents of soil at two depths of both oak stands were significantly different from each other so that the highest amount of K was estimated in CF (604 ppm) at a depth of 0 to 15 cm in soil samples below the tree canopy, whereas the

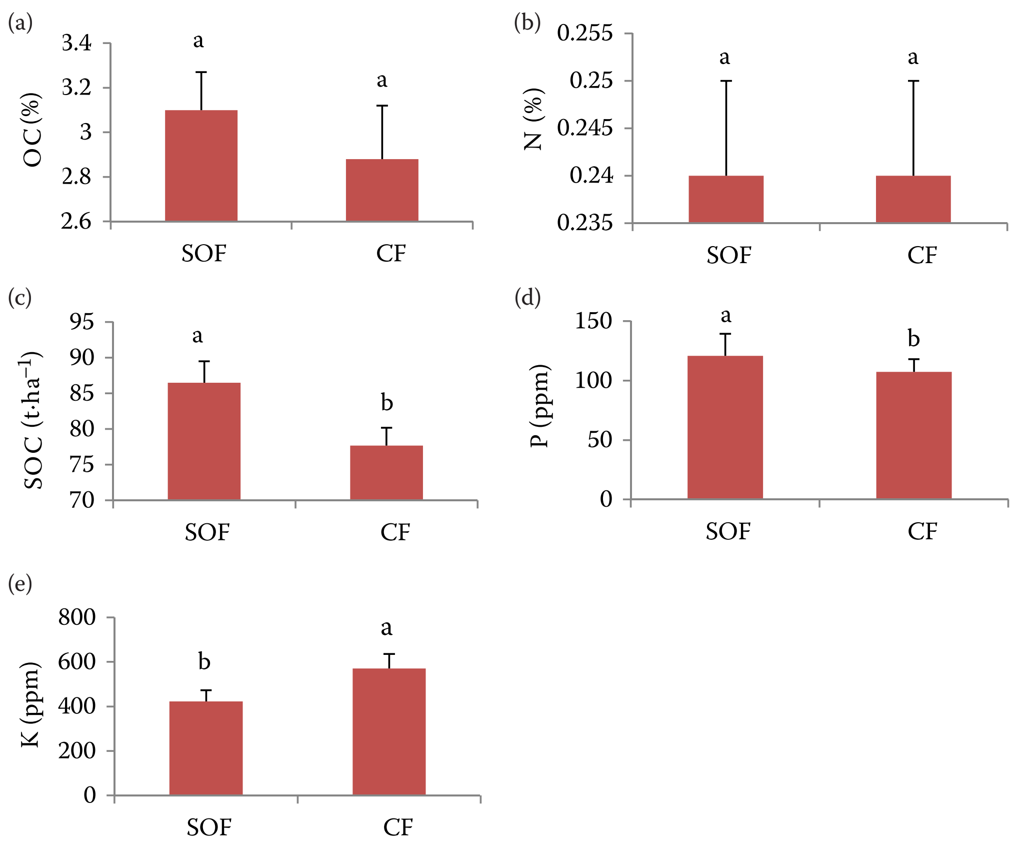

Fig. 2. Total means of soil properties in two oak forest stands, means with the same letters (a, b) indicate homogeneous groups or no significant difference between two Persian oak stands ($P < 0.05$)

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Table 3. Duncan's multiple range tests for different soil properties in two oak forest stands at two different depths and locations

Treatments	Distance (cm)	EC ($ds·m^{-1}$)	pH (pH H_2O)	BD ($g·cm^{-3}$)	OM (%)	OC (%)	SCS ($t·ha^{-1}$)	N (%)	P (ppm)	K (ppm)
SOF (under crown)	0–15	0.52 ± 0.12^{e}	7.2 ± 0.19^{b}	0.79 ± 0.02^{c}	6.43 ± 0.12^{a}	3.73 ± 0.07^{a}	44.20 ± 3.12^{ab}	0.28 ± 0.00^{a}	154 ± 35^{a}	532 ± 70^{b}
	15–30	0.76 ± 0.08^{bc}	7.5 ± 0.21^{a}	0.99 ± 0.04^{ba}	4.60 ± 0.53^{b}	2.67 ± 0.12^{ab}	39.64 ± 3.02^{c}	0.21 ± 0.02^{bc}	105 ± 28^{bc}	361 ± 50^{c}
SOF (outside of crown)	0–15	0.49 ± 0.07^{de}	6.8 ± 0.04^{c}	0.93 ± 0.01^{b}	5.95 ± 0.46^{a}	3.45 ± 0.27^{ab}	48.12 ± 3.68^{a}	0.26 ± 0.01^{a}	111 ± 23^{bc}	528 ± 75^{b}
	15–30	0.98 ± 0.13^{a}	7.3 ± 0.05^{b}	1.07 ± 0.02^{a}	4.41 ± 0.20^{c}	2.56 ± 0.24^{b}	41.09 ± 2.23^{bc}	0.19 ± 0.01^{c}	93 ± 29^{d}	220 ± 31^{d}
CF (under crown)	0–15	0.32 ± 0.06^{f}	7.2 ± 0.19^{b}	0.83 ± 0.01^{bc}	5.67 ± 0.45^{a}	3.29 ± 0.31^{ab}	40.96 ± 2.82^{bc}	0.28 ± 0.01^{a}	96 ± 27^{bc}	604 ± 73^{a}
	15–30	0.64 ± 0.12^{cd}	7.5 ± 0.08^{a}	0.87 ± 0.01^{bc}	4.65 ± 0.35^{b}	2.70 ± 0.29^{ab}	35.23 ± 2.01^{d}	0.22 ± 0.03^{b}	121 ± 45^{b}	543 ± 58^{b}
CF (outside of crown)	0–15	0.27 ± 0.01^{f}	7.2 ± 0.16^{b}	0.93 ± 0.02^{b}	5.55 ± 0.47^{a}	3.22 ± 0.27^{ab}	44.91 ± 3.05^{ab}	0.27 ± 0.01^{a}	102 ± 30^{bc}	542 ± 84^{b}
	15–30	0.81 ± 0.27^{b}	7.3 ± 0.13^{ab}	0.99 ± 0.03^{ba}	3.82 ± 0.23^{bc}	2.31 ± 0.17^{b}	34.30 ± 2.05^{d}	0.20 ± 0.02^{bc}	103 ± 36^{bc}	392 ± 45^{c}

SOF – seed originated forest, CF – coppice forest, EC – electrical conductivity, BD – bulk density, OM – organic matter, OC – organic carbon, SCS – soil carbon sequestration, N – Nitrogen content; P – phosphorus content; K – potassium content; means with the same letters (a, b, c, d, e and f) within the same column indicate no significant difference ($P < 0.05$).

highest P content was estimated in SOF (154 ppm) at a depth of 0 to 15 cm in soil samples under the tree crown.

Soil carbon sequestration

The mean soil carbon sequestration in SOF(under crown), SOF (outside crown), CF (under crown) and CF (outside crown) was 84.16, 89.07, 75.60 and 79.56 $t·ha^{-1}$, respectively. Among all status, SOF (outside crown) holds the highest amount of soil carbon (89.06 $t·ha^{-1}$), followed by SOF (under crown) (84.16 $t·ha^{-1}$) while CF (under crown) holds minimum soil carbon of 75.60 $t·ha^{-1}$ (Table 1). The vertical distribution of SCS varied among the two forest types (Table 3).

In both forest types, the deposition of SCS was generally higher in the top soils (0–15 cm) and decreased with soil depth. The highest proportion of SCS content was deposited at the 0–15 cm depth of SOF soil samples taken outside the tree crown (48.12 ± 3.68 $t·ha^{-1}$) and followed by CF samples collected at a 0–15 cm depth outside the tree crown (44.91 ± 3.05 $t·ha^{-1}$). The total SCS content in SOF (86.52 ± 3.01 $t·ha^{-1}$) was significantly higher than the content in CF (77.70 ± 2.48 $t·ha^{-1}$) (Fig. 2).

DISCUSSION

Physical and chemical soil properties

The decomposition of litterfall generates organic acids in the soil, which causes changes in the amount of exchangeable alkaline cations (calcium and magnesium) and acidic cations (iron and aluminium) in the soil which causes changes in pH that is reduced in the forest top soil (Everett et al. 1986). In this study, pH of soil outside the canopy of SOF was determined to be lower than pH of soil samples under the tree crown. It can be illustrated that carbonic acid is formed from the combination of CO_2 (caused by plant roots outside the canopy) with water (direct rain contact with vegetation outside the canopy contrary to under the tree canopy), when the acid dissolves equivalent calcium carbonate and reduces the pH (Everett et al. 1986).

The results show that the electrical conductivity outside and inside the canopy of Persian oak trees as well as at the two depths inside the canopy was

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significantly different. The electrical conductivity under the tree crown and outside the oak canopy increased with increasing depth in both oak stands (Table 3), the reason for this could be the effects of tree rooting, abundant litter under the tree crown and the effects of tree shade on the soil surface, causing significant changes in the electrical conductivity of soil in different positions. However, it is not possible to ignore the impact of canopy rainfall (throughfall and stemflow) on the amount of salts and consequently on the electrical conductivity of soil. Jaiyeoba (2003) stated that EC under the tree crown and outside the canopy of pine trees had a positive and significant relationship with increasing depth. Hinsinger et al. (2003) also mentioned that the electrical conductivity of soil in the pine tree from the trunk of pine tree to the outside of tree crown showed a decreasing trend in the top soil.

The most important factor in reducing the bulk density of soil is the effect of organic matter due to increased biological activity on the residual dry matter of tree leaves on the soil surface, which increases the agglomeration of organic matter under the tree canopy. Significant differences in soil bulk density between different situations in this study are due to the difference in soil organic matter content and the difference in agronomic agglomeration and rooting of plants (Table 3). According to the results of this research, the bulk density of soil increases from the surface to the depths and from the tree crown to the outside of the crown, which indicates the direct effect of the canopy on the reduction of bulk density. Tate et al. (2004) confirmed the results that the canopy cover is a major factor determining soil bulk density and oak trees create enhanced fertility beneath their canopy through organic matter incorporation and nutrient cycling leading to elevated soil quality relative to the soils outside the oak tree canopy (Dahlgren et al. 2003)

The results showed that the soil under the tree canopy has significantly higher phosphorus in comparison with the soil outside the tree crown while the soil phosphorus was reduced with increasing soil depth (Table 3). The main reason for these results is increased soil organic matter under tree crown as one of the important factors in soil nutrient storage. Wilson and Thompson (2005) in their study about the effect of Mesquite tree on soil confirmed that due to the increase in plant phosphorus in summer and autumn and the decomposition of plant leaves and remains under the canopy, the concentration of phosphorus under the tree crown is significantly higher than outside the tree canopy.

The amount of N and P in the soil under the canopy cover was the highest due to the presence of more organic matter and acidic soil in this position, because these two indicators of chemical quality of soil (nitrogen and phosphorus) have a strongly positive and significant relationship with the amount of organic matter (Moreno et al. 2007).

The results of this study showed that potassium content in the soil of coppice forest was higher than in the seed originated forest (Tables 1, 3). It can be argued that because of the type of existing minerals and bedrock in the coppice forest potassium may have increased in the soil of this forest.

Soil carbon sequestration

The amount of carbon sequestration in soil is related to two main soil parameters (organic carbon and bulk density), but these two indicators are strongly influenced by soil management and land-use change (Pibumrung et al. 2008). The difference in soil carbon sequestration is due to the difference in the type of ecosystem or the difference in plant species (Mortenson et al. 2004). The capacity of soil carbon sequestration varies according to the type of plant species, location and management method (Dinakaran, Krishnayya 2008).

The SCS is rapidly to decrease following the conversion from a seed originated natural forest to coppice forests. We found that the conversion of SOF into CF land decreased SCS on average by 8.8 $t \cdot ha^{-1}$ (10.17%) (Table 3). Soil C loss in CF was caused by overgrazing and forest degradation in the study area. The result corresponds to the study of Obara et al. (2000) on soil properties after deforestation in Thailand. In terms of SCS and soil depth, the results clearly demonstrated the vertical distribution. The highest SCS was found in the surface soils. This study indicated that more than 55% of the total SCS in soil was deposited at the 0–15 cm depth. According to the studies, the presence of vegetation, litter as well as animal dung on the surface of the forest ground increases soil organic matter and soil organic carbon in the top soil (Hinsinger et al. 2003; Pibumrung et al. 2008; Pant, Tewari 2014).

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The amount of soil organic carbon under the canopy was the highest, which has to be explained by the effect of oak tree canopy. Tree litterfall and decomposition of this litterfall by the microbial community under the canopy have increased the quality of soil organic carbon. It should be noted that the organic carbon accumulation at different depths of soil depends on humus amount, tree crown area and the type of existing species (Baldock, Oades 1992).

CONCLUSIONS

Climate change may have a principal effect on soil characteristics and processes, which may affect the SOC stock in forest ecosystem soils. In all forests, about 69% of carbon is stored in forest soils (Mohammadi et al. 2017) while there is some concern that an increase in global temperature may result in a long-term loss of the SOC stock (Ashton et al. 2012). Land-use change and soil degradation are global problems, particularly the desertification of drylands leads to a loss of vegetation cover and subsequent loss of organic C in soils and soil quality (FAO 2004; Li et al. 2013). Zagros forests are among the most important forests in Iran which are subjected to severe land-use changes. The long-term use of these forests by the local people to produce firewood and charcoal has led to converting the seed originated forests into coppice forests. In this study, we presented results of the study on how the soil carbon sequestration of Persian oak forest changes in stands of different origin (seed and coppice) in Zagros forests. The results in seed originated oak forest showed higher soil carbon stocks than in coppice oak forest. Deforestation, degradation and poor forest management have the potential to reduce the C pool in managed forests (Lorenz, Lal 2010) whereas sustainable forest management activities include the planting of adapted species with high NPP and more below-ground biomass production, fertilization and liming and rehabilitation can increase the forest ecosystem C pool (Hoover 2008). Therefore, the potential for sequestering C through the rehabilitation of Zagros forests is very important.

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