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Land use Change Effects on Carbohydrate Fractions, Total and Particulate Organic Matter of Forest Soils in Central Zagros Mountains

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Abstract: Soil carbohydrates and particulate organic matter may be considered as appropriate indicators of soil quality. Data regarding the soil carbohydrate fractions and particulate organic matter in forest and cropland soils in Central Iran is scarce. The main objective of this study was to analyze the effects of converting native forests to cropland on soil organic matter, soil carbohydrate fractions (carbohydrates extracted with distilled water, 0.5 M Na_2SO_4 and 0.5 M H_2SO_4 by the oven and shaker methods) and particulate organic matter in Lordegan region of central Zagros Mountains, Iran. Soil samples from forest Oak (*Quercus brantii* Lindl.) and cropland soils (tomato and snap bean) were taken from 0-20 cm depth. Forested and deforested soils were classified as typic calcixerolls and typic calcixerepts, respectively. The results showed that the amounts of total and particulate organic matter in native forest were almost four and twelve times higher ($p<0.001$) than those in the cropland site, respectively. Similarly, the ratio of particulate organic matter to soil organic matter was far greater in native forest (0.53) compared to cropland (0.19) site. Conversion of native forest to cropland resulted in significant decreases in soil carbohydrate fractions. For both soils, ANOVA indicated that extracted carbohydrate was lower in the shaken compared to the oven method. The concentrations of carbohydrate extracted with H_2SO_4 were higher than those extracted with Na_2SO_4 while those extracted with Na_2SO_4 transcended results when using water for both soils.

Key words: Soil organic matter, carbohydrate, POM, deforestation, zagros mountains

INTRODUCTION

In Zagros Mountains of central Iran, clear-cutting and converting the forests to croplands is one way of utilizing under-exploited land to food production. The Zagros forests cover approximately 5 million ha and constitute almost 40% of the forests of the country. The area is classified as semiarid forests (Sagheb-Talebi *et al*., 2004), sensitive and destructed ecosystems in Iran. The oak (*Quercus brantii* Lindl.) forests of Zagros have been exposed to deforestation for the last four decades. Deforestation, as a key reason for land degradation has increased desertification (Irshad *et al*., 2007).

Soil Organic Matter (SOM), that is a main sink for atmospheric CO_2 (Lal, 2004) a is important for soil fertility, productivity and quality (Gregorich *et al*., 1994). Mbah *et al*. (2007) showed that SOM play an important role in the aggregate stability and soil structure. Soil carbohydrates and Particulate Organic Matter (POM) constitute significant parts of the labile pool of the SOM and are mostly affected by land use changes (Spaccini *et al*., 2001; Chan, 2001). Notwithstanding, the positive influences of cultivation on SOM pools were reported by few researchers (Cochran *et al*., 2007; Raiesi, 2007; Fallahzade and Hajabbasi, 2011, 2012) many studies have suggested that conversion of native forests to cultivation has a wide range of negative effects on SOM. For example, Hajabbasi *et al*. (1997), Nael *et al*. (2004) and Nourbakhsh (2007) who concluded a significant decrease in the SOM pools in deforested lands compared with the native forest in Zagros Mountains. Also, several authors indicated that deforestation significantly reduced the POM and carbohydrates. For example, Spaccini *et al*. (2001) in Ethiopian highlands and Nigerian lowlands showed that SOM and carbohydrate content was higher in the forested than the cultivated soils. Ashagrie *et al*. (2007) concluded that total amounts of SOM and POM were significantly larger in the natural forest than in the cultivated soil in southeastern Ethiopia. In central Cordoba and Argentina, Bongiovanni and Lobartini (2006) reported that land use changes from natural forests to croplands resulted in significant

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decreases in soil carbohydrates and POM. In Zagros Mountains of Iran, the studies regarding the effects of deforestation on the SOM have focused on organic carbon and total nitrogen only. However, information regarding the soil carbohydrate and POM in forest and adjacent cropland fields in Zagros Mountains of Iran is scarce. Thus, the main objective of this study was to analyze the effects of converting forest to cropland on carbohydrate fractions and POM.

MATERIALS AND METHODS

The study site: The study was conducted at the forest and adjacent cropland sites located in Zagros Mountains, west central Iran (Fig. 1) with an altitude of about 2100 m above sea level. Mean annual rainfall is about 500 mm and an average annual temperature is 15°C (with cold winters, warm summers and semi humid climate). Topographically, the forest and adjacent cropland sites are situated on hillside with a high slope (30%) facing south. Forest site were principally covered by oak (*Quercus brantii* Lindl.). The adjacent cropland site was in an area converted to tomato and snap bean farming for the last four decades. In the cropland site, mineral N (as urea) and P (as di-ammonium phosphate) fertilizers are usually applied to improve soil productivity. The crop residues are removed or burned from the field after harvest. Soils of the area are calcareous with high calcium carbonate contents in the surface layer, developed on limestone parent materials.

Soil sampling and analysis: In October 2009, soil samples were collected from forest and adjacent cropland sites to explore the effects of deforestation on carbohydrate fractions and POM. At each site, three points were sampled (each point at a distance of 30 m from each other). Within each sampling point, three soil cores of 0-20 cm depth were taken within 2 m radius and composited. In forest site, soil samples were taken after the removal of the surface organic layer. Soil samples were air-dried and sieved through 2 mm sieve size prior to the physical and chemical analysis. Soil texture was determined by the pipette method (Gee and Bauder, 1986) and organic matter by the Walkley-Black (Nelson and Sommers, 1996). The separation of POM was performed by Loss on Ignition (LOI) following the procedures explained by Cambardella *et al.* (2001). Briefly, 30 g of soils (<2 mm) was dispersed in 100 mL sodium hexametaphosphate (5%) for 16 h on a shaker at 120 strokes per min. The suspensions were sieved to pass a 0.05 mm sieve for separate POM+sand particles. The collected sand particles and POM were dried at 55°C to constant weight and then subjected to 450°C for 4 h to determine POM by LOI method.

Carbohydrate content: Soil carbohydrate fractions were extracted by two methods including: shaker and oven and three types of extractants containing: distilled water, 0.5 M Na_2SO_4 and 0.5 M H_2SO_4 solutions.

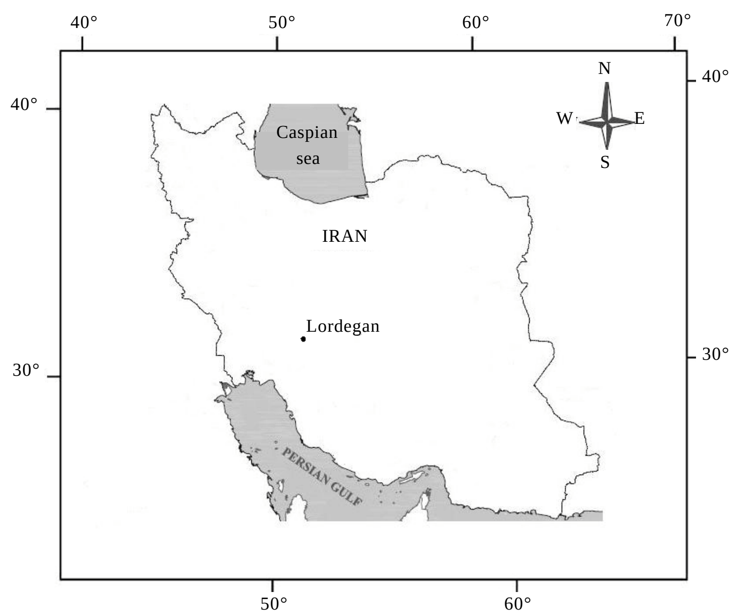

Fig. 1: Location of the study area in central Zagros Iran

The carbohydrate extraction procedures were performed as follows:

- One gram of soil was mixed with 10 mL of each extractants and shaken in a shaker for 16 h
- One gram of soil was mixed with 10 mL of each extractants and heated (85°C) in oven for 16 h

The soil suspensions were centrifuged at 3000 rpm for 30 min. After extraction, carbohydrate concentration of the extracts was determined using phenol-sulfuric acid method (Dubois *et al*., 1956).

Statistical analysis: The effect of land use change (conversion of forest into cropland site) on SOM, POM and carbohydrate fractions was determined by one-way Analysis of Variance (ANOVA) in completely randomized design with three replicates. A complete randomized factorial design with three replications was used to compare the effects of methods and extractants on carbohydrate concentration. Statistical procedures were carried out using the software package SAS 9.1 for Windows. Means were separated by Duncan test at $p<0.05$.

RESULTS AND DISCUSSION

Forested and deforested soils were classified as typic calcixerolls and typic calcixerepts, respectively. Soil textures (silty, clay, loam) of the two sites were identical showing no significant effect of land use changes in this regard.

Soil organic matter content: The amount of SOM was highest in forest and lowest in the cropland soils (Table 1). At 0-20 cm depth, the amount of SOM in forest soils was about 4.5 times higher than those of cropland soils (Table 1). The decreased in amount of SOM in cropland soils may partially be attributed to the lower plant residues input in the cropland soil during land preparation for cropping. Therefore, in cropland sites crop residues during land preparation were burned. According to the reports, residue burning considerably reduces SOM in the topsoil (Vagen *et al*., 2005).

Table 1: The amounts of soil and particulate organic matter and ratio of POM/SOM in forest and cropland sites

	Site		Summary ANOVA[a] results		
Parameter	Forest	Cropland	Mean square	f-value	p-value
SOM[b] (%)	5.90±0.15[a]	1.35±0.04[b]	31.02	869.80	<0.001
POM[c] (%)	3.12±0.17[a]	0.26±0.006[b]	12.31	265.12	<0.001
POM/SOM ratio	0.53±0.03[a]	0.19±0.005[b]	0.17	154.70	<0.001

[a]Analysis of variance. [b]Soil organic matter. [c]Particulate organic matter. Means within a row followed by the same letterre a not significantly different at $p<0.05$. Numbers in parentheses are standard errors (n = 3)

The results of this study support the previous findings of Nael *et al*. (2004) who reported a considerable decrease in soil organic carbon pools in protected forest compared to the disturbed forest in Zagros Mountains. Also, Nourbakhsh (2007) in central Zagros Mountains reported that the amount of SOM was significantly lower in the deforested counterparts compared with the native forest. Similarly, Emadi *et al*. (2008) in the North Highlands of Iran (Zolfaghari and Hajabbasi, 2008) in central Zagros Mountains and Brahim *et al*. (2009) in Northern Tunisia reported that conversion from the native forest to cultivated fields resulted in significant decreases in soil organic carbon concentration.

The data of POM contents in the forest and cropland sites are shown in Table 2. The amount of POM was significantly higher in forest compared to the cropland site. Greater inputs of fresh residues from forest plants could be accounted for the higher POM in forest relative to cropland site. These results are in agreement with the observation of Bongiovanni and Lobartini (2006) and Ashagrie *et al*. (2007) who found that land use changes from natural forests to croplands resulted in significant decreases in the amounts of POM. The POM/SOM ratio of forest and cropland soils is shown in Table 2. At 0-20 cm depth, the ratio of POM/SOM in forest soils was about three times higher than this in cropland soils (Table 2).

The concentration of carbohydrate fractions: The analysis of variance indicated that there was a significant effect ($p<0.001$) of method and extractant on carbohydrate extracted from the forest and cropland soils (Table 2). The carbohydrate concentration was higher in the oven than in shaker method for both the forest and cropland soils (Table 3) because in the shaker method, the carbohydrates were extracted by mechanical process but

Table 2: ANOVA factorial model for the effects of methods and extractants on carbohydrate concentrations within each soil

SOV[a]	df[b]	SS[c]	MS[d]	f-value	p-value
Forest soil					
Method	1	52.66	52.66	590.19	<0.001
Extractant	2	87.47	43.73	490.08	<0.001
Method×extractant	2	16.76	8.38	93.88	<0.001
Error	12	1.07	0.08		
Total	17	157.96			
Cropland soil					
Method	1	4.92	4.92	262.05	<0.001
Extractant	2	16.23	8.11	432.24	<0.001
Method×extractant	2	2.49	1.25	66.37	<0.001
Error	12	0.23	0.02		
Total	17	23.86			

[a]Source of variation, [b]Degree of freedom, [c]Sum of squares, [d]Mean square

Table 3: Concentrations (g kg^{-1}) of extracted carbohydrate by several methods and extractants in the forest and cropland soils

	Extraction methods		
Site	Shaker		Oven
Forest	3.22±0.46[b]		6.65±1.12[a]
Cropland	1.63±0.21[b]		2.68±0.47[a]
	Extractants		
Site	0. 5 M H_2SO_4	0. 5 M Na_2SO_4	Distilled water
Forest	7.84±1.38[a]	4.47±0.52[b]	2.50±0.43[c]
Cropland	3.48±0.46[a]	1.71±0.15[b]	1.29±0.11[c]

Means (n = 9 and n = 6 for methods, extractants and statistical analysis, respectively) within a row followed by the same letter are not significantly different at p<0.05 according to LSD test

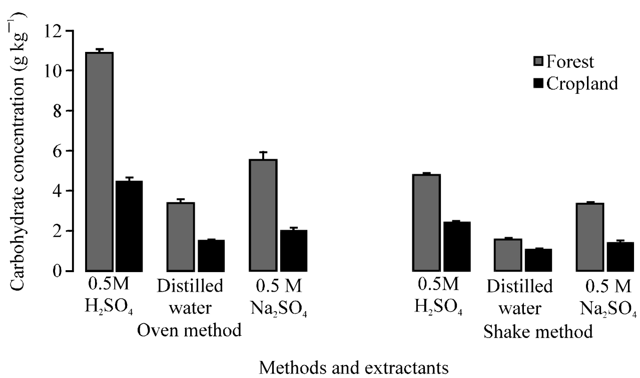

Fig. 2: The concentrations (g kg^{-1}) of extracted carbohydrate fractions by several methods and extractants in the forest and cropland soils. Bars indicate standard errors (n = 3)

in the oven method, the carbohydrates were extracted with high heat (85°C) for a time period (16 h) during extraction. Adesodun *et al*. (2001) also reported that the concentration of hot water-soluble carbohydrates (heating method) was greater compare to the cold water-soluble carbohydrates (shaker method).

Carbohydrates recovery from both soils was significantly greater when extracted with 0.5 M H_2SO_4 in comparison to 0.5 M Na_2SO_4 and distilled water (Table 2). This is probably because of the higher hydrolysis of hemicelluloses in the acid method. Puget *et al*. (1999) assumed that dilute acid (0.5 M H_2SO_4) may hydrolyze the hemicellulose leading to the higher release of xylose. The concentration of extracted carbohydrate using distilled water was lower than that of the other extractants.

Soil carbohydrates may be extracted via numerous extractants. Adesodun *et al*. (2001) used two extractants contain distilled water and 0.25 M H_2SO_4 for extraction of soil carbohydrates. Bongiovanni and Lobartini (2006) applied 0.5 M H_2SO_4 solution to the extract of the soil carbohydrates. Fallahzade and Hajabbasi (2011) recently applied distilled water and 0.25 H_2SO_4 solutions for extraction of carbohydrate in a clay soil. Fallahzade and Hajabbasi (2012) also used 0.25 H_2SO_4 solutions for hydrolysis and release of carbohydrate in desert, wheat and alfalfa field soils in central Iran.

There was a significant method×extractant interaction on the concentration of carbohydrate for both soils (Table 2). The amount of carbohydrate was significantly higher in the forest compared to the cropland soils (Fig. 2). This could be due to a greater return of plant residues (especially leaf residues) and less soil disturbance in the forest which led to a greater rate of SOM in forest lands.

In general, the amount of carbohydrates extracted by each extractant was significantly ($p<0.001$) lower in shaker than in the oven method. Using oven method along with 0.5 M H_2SO_4 extractant had the highest yields of hydrolyzed carbohydrates across different procedures. Meanwhile, using shaker method along with distilled water extractant had the lowest yields of hydrolyzed carbohydrates across different procedures (Fig. 2).

CONCLUSIONS

Results of the current research revealed the negative impacts of land use conversion from native forest to croplands. These effects basically were shown on SOM, POM and carbohydrate fractions. Furthermore, theses effects can reduce carbon sequestration potential in the soil and thus raising CO_2 concentrations in the atmosphere. The carbohydrate concentration was higher in oven than in the shaker method for both soils. Also, the results indicated that using oven method along with 0.5 M H_2SO_4 extractant had the highest yields of hydrolyzed carbohydrates across different procedures.

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