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Carbon Stocks in Harran Plain Soils, Sanliurfa, Turkey

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Abstract

Soils are an important component of the global carbon cycle and can be net sources or sinks of atmospheric carbon dioxide (CO_2). The goals of the present study were to analyze the soil organic carbon (SOC) and soil inorganic carbon (SIC) content of Harran Plain soil in Sanliurfa, Turkey, part of the Southeast Anatolia region (SAR), and to estimate carbon stocks (CSs) in soil series that are representative of arid and semiarid lands. To this end, soil samples were collected from 16 profiles in the Harran Plain at depths of 100, 120, and 160 cm of the genetic horizons, and the SOC stocks in the three soil depths were estimated. The carbon stock was 56.41 Tg of C in the 0-100 cm layer, 67.80 Tg of C in the 0-120 cm layer and 87.91 Tg of C in the 0-160 cm layer. For the three soil depths 100, 120, and 160 cm, the SOC content ranged from 6.33 to 11.04, 7.11 to 11.98 and 8.72 to 16.53 kg of C m^{-2}, respectively, and the soil inorganic carbon content ranged from 8.83 to 19.26, 11.00 to 23.34 and 14.82 to 32.64 kg of C m^{-2}, respectively.

Keywords: soil organic carbon, soil inorganic carbon, carbon stocks, sequestration

Introduction

Soil is a key component of the global carbon cycle. Soil organic carbon (SOC) stocks are the largest carbon reservoirs in the world. Soil organic carbon (SOC) plays a critical role in mitigating the effects of greenhouse gases and is essential for enhancing soil quality, sustaining and improving food production, maintaining clean water and reducing CO_2 in the atmosphere. Alternatively, soil inorganic carbon (SIC) causes SOC decomposition, enhances salinity, restricts root proliferation (Eswaran and Vanden Berge, 1992; Pal *et al.*, 1999) and immobilizes soil plasma (Boul *et al.*, 1980). Mineral soils are a vast reservoir of carbon, containing 1150 to 2200 Pg of C in a meter of soil (Post *et al.*, 1982; Eswaran *et al.*, 1993; Batjes, 1996). More precisely, the IPCC estimated that soil contains 1750±250 Pg of C, of which 835 Pg is SIC (IPCC, 2001). The total SOC content of all soils in the 0-100 cm (upper 0-1 m) layer is between 1500 and 2000 Pg of C (Eswaran *et al.*, 1993; Batjes, 1996). Carbon pools in soils must be accurately estimated to reduce atmospheric CO_2 and anticipate climate change (Batjes and Sombroek, 1997; Lal *et al.*, 1998, 2000). The enhancement of SOC and the introduction of good management practices are important for agricultural lands. High SOC contents lead to increased fertility and carbon sequestration. Moreover, organic matter in soil stabilizes soil structure and enhances the resistance of soil to degradation (Mbah *et al.*, 2007). Dependable inventories of SOC stocks are fundamental and can be used to assist countries in fulfilling the goals of the National United Nations Framework Convention on Climate Change (NUNFCCC) (Tompkins and Amundsen, 2008). In addition, SOC is essential for a functioning ecosystem. Moreover, SOC stocks are also relevant to the United National Conventions to Combat Desertification because areas with low SOC content generally have been subjected to land degradation (Bia *et al.*, 2008). Except for a few notable exceptions in semiarid regions (Batjes, 2006; Al-Adamat *et al.*, 2007), most countries evaluate the SOC of temperate (Arrouays *et al.*, 2001) or tropical regions (Bernoux *et al.*, 2002; Batjes, 2005). The SOC per unit area of dry land is lower than that of other terrestrial ecosystems. Thus, the SOC and SIC content of Harran Plain soil in the Southeast Anatolia region must be assessed. Organic carbon is one of the most important constituents of soils and improves soil structure, soil chemical and physical properties and soil biological factors. Moreover, organic carbon storage in SAR soils reflects the capacity of arid and semiarid regions to sequester organic carbon. In the present study, the SOC and SIC stocks in Harran Plain soils at depths of 0-100, 0-120 and 0-160 cm were estimated.

Materials and methods

Materials

The Harran Plain extends between 38°8′ and 39°12′E longitude and 36°42′ and 36°42′ N latitude and covers approximately 225,000 ha (Fig. 1). The Harran Plain is situated in the city of South Sanliurfa and contains a variety of natural regions. Two dominant climate zones are observed in the plain. Namely, the northern region is semiarid (450 mm $year^{-1}$), and the (II) southern region is arid (200-300 mm $year^{-1}$). The elevation of the sampling site is 400 m, and the climate is a typical arid and semiarid

Tab. 1. Mean climate data at the Akcakale and Sanliurfa Station (TSMS, 2008)

	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Precipitation (mm) (Akcakale)	47.39	45.83	40.46	27.56	17.24	0.99	0.81	0.47	18.79	33.05	47.38	47.39	277.81
Precipitation (mm) (Sanlıurfa)	77.21	78.36	65.55	44.41	27.51	3.52	0.79	1.06	0.91	27.58	49.88	75.31	448.11
Evaporation (mm)	-	-	61.8	119.6	203.1	332.8	421.1	421.1	291.9	291.9	59.3	-	2022.8
Mean Temperature (^{0}C)	4.9	6.6	10.3	17.8	23.1	29.2	34.8	31.3	26.4	19.1	14.4	8.0	18.8
Min. Temperature (^{0}C)	-2.4	-1.5	-0.6	6.1	10.6	18.5	22.7	20.4	13.8	9.4	5.7	1.0	8.65
Max. Temperature (^{0}C)	20.5	16.6	25.5	29.6	35.3	40	46.8	43	38.2	31.6	26.2	18.0	25.0
Mean relative humidity (%)	74.3	63.0	55.2	56.8	41.0	36.7	33.4	43	46.1	54.4	52.9	71.7	52.4
Mean soil temperature at a depth of 5 cm (^{0}C)	5.6	7.6	11.7	19.7	27.4	34.7	39.8	37.2	31.3	22.4	14.5	8.1	21.7
Soil temperature at a depth of 10 cm (^{0}C)	6.0	7.6	11.4	19.2	26.1	32.5	37.4	35.8	30.8	22.8	15.3	8.6	21.1

continental climate with remarkable seasonal and diurnal temperature variations and low rainfall. The annual mean precipitation is 300-450 mm, and the mean annual evaporation is 2000 mm. The mean precipitation from April to October is 321.80 mm, which accounts for approximately 93% of the annual precipitation. The annual temperature is 6.7^{o}C; however, the monthly mean temperature is less than 5^{o}C from November to March and is between 7.4^{o}C and 21.9^{o}C from April to October (Tab. 1). The area between Harran and Akcakale is the lowest area of the study

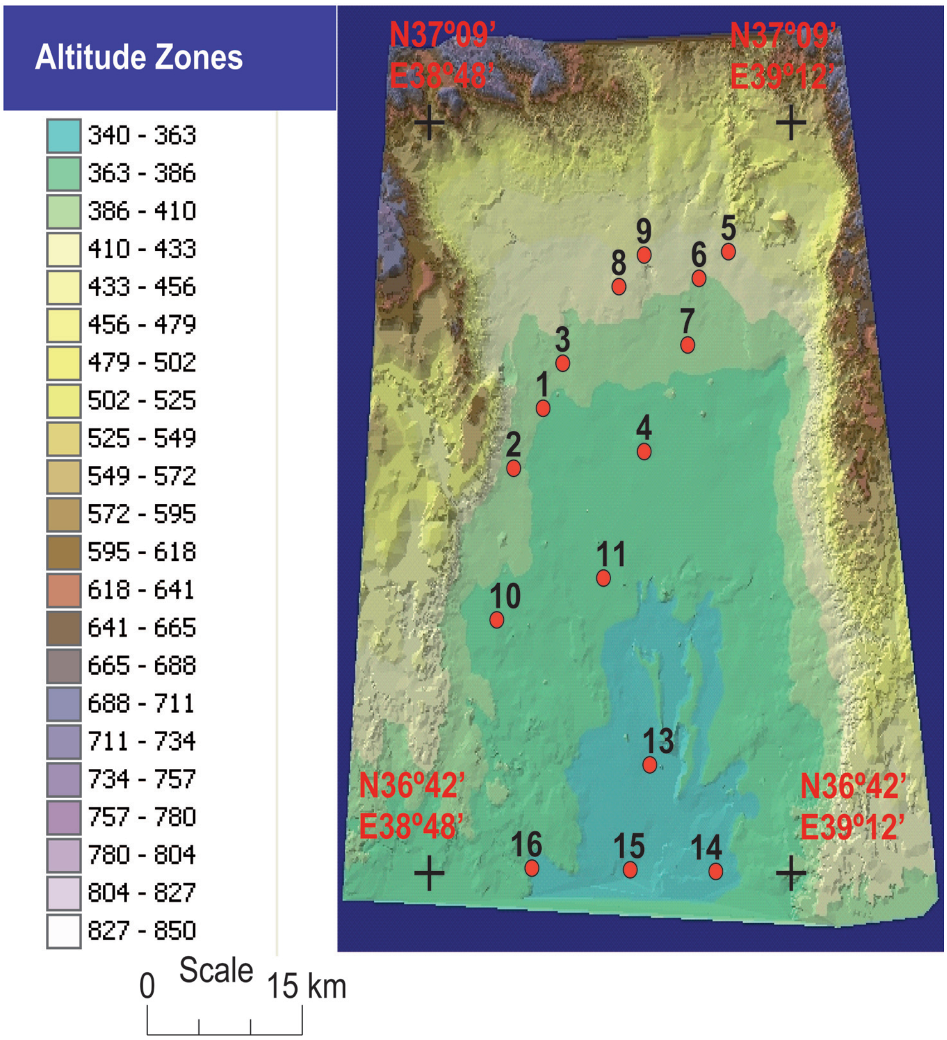

Fig. 1. Location of the Harran Plain

Tab. 2. Soil Taxonomy of Harran Plain soils (SSS, 1975; Dinc *et al.*, 1993)

Soil Taxonomy				Soil Series	FAO/UNESCO
Orders	Suborders	Great Soil Groups	Subgroup		
Entisol	Fluvent	Torrifluvent	Vertic Torrifluvent	Ikizce	Calcaric Fluvisol
			Typic Torrifluvent	Bellitas	
				Cekcek	
				Urfa	
	Orthent	Torriorthent	Lithic Torriorthent	Fatik	Litosol
Vertisol	Torrert	-------	Typic Torrert	Begdeş	Chromic Vertisol
				Bozyazi	
				Akcakale	
				Kısas	
			Paleustollic Torrert	Ugurlu	
Aridisol	Orthid	Gypsiorthid	Typic Gypsiorthid	Cepkenli	Gypsic Xeresol
		Paleorthid	Typic Paleorthid	Gülveren	Calcic Xeresol
				Kap	
		Calciorthid	Typic Calciorthid	Meydankapi	
				Gündas	
				Hancigaz	
				Ekinyazi	
				Akören	
				Irice	
				Gürgelen	
				Sultantepe	
			Vertic Camborthid	Harran	
				Karabayir	
		Camborthid	Typic Camborthid	Sirrin	Haplic Xeresol
				Konuklu	

region. The Harran Plain contains 25 soil series, including Bellitas (5), Ikizce (7) and Cekcek (2), which are Entisols; Bozyazi (12), Ugurlu (1), Begdes (10), Akcakale (15) and Kisas (4), which are Vertisols; and Gurgelen (6), Ekinyazi (14), Akoren (13), Irice (9), Harran (11), Kap (16), Sultantepe (3) and Sirrin (8), which are Aridisols (Dinc *et al.*, 1993; SSS, 1975) (Tab. 2).

Methods

We calculated the SOC content as a portion of the total soil organic matter content (Post *et al.*, 1998). As suggested by other investigators, a conversion coefficient of 0.58 was used in the present study (Nelson and Sommers, 1982; Fang *et al.*, 1996; Post *et al.*, 1998; Scott *et al.*, 1999; Li and Zhao, 2001). Soil profile data were aggregated according to the soil order, the soil suborder and the great group level of classification. To derive the average SOC content of each soil profile, we used the thickness of each horizon as a weighting coefficient. For the various horizons that comprise a complete soil profile, the soil bulk density (D_b), the organic carbon content and the calcium carbonate content were determined according to standard techniques. The bulk density of the soil was measured as described in Black (1965), and the organic carbon content was measured via Fe_2SO_4 titration of an acid-dichromate digestion (Sakin, 2010) (Eq. 1). Calcium carbonate was measured by nanometrically collecting the CO_2 that evolved during HCl treatment (Soil Conservation Service, 1972). In the present study, calcium carbonate equivalents were converted to the carbon content by multiplying by the mole fraction of carbon in $CaCO_3$ (0.12) (Sakin, 2010) (Eq. 2).

$$SOC = (Di \times D_b i \times \%OCi/1.724) \times 10 \quad (1)$$

$$SIC = (Di \times D_{bi} \times \%Cai)/10 \times 0.12 \quad (2)$$

where SOC is the soil organic carbon stock (kg C m^{-2}), SIC is the soil inorganic carbon stock (kg C m^{-2}), $D_b i$ is the bulk density (Mg m^{-3}) of layer i, Oci is the proportion of organic carbon (%) in layer i, Di is the thickness of the layer (cm), 0.58 (1.724) is the Van Bemmelen factor and Cai is the proportion of calcareous species (%).

Bernoux *et al.* (2002) used a similar method to calculate carbon stocks (CSs) in Brazilian soils. The organic carbon content of each group was multiplied by the respective area (Batjes, 1996) to measure soil organic and inorganic carbon stocks.

Results and discussion

The total CS in the 0-100 cm layer was estimated to be 56.41 Tg (1 Tg = 10^{12} g) or 0.056 Pg (1 Pg = 10^{15} g) of C, of which 20.16 Tg was SOC and 36.25 Tg was SOC. Moreover, 67.80 Tg of C was found in the 0-120 cm layer, of which 23.27 Tg was SOC and 44.53 Tg was SIC. Lastly, 87.91 Tg of C was observed in the 0-160 cm layer, of which 28.40 Tg was SOC and 59.51 Tg was SIC.

The mean SOC density was greater than 11.04 kg of C m^{-2} in Sirrin soils, 10.25 kg of C m^{-2} in the 0-100 cm layer of Irice soils, less than 7.14 kg of C m^{-2} in Akoren soils and 6.70 kg of C m^{-2} in Harran soils (Fig. 2 and Tab. 3). The low SOC concentrations were attributed to poor soil practices such as excessive tillage, imbalanced fertilizer usage, little or no crop residue returned to the soil and severe soil degradation. Consequently, even the well-established relationship between climate (temperature and precipitation) (Jenny and Raychaudhary, 1960) and SOC concentration was not observed. As shown in Tab. 3, consistently low SOC concentrations were observed in soils in the rainfall regime of 270 to 450 mm/y.

The Harran Plain possessed low carbon stocks (CS) because of the effects of the arid climate (277.81 mm precipitation). In contrast, the repartitioned Northern Plain possessed greater carbon stocks (448.11 mm precipitation) than the southern region because the arid climate influences vegetation and organic matter decomposition (Bernoux *et al.*, 2002).

The carbon stock values obtained in the present study are consistent with the data (Batjes, 1996) presented in the WISE (World Inventory of Soil Emission Potentials) soil

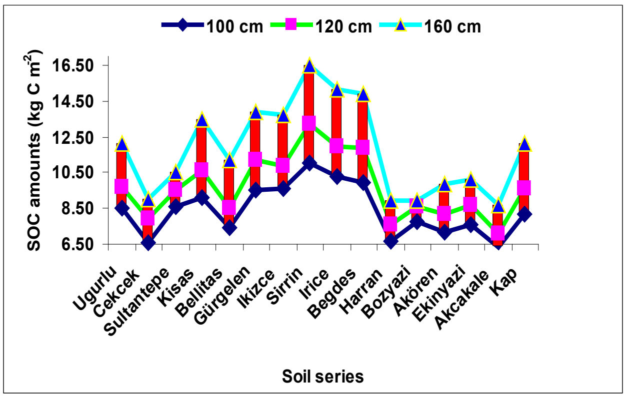

Fig. 2. Soil organic carbon (SOC) content of Harran Plain soils

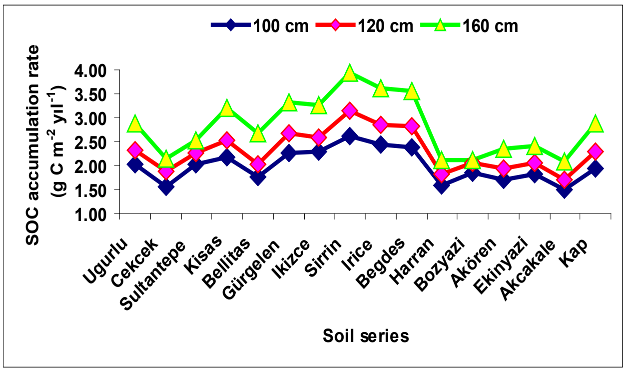

Fig. 3. Soil organic carbon (SOC) accumulation rates in Harran Plain soils

Tab. 3. SOC content of Harran Plain soils (kg of C m^{-2})

Soil series	100 cm	120 cm	160 cm
Ugurlu (1)	8.54	9.71	12.1
Cekcek (2)	6.57	7.92	8.98
Sultantepe (3)	8.56	9.52	10.57
Kisas (4)	9.09	10.6	13.44
Bellitas (5)	7.43	8.53	11.24
Gürgelen (6)	9.52	11.22	13.92
Ikizce (7)	9.64	10.83	13.74
Sirrin (8)	11.04	13.19	16.53
Irice (9)	10.25	11.98	15.19
Begdes (10)	9.98	11.86	14.93
Harran (11)	6.70	7.61	8.92
Bozyazi (12)	7.80	8.64	8.9
Akören (13)	7.14	8.14	9.89
Ekinyazı (14)	7.63	8.68	10.14
Akçakale (15)	6.33	7.11	8.72
Kap (16)	8.17	9.61	12.09
General mean	8.96	10.34	12.62

Tab. 4. Organic carbon accumulation rates for Harran Plain soils (g of C m^{-2} yr^{-1})

Soil series	100 cm	120 cm	160 cm
Ugurlu (1)	2.03	2.31	2.88
Cekcek (2)	1.56	1.89	2.14
Sultantepe (3)	2.04	2.27	2.52
Kisas (4)	2.16	2.52	3.20
Bellitas (5)	1.77	2.03	2.68
Gürgelen (6)	2.27	2.67	3.31
Ikizce (7)	2.30	2.58	3.27
Sirrin (8)	2.63	3.14	3.94
Irice (9)	2.44	2.85	3.62
Begdes (10)	2.38	2.82	3.55
Harran (11)	1.60	1.81	2.12
Bozyazi (12)	1.86	2.06	2.12
Akören (13)	1.70	1.94	2.35
Ekinyazı (14)	1.82	2.07	2.41
Akcakale (15)	1.51	1.69	2.08
Kap (16)	1.95	2.29	2.88
General mean	2.13	2.46	3.00

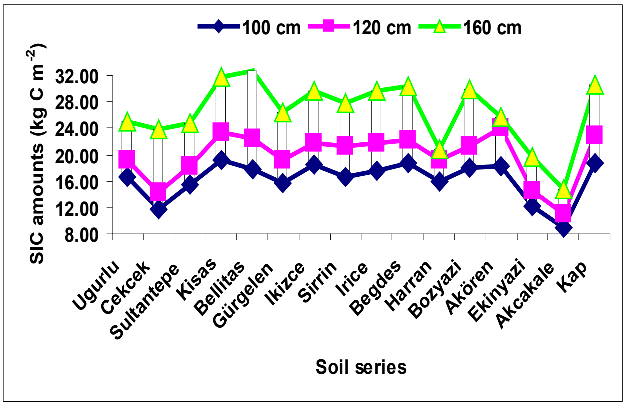

Fig. 4. Soil inorganic carbon (SIC) content of Harran Plain soils

Tab. 5. SIC content of Harran Plain soils (kg of C m^{-2})

Soil series	100 cm	120 cm	160 cm
Ugurlu (1)	16.56	19.29	25.12
Cekcek (2)	11.82	14.36	23.74
Sultantepe (3)	15.39	18.23	24.89
Kisas (4)	19.27	23.35	31.75
Bellitas (5)	17.69	22.40	32.65
Gürgelen (6)	15.58	19.21	26.39
Ikizce (7)	18.42	21.63	29.56
Sirrin (8)	16.62	21.39	27.80
Irice (9)	17.62	21.65	29.60
Begdes (10)	18.73	22.31	30.28
Harran (11)	15.87	19.12	20.89
Bozyazi (12)	18.00	21.21	29.80
Akören (13)	18.29	24.15	25.78
Ekinyazi (14)	12.24	14.47	19.64
Akcakale (15)	8.83	11.01	14.82
Kap (16)	18.62	22.81	30.55
General mean	16.11	19.79	26.45

database. Batjes (1996) reported that the worldwide mean carbon stock for the 0-100 cm layer was 9.6, 11.1 and 9.6 kg of C m^{-2} for Kastanozems, Vertisols and Cambisols, respectively. Brahim *et al.* (2010) reported that the mean carbon stock for Tunusian soils in the 0-100 cm layer was 4.04, 13.88 and 15.92 kg of C m^{-2} for Lithosol, Pozoluvisols and Luvisols, respectively.

The total SOC stocks for the Harran Plain were comparable, regardless of the method used for their estimation. The estimated SOC stocks at a depth of 0-100 cm were similar to the amounts (6.38 to 11.04 kg C m^{-2}) reported by Brahim *et al.* (2010) and Sakin *et al.* (2010a; b) (4.04 to 13.38 kg C m^{-2}).

The rate of SOC accumulation in the study area was approximately 1.56 to 2.63 g of C m^{-2} in the 0-100 cm layer. The SOC accumulation rate was higher in Sirrin soils (2.63 g C m^{-2}) than in Cekcek soils (1.56 g C m^{-2}). Soil organic carbon accumulation at a depth of 0-120 and 0-160 cm was 1.89 to 3.14 and 2.12 to 3.94 g of C m^{-2}, respectively (Fig. 3 and Tab. 4). Landi *et al.* (2004) reported that the carbon accumulation rate in the 0-100 cm layer of Canadian soils was 1.0 to 1.25 g of C m^{-2}. These results are similar to those reported by McGill *et al.* (1988) for the same zone.

The greatest mean SIC density was 19.27 kg of C m^{-2}, which was observed in Kisas soils, followed by 18.73 kg of C m^{-2}, which was observed in the 0-100 cm soil depth of Begdes soils. Lastly, the SIC was 11.82 kg of C m^{-2} in Cekcek and 8.83 kg of C m^{-2} in Akcakale (Tab. 5). The SOC and SIC content of the other depths (100, 120 and 160 cm) are shown in Fig. 4 and Tab. 5. The total soil C pool also consists of SIC, which is generally high in calcareous soils of arid and semiarid regions. Calcareous soils are widely distributed throughout the plain.

Conclusions

Soils in the Harran Plain stored 56.41 Tg (1 Tg = 10^{12} g) or 0.056 Pg (1 Pg = 10^{15} g) of C, and the mean SOC density and SIC density in the 0-100 cm layer were 8.96 kg of C m^{-2} and 16.11 kg of C m^{-2}. SOC was spatially variable because of the climate and land use practices in the Harran Plain. Namely, high SOC contents corresponded to areas of high rainfall, and low rainfall was related to a low SOC density in the southern region of the study area.

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