African Journal of Agricultural Research Vol. 5(19), pp. 2737-2743, 4 October, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Organic and inorganic carbon stocks and balance of Adana city soils in Turkey

E. Sakin[1]*, A. Deliboran[2], E. D. Sakin[1] and E. Tutar[1]

[1]Department of Soil Science and Plant Nutrition, Agriculture Faculty, Harran University, Osmanbey Campus, 63020 Sanlıurfa, Turkey.
[2]Directorate of Southeast Anatolia Region Soil-Water Researches and Agricultural Research Institute, Sanlıurfa, Turkey.

Accepted 25 August, 2010

Carbon stocks are calculated between from 0 - 100 cm depths of Adana great soil groups (GSG). Total carbon stock is 567.19 Tg in 0 - 100 cm, 168.37 Tg of which is organic carbon (OC) and 398.83 Tg of which is inorganic carbon (IC). While 77.81% of soil organic carbon consists of alluvial, brown and non-calcareous brown forest soils, 59.77% of soil inorganic carbon (SIC) consists of alluvial, colluvial and brown forest soils. Organic carbon stocks are mostly seen in non-calcareous brown forest soils (53.75 Tg or 31.92% of OC stocks, 22.61% of all area). The least stock is determined in alluvial coast soils (0.02 Tg or 0.01% of OC stocks, 0.01% of all area). Inorganic carbon stocks are mostly found in alluvial soils (165.7 Tg or 41.65% of SIC stocks, 19.88% of all area) and it is least seen in alluvial coast soils (0.12 Tg or 0.03% of SIC stocks, 0.01% of all area). While soil organic carbon amount is between 6.01 - 13.78 kg C m^{-2}, soil inorganic carbon amount changes between 26.27-60.01 kg C $m^{-2.}$ Generally, it is seen that soil organic carbon amount is low in the area where intense agriculture techniques are used and it is high in meadow and forest areas which form high areas.

Key words: Adana soils, soil organic carbon amounts and stocks, soil inorganic carbon amounts and stocks.

INTRODUCTION

Global carbon stocks and balances have become very important objects in recent years. The role of vegetation in the regulation of atmospheric CO_2 level is well known. Discovery of the increasing CO_2 concentration in the atmosphere and threat of global warming in the last two decades have encouraged scientists to find ways and means to control it.

Soil organic carbon is necessary for raising quality of soil, developing and maintaining quality of food production, saving clean water and reducing the CO_2 which has been rising in atmosphere. Moreover, inorganic carbon restricts root growth, raises salinity and causes reduction of organic materials (Eswaran and Van den Berge, 1992; Pal et al., 1999).

Soils creates very important environment for storing carbon and balancing emission. Pedosphere (soil sphere), also plays an important role affecting gas changes in the atmosphere. Soil organic carbon and inorganic carbonates create two big carbon pools in pedosphere and it is stated that these are related to each other closely (Mermut and Eswaran, 2001).

World mineral soils have major carbon reserves so it is estimated that there are 1115 - 2200 Pg C, (Post et al., 1982; Eswaran et al., 1993; Batjes, 1996), 1500 Pg C (Schlesinger and Andrews, 2000), 1580 Pg C (Houghton, 2007) in 1 m soil profile. According to IPCC, it is estimated at this rate 1750±250 Pg C indicating that 835 Pg of which is inorganic carbon. It is predicted that there are 2500 Pg C (Amundson, 2001) in 2 m depth of soil. According to a research of Janzen (2004), much of carbon is found in inorganic form under 1 m depth. He

*Corresponding author. E-mail: esakin@harran.edu.tr. Tel: 904143183683. Fax: 904143183682.

Abbreviations: SOC, Soil organic carbon; **SIC,** soil inorganic carbon; **IC,** inorganic carbon; **OC,** organic carbon; **GSG,** great soil group; **CO_2,** carbon dioxide; **GDSRW,** General Directorate of State Hydraulic Workers; **SAR,** Southeast Anatolia Region; **TSMS,** Turkish State Meteorological Service; **BD,** bulk density; **GDSR,** General Directorate of Rural Service; **MWEG,** Member of the ecosystem working groups; **IPCC,** Intergovernmental Panel on Climate Change.

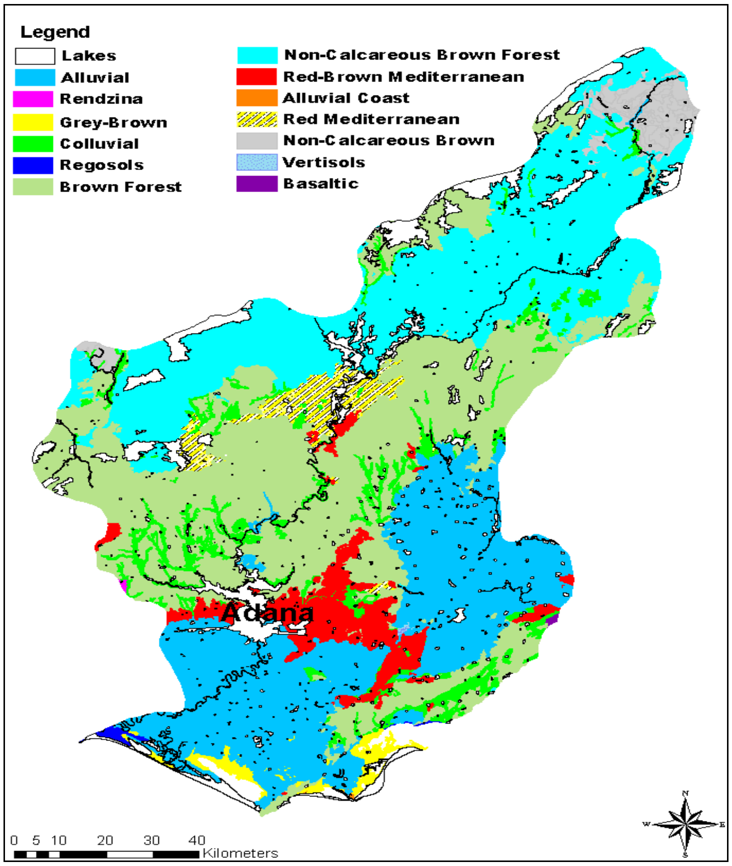

Figure 1. Adana City Great Soil Groups.

expressed that the most important upper-soil organic carbons are forests.

It is estimated that the carbon stock of Turkey is 6.30 - 6.90 Pg C (Sakin and Mermut, 2010) and 6.79 Pg C (Amthor et al., 1998) in 1 m soil profile. Sakin and Mermut (2010), according to their research, determined that in Southeast Anatolia Region (SAR), which constitutes 10% of Turkey, 0.63 Pg C is found in 1 m soil profile and they expressed that they estimated these findings with the help of SAR region carbon stock. However, there is no valid information on SOC and SIC in Turkey.

The information about carbon stocks and flux is rather limited in Turkey. The objective of this paper is to estimate organic and inorganic carbon amounts and stocks in Mediterranean regions of Adana.

MATERIALS AND METHODS

Materials

The study was carried out in Adana region, in Turkey. The land investigated in the research is located between longitudes 37° 30' and 33° 45' E and between latitudes 37° 45' and 36° 30' N and which has an area of about 17 252.67 km^2 and constitutes 2.21% of Turkey. There are 13 GSG in Adana. These are by order of their area; Alluvial, Alluvial Coast soils, Rendzinas, Grey-Brown, Colluvial, Brown Forest, Non-calcareous Brown Forest, Red-brown Mediterranean, Red Mediterranean, Non-calcareous Brown, Vertisols and Basaltic soils (Figure 1), (GDRS, 1996). 15 soil series were classified and determined according to profiles by opening 15 soil profiles (Nuns, 1956; GDSH, 1962; Soil-Water, 1973). Among soil series, Misis, Dağcı, Adana and İnaplı series existed on travertine and conglomerate terraces on high land. İncirlik and Arkaca existed on delta basin which occurred on alluvial fans. Yenice, Çanakçı, Arıklı, Arpacı, Gemisüre and Oymaklı series existed on delta basin. Helvacı and Pekmez series occurred on hollows of delta basin. Baharlı occurred on sand materials (Mancı, 1977).

The climate of study area was influenced by Mediterranean condition. Mean annual air temperature changes between 16.7 and 18°C. Mean annual precipitation varied between 601.0 and 1156.6 mm. (TSMS, 1974). Flora of the research area generally consists of products like barley, wheat, cotton and corn. Highlands consist of meadows and forests (Tamcı, 1977).

Method

One profile of each GSG was examined. Samples were taken from each horizon and 73 samples, Walkely and Black (1934) method for organic carbon analysis, Scheibler's calcimeter for $CaCO_3$ (Hızalan, 1965) and volume weight method were used (Sakin et al., 2010). Soil inorganic carbon (SIC) was determined by measuring CO_2 gas which can be found at the end of interaction of $CaCO_3$ with the HCL acid. $CaCO_3$ equivalent was converted to inorganic carbon with the

Table 1. SOC and SIC amounts of Adana Great Soil Groups (kg C m^{-2}).

Great soil groups	0 - 100 cm	
	SOC	SIC
Alluvial	9.84	48.32
Red-Brown Mediterranean	9.85	-
Grey-Brown	11.29	54.56
Colluvial	12.17	60.01
Regosols	6.01	35.43
Brown Forest	8.34	26.27
Non-calcareous Brown Forest	13.78	-
Rendzina	8.34	30.00
Alluvial Coast	9.90	48.32
Red Mediterranean	9.65	-
Non-calcareous Brown	9.01	-
Vertisols	7.07	36.00
Basaltic	8.50	-
Mean	9.52	42.36

0.12 coefficient (as one molecule includes 12 g C) (Schlesinger, 1982). Mean organic and inorganic carbon amount (kg C m^{-2}) was computed according to each horizon taken from 13 GSG and between 0 - 100 cm soil depth.

RESULTS AND DISCUSSION

Results

In GSGs of Adana, between 0 - 100 cm soil depth, storage of organic carbon amounts are high to low as presented in Table 1. Brown Forest 18.55, Non-calcareous Brown Forest 13.78, Colluvial 12.17, Grey-Brown 11.29, Alluvial Coast 9.90, Red-Brown Mediterranean 9.85, Alluvial 9.84, Red Mediterranean 9.65, Non-calcareous Brown 9.01, Basaltic 8.50, Rendzina 8.34, Vertisols 7.07 and 6.66 kg C m^{-2} in Regosol soils (Table 1). Soil inorganic carbon amounts are high to low as presented in Table 1. Colluvial 60.01, Grey-Brown 54.56, Alluvial ve Alluvial Coast 48.32, Vertisols 36.00, Regosols 35.43, Rendzinas 30.00 and Brown Forest soils 26.27 kg C m^{-2}, however, it can not be measured in Red-Brown, Non-calcareous Brown Forest, Red Mediterranean, Non-calcareous Brown and Basaltic wide soil groups. SOC and SIC amounts in the research conducted in Adana region are close to results of Sakin and Mermet (2010). In Regosol and Vertisol GSGs, SOC amount is lower than result of Brahim et al., (2009). According to researches of Neufeldt (2005), Grabe et al. (2003), average SOC amount is lower. However, the same result can be seen in areas where the precipitation is lower.

SOC amounts are examined in 3 categories in this region (Figure 2). According to this categorization, (i) between 6.00 - 9.00 kg C m^{-2} there are Regosol, Rendzina, Vertisols and Basaltic SGS, (ii) between 9.01 – 12.30 kg C m^{-2} there are Alluvial, Alluvial Coast, Grey-Brown, Colluvial, Red Mediterranean and Non-calcareous Brown wide soil groups and (iii) between 12.31 - 18.55 kg C m^{-2} there are Brown Forest and Non-calcareous Brown Forest GSG (Figure 2). The SIC amount of soils are examined in 3 categories. These are (i) between 0.00 - 0.00 kg C m^{-2} Red-Brown Mediterranean, Non-calcareous Brown Forest, Red Mediterranean, Non-calcareous Brown and Basaltic GSG, (ii) between 26.00 - 35.50 kg C m^{-2} Regosol, Brown Forest and Rendzina wide soil groups, (iii) between 35.51 - 60.01 kg C m^{-2} Alluvial, Grey-Brown, Colluvial, Alluvial Coast and Vertisol GSGs (Figure 3). Sakin and Mermut (2010) have used the similar categorizations for SOC and SIC in Southeast Anatolia Region (SAR).

The SOC and SIC stocks of Adana GSG are given in Table 2. According to this, by the order of: Non-calcareous Brown Forest 53.75, Brown Forest 49.91, Alluvial 33.75, Colluvial 10.93, Red Brown Mediterranean 6.78, Red Mediterranean 5.05, Grey-Brown 3.94, Non-calcareous Brown 3.62, Basaltic 0.26, Regosol 0.21, Rendzina 0.08, Vertisol 0.06 and Alluvial Coast GSGs 0.02 Tg C include SOC stocks. Total SOC stocks are 168.37 Tg (1 Tg = 10^{12} g) or 0.168 Pg (1 Pg = 10^{15} g) C. SIC stocks of soils are; Alluvial 165.72, Brown Forest 157.22, Colluvial 53.89, Grey-Brown 19.05, Regosol 1.24, Vertisol 0.32, Rendzina 0.27 and Alluvial Coast GSGs 0.12 Tg C. Total SIC stocks are 398.82 Tg C or 0.399 Pg C. According to research of Sakin and Mermut (2010), SOC and SIC stocks in SAR region cities are found as: Adiyaman (720 788.36 ha) 46.07, Antep (674 772.42 ha) 48.10, Batman (451 913.30 ha) 30.84, Diyarbakir (1 526 931.66 ha) 133.74, Kilis (142 230.73 ha) 11.38, Mardin (862 571.83 ha) 73.92, Siirt (562 706.82 ha) 47.70, Sırnak (712 073.24 ha) 59.61, Urfa (1 925 816.84 ha) 144.10 Tg C and SIC stocks are; 123.64,

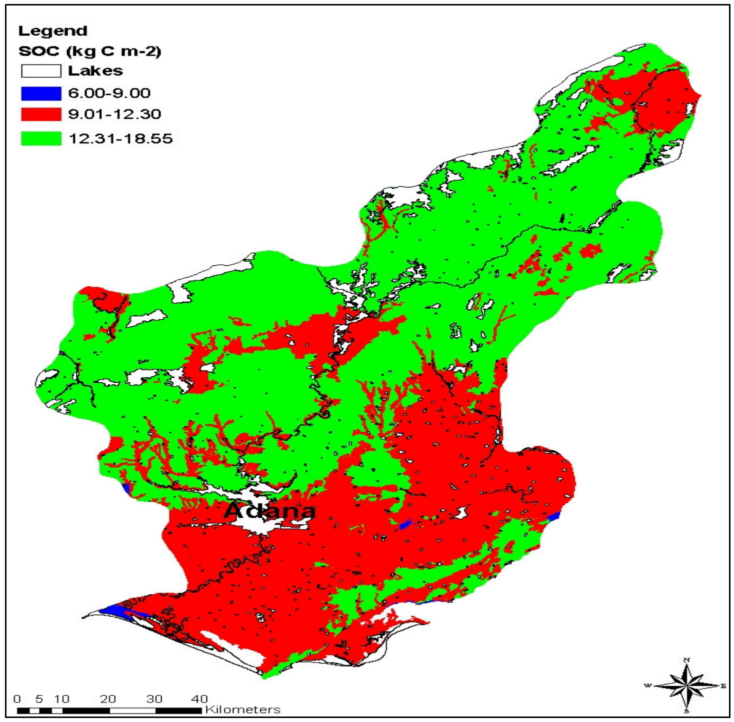

Figure 2. Soil organic carbon amounts of Adana Great Soil Groups.

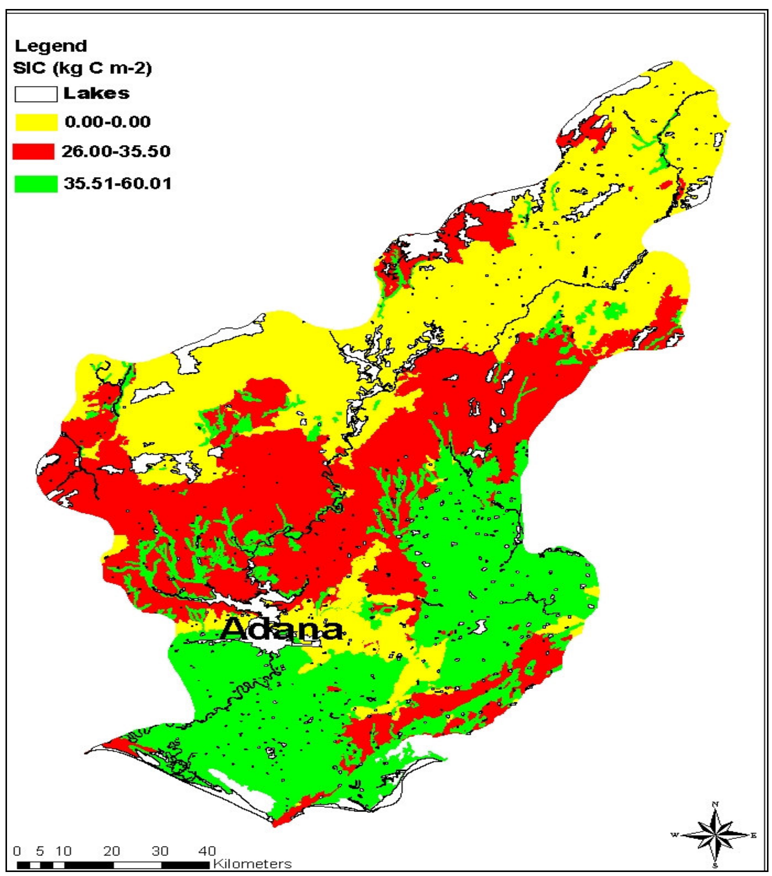

Figure 3. Soil inorganic carbon amounts of Adana Great Soil Groups.

Table 2. Carbon stocks of Adana Great Soil Groups (1 Tg C = 10^{12} g C).

Great soil groups	Area (ha)	Area (%)	0 - 100 cm	
			SOC	SIC
Alluvial	342 959	19.88	33.75	165.72
Red-brown mediterranean	68 868	3.99	6.78	
Grey-brown	34 919	2.02	3.94	19.05
Colluvial	89 794	5.20	10.93	53.89
Regosols	3 494	0.20	0.21	1.24
Brown forest	598 471	34.69	49.91	157.22
Non- calcareous brown forest	390	072	22.61	53.75
Rendzina	906	0.05	0.08	0.27
Alluvial coast	243	0.01	0.02	0.12
Red mediterranean	52 315	3.03	5.05	-
Non-calcareous brown	40 196	2.33	3.62	-
Vertisols	881	0.05	0.06	0.32
Basaltic	3 075	0.18	0.26	
Other Areas	-	-	-	-
Hydromorphic alluvial	17 236	1.00	-	-
Coast Dune	9 679	0.56	-	-
Rocks and Dunes	67 568	3.92	-	-
Rivers	4 591	0.27	-	-
Total	1 725 267	100.00	168.37	397.82

146.78, 165.21, 135.59, 67.84, 191.43, 123.61, 146.50 and 144.41 Tg C.

Soil organic carbon stock is found as 168.37 Tg C. While Alluvial, Brown Forest and Non-calcareous Brown Forest soils form 77.18% of Adana city, they constitute 81.6% (137.41 Tg C) of TOC stocks (Table 2). SIC stock is 398.82 Tg C and it consists of Allüviyal, Colluvial and Brown Forest soils which constitute 59.77% of all area. Moreover, these three GSG are equal to 94.5% of (376.83 Tg C) SIC stocks (Table 2). Total carbon stocks of Adana soils are 567.19 Tg C or 0.567 Pg C.

Approximately 36.5% (207.13 Pg C) of total carbon stock of region consists of Brown Forest soils, 35.15% (199.47 Pg C) of them consists of Alluvial soils. These two GSG constitute 71.66% (406.60 Pg C) of carbon stocks. The rest percentage of them consists of other groups (Table 2).

DISCUSSION

Reasons for variation in organic carbon amounts and stocks

The reasons for high SOC amounts of Brown Forest wide soil groups (GDRS, 1996) which existed on main material including high amount of calcareous and Non-calcareous Brown Forest wide soil groups on which the effects of calcareous washing, organic material saving, oxidation, clay, the washing of Fe-Al oxides from A horizon to B during the occurrence can be explained with factors like high precipitation, altitude, upper biomass entrance and low temperature. Moreover, despite its clay content is not high like Vertisol, Alluvial soils and clay cause Fe-Al oxides and hydroxides. The disruption of organic material which is compounded with sand particles is faster than organic material which is compounded with clay. The effect of temperature is very important on disruption. Bruke et al. (1989) states that, clay combines with organic material and creates a compound which saves carbon against disruption.

Kögel-Knaber et al. (2008) expresses that clay, Fe-Al oxide and hydroxides compounding with carbon in soil create organo-mineral complexes and this save the carbon against the oxidation. Singh et al. (2003a, b) says that this relation between clay and carbon is not seen every time. If this situation was permanent, the SOC amount of Vertisol GSGs would be higher than other GSGs. As seen in Table 1, the least SOC amount is found on the Vertisol than Regosol soils. Velayutham et al. (2002) states that, the positive effects of 2:1 type clay minerals on Vertisol soils decrease because of excessive cultivation.

They say that carbon amounts are low on farming area such as Vertisols because of intense cultivation systems (Jolivet et al., 1997; Walker et al., 2000; Shephered et al., 2001; Murty et al., 2002; Keeny et al., 2002). As was seen in the research studies in Adana region, the organic carbon amounts of meadows and forests are high. These reflect how farming techniques affect the carbon stocks in the soil. Sakin and Mermut (2010) in their research show that farming activities cause 57% decline on carbon stocks rate. Ardo and Olsson (2003), Li et al. (2007), mention disadvantages of intense farming systems on the SOC stocks.

According to Batjes (2006) and Guo and Gifford (2002), when meadows are converted to forests, stocks will raise much more. According to Bradley (2005) and Tarnocai and Lacelle (1996), rain raises related to becoming forested. Tomlinson and Milne (2006) explain that 75% of carbon is stored in forest areas. SOC amounts and stocks of Brown Forest and Non-Calcareous Brown Forest soils are pretty high which are generally in forests and meadows and on which farming activities are not done.

The other factors affecting the carbon stocks and amounts are volume weight, horizon thickness and region area which are parameters used during calculation. Although C% context of Colluvial Great Soil Groups are high, as it covers restricted area, SOC stocks are lower than Brown Forest and Non-Calcareous Brown Forest Great Soil Groups. Singh et al. (2007) confirms these ideas. Despite the low carbon content of Haplusteps, their SOC is similar to Torripsamments. This is related to volume weight. They express that if the carbon percentage is low and volume weight is high, carbon density is high.

Reasons for variation of inorganic carbon amounts and stocks

It is stated that as parting $CaCO_3$ comes together on solum as washed after raining, Aridisolls include more SIC than the other soil orders (Singh et al., 2003a, b). In dry regions, low organic ion activities and repeated aridity increase calcium saving processes. In the region, main material calcareous increases SIC amounts and stocks of Alluvial, Colluvial, Regosol, Brown Forest, Vertisol and Grey Brown Great Soil Groups. However, inorganic carbon amount is high in Colluvial soils; SIC stocks are lower than Alluvial and Brown Forest soils because of small area. Furthermore, SIC amounts of Brown Forest soils are low but as it has big area, SIC stocks are much more than other huge soil groups except alluvial soils. The factors affecting inorganic carbon stocks are volume weight, area and horizon thickness.

Conclusion

Like effects of precipitation, clay content, the usage of land, temperature on the carbon amount and stocks, calcareous situation of the main material on which soil existed affect organic carbon amounts and stocks. In farming areas, intensive farming techniques and not using conservative farming cause reduction on carbon stocks and CO_2 release. Although factors like cultivation, temperature, rain don't affect inorganic carbon amounts and stocks, these factors highly affect organic carbon amounts and stocks in Adana region soils.

The main factors which affect carbon amounts are climate, clay and calcareous in soil and slope. The effect of precipitation on the carbon amount is very important. If precipitation increases, biomass raise and upon this situation organic carbon increases. The other parameter of climate is heat and it cause to disrupt of organic materials faster. Despite high precipitation in the region, the reason of low carbon amount is high temperature in the region. When climate factors are permanent and clay and calcareous amounts are taken into consideration, the effects of this parameter on carbon stocks are pretty important. The other factor seen in this study is slope. Especially, when the carbon amounts of the profiles taken from the same GSG are compared, it is seen that carbon is lower in the more slopped areas. A detailed research is needed to define all factors affecting carbon stocks.

The soil organic carbon decline is a global issue. Related to this decline, land degradation begins. For this reason, minimum soil cultivation, conservative farming, increase of biomass and saving plant waste and adding them to soil are necessary. It is stated that if organic carbon is raised, the effects of a lot of physical factors such as soil structure, jam, cracking and the most importantly erosion will decrease.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and thanks to my supervisors Dr. A.R. Mermut and Dr. F.İnce for their understanding, advises my study, and my mother A.Sakin for patience.

REFERENCES

Amundson R (2001). The Carbon Budget in Soils. Annu. Rev. Earth Planet. Sci., 29: 535- 562.

Amthor JS, MWEG (1998). Terrestrial Ecosystem Responses to Global Change Research Strategy. Ridge National Lab. Environmental Sciences Division. Publication, USA, 4821: 39.

Ardo J, Olsson L (2003). Soil Carbon Sequestration in Traditional Farming in Sudanese Dry Lands. Environ. Manage., 33: 318–329.

Batjes NH (1996). Total Carbon and Nitrogen in the Soils of World. Europ. J. Soil Sci., 47: 151–163.

Batjes NH (2006). Soil Carbon Stocks of Jordan and Projected Changes upon Improved Management of Croplands. Geoderma, 132: 361–371.

Bradley RI, Milne R, Bell J, Lilly A, Jordan C, Higgins A (2005). A Soil Carbon and Land Use Database for the United Kingdom. Soil Use Manage., 21: 363–369.

Brahim N, Gallali T, Blavet D, Bernoux M (2009). Soil Organic Carbon Stocks at Tunisia Scale for Different Soil Types. 10th International Meeting on Soils with Mediterranean Type of Climate, CNRS Pres, pp. 107–111, Beirut, Lebanon.

Bruke IC, Yonkar CM, Parton WJ, Cole CV, Flach K, Schimel DS (1989). Texture, Climate and Cultivation Effects on Soil Organic Matter Content in US Grassland Soils. Soil Sci. Soc. Am. J.l 53: 800-803.

General Directorate of State Hydraulic Works (GDSHW) (1962). Middle Seyhan Project, Maraş Gavur Plain Planning and Land Classification

Report. Study Reports Number: 105: 8-9s, Ankara.
General Directorate of Rural Services (1996). Adana City Land Entity. General Directorate of Rural Services Project Study and Directorate, Ankara.
Eswaran H, Van Den Berge E (1992). Impact of Building of Atmospheric CO_2 on Length of Growing Season in the Indian Subcontinent. Pedologie 42: 289–296.
Eswaran H, Van Den Berge E, Reich P (1993). Organic Carbon in Soils of the World. Soil Science Society of American Journal 57, 192–194.
Grabe M, Kleber M, Hartmann KJ, Jahn R (2003). Preparing a Soil Carbon Inventory of Saxony-Anhalt, Central Germany using GIS and the State Soil Data Base SABO_P. J. Plant Nutr. Soil Sci. 166: 642 – 648.
Guo LB, Gifford RM (2002). Soil Carbon Stocks and Land Use Change: a Meta Analysis. Glob. Chang. Biol., 8: 345–360.
Hizalan E, Unal H (1966). İmportant Chemical Analysis of Soil. Ankara University Publishment, Ankara.
Houghton RA (2007). Balancing the Global Carbon Budget. Annual Rev. Earth Planetary Sci., 35: 313–347.
Janzen HH (2004). Carbon Cycling in Earth System – a Soil Science Perspective. Agric. Ecosyst. Environ., 104: 399-417.
Jolivet C, Arrouays D, Andreux F, Leveque J (1997). Soil Organic Carbon Dynamics in Cleared Temperate Forest Spodosol Concerted to Maize Cropping. Plant Soil, 191: 225-231.
Keeny EA, Hall JW, Wang C (2002). Temporal Trends in Soil Properties at a Soil Quality Benchmark Site in the Lower Fraser Valley, British Colombia. Canadian J. Soil Sci., 82: 499–509.
Kögel-Knabner I, Guggenberger G, Kleber M, Kandeler E, Kalbitz K, Scheu S, Eusterhues K Leinweber P (2008). Organo-Mineral Associations in Temperate soils: Integrating Biology, Mineralogy, and Organic Matter Chemistry. J. Plant Nutr. Soil Sci., 171: 61-82.
Li ZP, Han FX, Su Y, Zhang TL, Sun B, Monts DL, Plodinec MJ (2007). Assessement of Soil Organic and Carbonate Carbon Storage in China. Geoderma, 138; 119–126.
Mermut AR Eswaran H (2001). Some Major Developments in Soil Science Since the Mid - 1960s. Geoderma, 100: 403 - 426.
Murty D, Krischbaum MUF, Mxmurtie RE, Mcgilvray H (2002). Does Conversion of Forest to Agriculture Land Change Soil Carbon and Nitrogen? A Review of the Literature. Global Change Biol., 8: 105–123.
Neufeldt H (2005). Carbon Stocks and Sequestration Potentials of Agriculture of Soils in the Federal State of Baden – Württemberg SW Germany. J. Plant Nutr. Soil Sci., 168: 202 – 211.
Nuns FK (1956). Work Plans for Soil Survey of the Seyhan Delta Area TA Project 77-149, USOM, Turkey.
Pal DK, Dasog S, Vadivelu S, Ahuja RL, Bhattacharyya T (1999). Secondary Calcium Carbonate in Soils of Arid and Semi Arid Regions of India. In: Lal, R., Kimble, J.M., Stewart, B.A. (Eds.), Climate Change and Pedogenic Carbonates. CRC Press, Boca Raton, FL, p. 185.
Post WM, Emmanuel WR, Zinke PJ, Stagenberger AG (1982). Soil organic pool and world life zones. Nature, 298: 156–159.
Sakin E, Deliboran A, Tutar E (2010). Bulk Density of Harran Plain Soils in Relation to Other Soil Properties. Afri. J. Agric. Res., (in press).
Sakin E, Mermut AR (2010). Carbon Balance and Stocks of Soils Southeast Anatolia Region (SAR). Harran University. Graduate School of Natural and Applied Sciences Department of Soil Science. PhD Thesis, Sanlıurfa, 234 p.
Schlesinger WH (1982). Carbon Storage in the Caliche of Arid Soils; A Case Study from Arizona. Soil Sci., 133(4): 247-255
Schlesinger WH, Andrews JF (2000). Soil Respiration and the Global Carbon Cycle. Biogeochemistry, 48: 7-20.
Shephered TG, Saggar S, Newman RH, Ross CW, Dando JL (2001). Tillage Induced Change to Soil Structure and Soil Carbon Fraction in New Zealand soils. Australian J. Soil Res., 39, 465-489.
Singh SK, Baser BL, Shyampura RL, Narain P (2003a). Chemical Composition and Charge Behavior of Smectites in Vertisols of Rajasthan. J. Indian Society Soil Sci., 50: 106–111.
Singh SK, Baser BL, Shyampura RL, Narain P (2003b). Genesis of Lime Nodules in Vertisols of Rajasthan. J. Indian Society Soil Sci., 51: 273-278.
Singh SK, Singh AK, Sharma BK, Tarafdar JB (2007). Carbon stock and organic carbon dynamics in soils of Rajasthan, India. J. Arid Environ., 68: 408-421.
Tamci M (1977). The situation of Micro elements (Boron, Manganese, Copper, Zinc) of some series in East Mediterranean Region and a study on the relations of these elements with soil features . Cukurova University Agriculture Faculty Soil Science Department, Ph. D Thesis, Adana, p. 152s.
Tomlinson RW, Milne RM (2006). Soil Carbon Stocks and Land Cover in Northern Ireland from 1939 to 2000. Appl. Geogr., 26: 18–39. Turkish State Meteorological Service (TSMS) (1974). Meteorology Bulletin. Prime Ministry Printing Establishment, Ankara.
Soil-Water (1973). Developed Turkish Map 1/25 000 Land Plots.
Velayutham M, Pal DK, Bhattacharya T (2002). Organic Carbon Stock in Soils of India. In: Lal, R., Kimble, J.M., Stewart, B.A. (Eds.), Global Climate Change and Tropical Ecosystem. CRC/Lewis Publishers, Boca Raton, FL, p. 93.
Walkely A, Black LA (1934). An Examination of the Determining Method for Determining Organic Soil Matter and an Proposed Modification of the Chromic Acid Titration Method. Soil Sci., 37: 29–38.
Walker BD, Haugen-Kozyra K, Coen GM, Wang C (2000). Comparison of Cultivated and Native Soils in a Morainal Landscape in East Central Alberta. Research Branch, Agriculture Canada and Agriculture Food Canada, Semiarid Prairie Agriculture Research Center Swift Current, SK. SPARC Miscellaneous Publication No. 379 M0 211 50 pp.