CARBON CONTENT AND C/N RATIO IN PANNONIAN AND MEDITERRANEAN SOILS

[1]Milan Mesic – [2]Marta Birkas – [1]Zeljka Zgorelec – [1]Ivica Kisic – Aleksandra Jurisic – [1]Ivana Sestak

[1]Department of General Agronomy, Faculty of Agriculture, University of Zagreb, Svetosimunska c. 25, 10 000 Zagreb, Croatia, mmesic@agr.hr, tel: +385 1 239 3956

[2]Department of Soil Management, Institute of Crop Production Science, Szent Istvan University Gödöllö, Páter Károly u. 1, H-2103 Gödöllö, Hungary, Birkas.Marta@mkk.szie.hu, tel: +36-28-522-000/1674

Abstract

Soils are the largest carbon reservoir of the terrestrial carbon cycle. The quantity of C stored in soils is highly significant; soils contain about three times more C than vegetation and twice as much as that which is present in the atmosphere. Proper management of soil carbon requires an understanding of the cycling and balance of carbon. Soils vary greatly in their organic matter content. Soil organic matter consists of two groups of compounds, nonhumic and humic substances both play important roles in the environment affecting the biochemical, physical and chemical properties of soil.

Within Bilateral Project between Hungarian and Croatian scientists "*Impact of tillage and fertilization on probable climate threats in Hungary and Croatia, soil vulnerability and protection*" carbon storage were determined in different soil types in agroecological conditions of Pannonian plain and in Mediterranean conditions. Total carbon content, pH and C/N ratio in different natural (grasslands, meadows, forests) and agro ecosystems (vineyards, gardens and crop fields) were determined. Soil samples were taken during the spring and summer 2010 at different locations. Sampling depths varied from 0-3 cm, 3-10 cm, 0-30 cm, 30-60 cm and 60-90 cm depending on the location, region, soil type and type of ecosystem.

At 15 different locations, 5 in Pannonian plain and 10 in Mediterranean following results are recorded: soil pH (in 1 M KCl, 1:2.5 (w/v)) varied between 5.0 measured at Mediterranean pasture and 7.6 recorded in a crop field of Pannonian plain on Chernozem; CN ratio varied from 11 up to 39 noted in Mediterranean vineyard on Cambisol calcaric; carbon content observed in this study varied from 3.3 g C/kg measured in Szentgal at agricultural crop field on Eutric Cambisol in deeper layers (< 60 cm) up to 107.2 g C/kg measured at Mediterranean grassland in surface layer (0-3 cm).

Keywords: carbon content, C/N ratio, Pannonian plain, Mediterranean

Aims and background

Total carbon (C) in soils is the sum of both organic and inorganic C. Organic C is present in the soil organic matter (SOM) fraction, whereas inorganic C is largely found in carbonate minerals. Not all soils contain inorganic C because of dissolution during soil formation of carbonate minerals originally present in parent material. However, organic C is present in all agricultural soils. In soils formed from calcareous parent material under arid conditions, it is not unusual for the inorganic C concentration to exceed the amount of organic C present (*SSSA*, 1996). The cycle of carbon on Earth is the story of life on this planet. Soils are the largest carbon reservoir of the terrestrial carbon cycle. The quantity of C stored in soils is highly significant; soils contain about three times more C than vegetation and twice as much as that which is present in the atmosphere (*FAO*, 2004). Whether the goal is to reduce greenhouse gas emission or to enhance soil quality and plant production, proper management of SOM requires an understanding of the cycling and balance of carbon. The rate at which SOM either increases or decreases is determined by the balance between gains and losses of carbon. In Agroecosystem many different factors affect the balance between gains and losses of SOM (*Brady and Wail*, 2010). SOM is mostly an accumulation of dead plant matter and partially decayed and resynthesized plant and animal residues (*Bohn et al*., 2001).

In the other point of view soil is formed when the ions in rock minerals at the Earth's surface change, or weather, to more stable chemical states. Soil development, in the chemical sense, is roughly synonymous with weathering (*Bohn et al.*, 2001). *Jenny*, 1941 proposed that soil development should be regarded as the result of five soil forming factors: climate, topography, biosphere, parent material and time. The relative importance of each factor as well varies with local and regional conditions. The soil forming factors also are interdependent.

Soils vary greatly in their organic matter content. SOM consist of two groups of compounds, nonhumic and humic substances both play important roles in the environment and affect biochemical, physical and chemical properties of soil. Despite the relatively low concentration of SOC in mineral soils compared to inorganic components this pool of carbon is an important component of the global carbon budget and cycle (*Essington*, 2004).

The content of soil organic carbon (SOC) is universal soil quality indicator with significant influence on soil properties. Soil organic carbon today is in the centre of interest because of international conventions on climate change (UNFCC), biodiversity (CBD) and desertification (UNCCD). Therefore, it is very important to understand the processes that influence changes in soil organic carbon particularly in Pannonian and Mediterranean region.

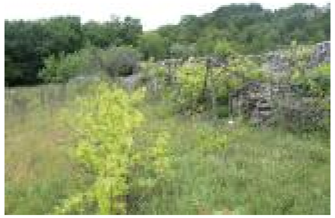
Experimental circumstances

In different natural (grasslands, meadows, forest) and artificial agro ecosystems (vineyards, garden, crop field) during the spring and summer 2010 soil samples were taken at different soil depths (table 1 & Picture 1). Sampling depths varied from 0-3 cm, 3-10 cm, 0-30 cm, 30-60 cm and 60-90 cm depending on the location, region, soil type and type of ecosystem. Soil samples were collected as composite samples (from 7 – 10 single samples). Air dried soil samples were milled, sieved (< 2 mm) and homogenized, than prepared according to the protocol for pretreatment of samples for physical and chemical analysis (ISO 11464).
Selected parameters were determined in the soil samples as follows: pH, plant available P_2O_5 and K_2O, organic matter, total nitrogen, total carbon, total sulphur and carbonate content. This paper presents results of total carbon, total nitrogen and pH.

The soil pH was determined in 1:2.5 (w/v) in (1 M KCl) soil suspension (modified ISO 10390). Total carbon (TC) content and total nitrogen (TN) content were determined by dry combustion method (ISO 10694) and (ISO 13878), respectively at CHNS analyzer, (Vario Macro, Elementar 2006).

Table 1 Investigated locations

Location	Sampling depths, cm	Region	Land use	Soil Type	Latitude Longitude
Lok1	0-30 30-60 60-90	**Hungary - Pannonian plain**	agriculture crop field	Chernozem	N 46°20'42,78'' E 20°49'51,24''
Lok2	0-30 30-60 60-90		agriculture crop field	Chernozem	N 46°20'14,28'' E 20°51'34,32''
Kar1	0-30 30-60 60-90		meadow	Chernozem	N 47°16'55,80'' E 20°53'41,82''
Szentgál	0-30 30-60 60-90		agriculture crop field	Eutric Cambisol	N 47°08'32,22'' E 17°40'49,02''
Szentgál grassland	0-30 30-60 60-90		meadow	Eutric Cambisol	N 47°07'51,96'' E 17°42'46,98''
Lub1	0-30	**Croatia – Islands – Adriatic region**	vegetable garden	Rigosol on karst	N 44°53'21,18'' E 14°19'58,02''
Lub2	0-30		vineyard	Rigosol on karst	N 44°53'31,50'' E 14°20'12,96''
Lub3	0-3		karst pasture	Rendzina on dolomite and limestone	N 44°53'24,90'' E 14°20'04,26''
ML1	0-3		afforested *Pinus halepensis* forest	Calcocambisol on limestone	N 44°31'28,50'' E 14°27'23,34'
ML2	0-3		afforested *Pinus halepensis* forest	Calcocambisol on limestone	N 44°31'35,04'' E 14°27'07,68''
B12	0-3 3-10		meadow: *Dactylis glomerata*, *Rosa Canina*, *Ficus carica*	Terra rossa	N 45°05'32,13'' E 14°18'28,07''
B13	0-30		olive trees with typical vegetation for Northern Mediterranean	Rigosol on karst from Calcocambisol on limestone	N 45°06'34,19'' E 14°21'11,61''
B14	0-3 3-10		pasture	Calcocambisol on limestone	N 45°04'10,84'' E 14°21'43,50''
B15	0-3 3-10		grassland: *Salvia officinalis*, *Stipa eriocaulis*, *Juniperus oxycedrus*	Lithosol on limestone and dolomite	N 45°03'26,11'' E 14°21'50,26''
B16	0-30		abandoned vegetable garden	Rigosol on karst	N 45°02' 23,68'' E 14°21' 21,66''

 Lok 1 - agriculture crop field, Hungary	 Lok 2 - agriculture crop field, Hungary	 Kar 1 - meadow, Hungary	 Szentgál - agriculture crop field, Hungary	 Szentgál grassland - meadow, Hungary
 Lub 1 – vegetable garden, Croatia	 Lub 2 – vineyard, Croatia	 Lub 3 – karst pasture, Croatia	 ML 1 – forest, Croatia	 ML 2 – forest, Croatia
 B12 - meadow, Croatia	 B13 – olive orchard, Croatia	 B14 – pasture, Croatia	 B15 – grassland, Croatia	 B16 – abandoned vegetable garden, Croatia

Picture 1 Photos of all investigated locations and its variability on land management

Results and discussion

Results of carbon content in typical Pannonian and Mediterranean soils are presented at *Figures 1 and 2.* According to *Hobley and Willgoose* (2010) issues and considerations regarding measurement of carbon stocks, and particularly SOC stocks can be divided to several groups; sampling issues, temporal issues, measurement issues, and, finally issues about vertical distribution of SOC and sample depths. In this research it was not possible to follow demanding and expensive procedures for soil sampling as it is described in "Soil sampling protocol to certify the changes of organic carbon stock in mineral soil of the European Union" (*Stolbovoy et al.*, 2007) because of very limited funds. But it is important to stress that without more detailed research it will be impossible to discuss carbon inventory and changes in carbon stocks over time.

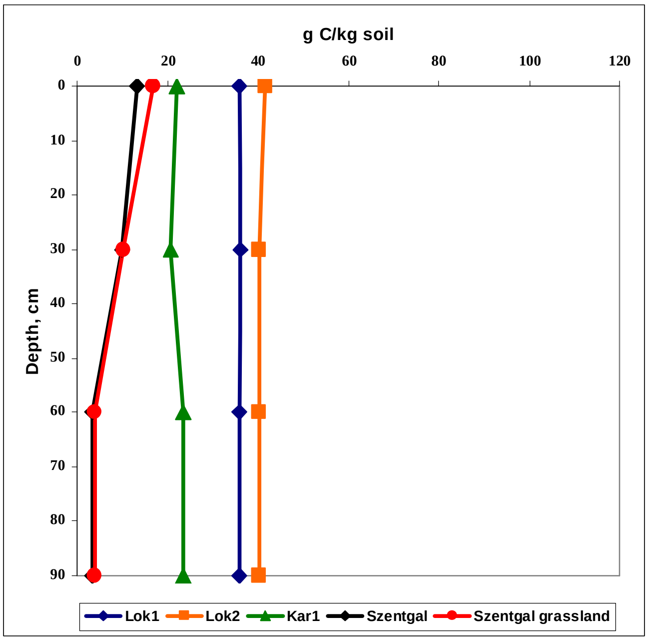


Figure 1 Carbon storage in typical Panonnian soils, 0-90 cm

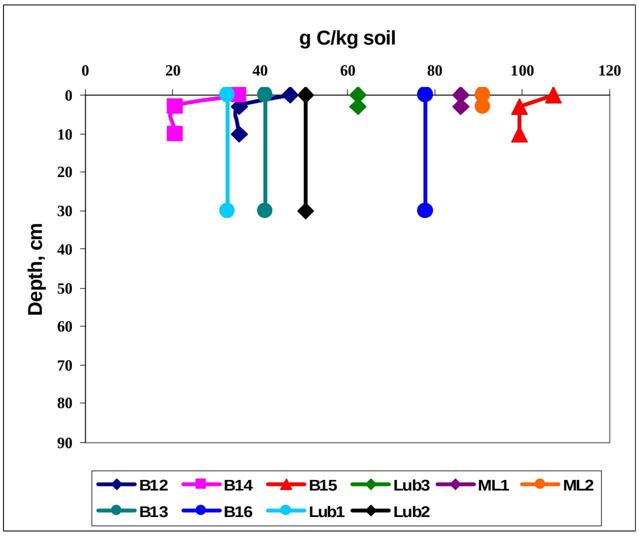


Figure 2 Carbon storage in typical Mediterranean soils, 0-3 cm and 0-30 cm

Total carbon content observed in this study varied from 3.3 g C/kg measured in Szentgal at agricultural crop field on Eutric Cambisol in deeper layers (< 60 cm) up to 107.2 g C/kg measured at Mediterranean grassland in surface layer (0-3 cm). Carbon content in soil is a result of natural pedogenetic processes and land management patterns. Main difference in carbon storage between Pannonian and Mediterranean soils is related to the soil depth. Although carbon content in shallow samples taken from Mediterranean environment is higher in average, overall carbon storage is much higher in soils from Pannonian region because of soil depth and other relevant soil properties. Figures 3 and 4 present results of soil pH and C/N ratio in all investigated soils. Soil pH (in 1 M KCl, 1:2.5 (w/v, ***Figure 3***) varied between acid (5.0) measured at Mediterranean pasture and weakly alkaline (7.6) recorded in a crop field of Pannonian plain on Chernozem (***Figure 3***). C/N ratio varied from 11 up to 39 noted in Mediterranean vineyard on Cambisol calcaric (***Figure 4***).

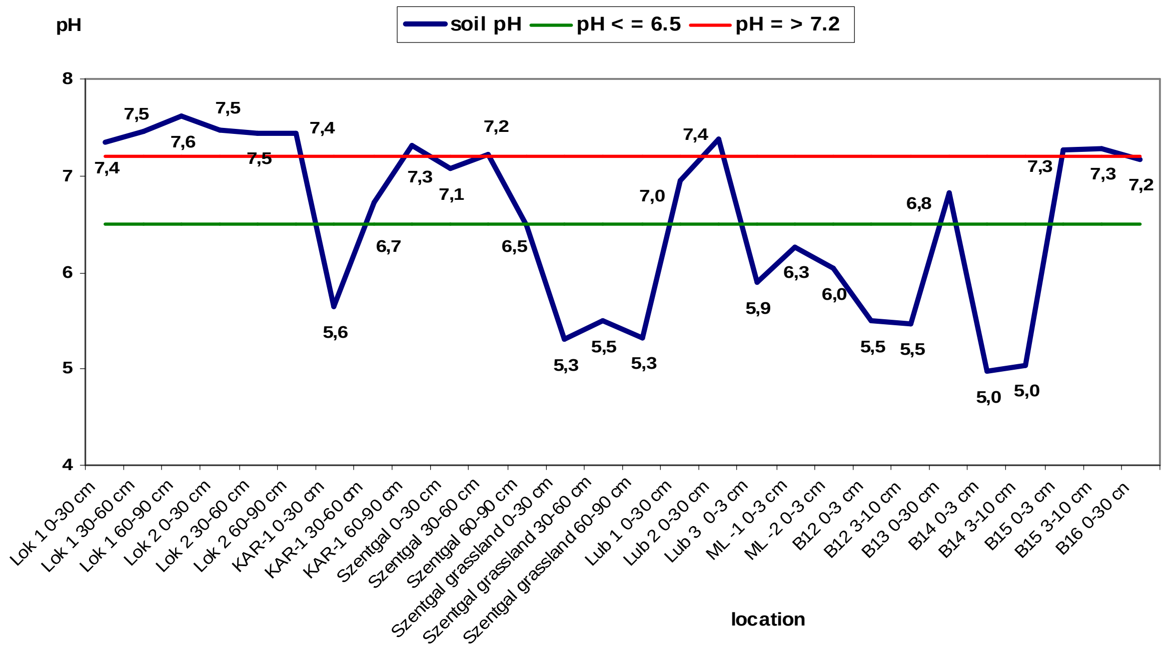


Figure 3 pH in investigated Pannonian and Mediterranean soil samples

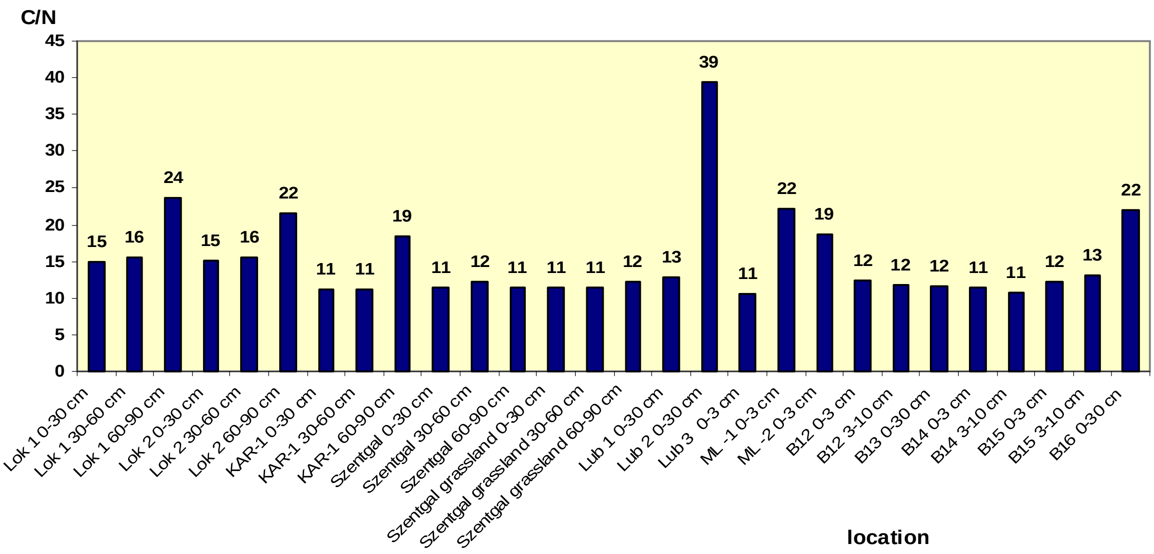


Figure 4 C/N ratio in investigated Pannonian and Mediterranean soil types

Usually it is accepted that the optimal C/N ratio is around 10 while ratio over 30 is considered extremely high and can result in some soil nitrogen deficiencies. According to our results, from 28 samples 17 have C/N ratio between 11 and 13, then 6 have C/N ratio in a range from 15 to 19, while 4 soil samples have C/N ratio 22, and one sample 39.

C/N ratio in arable (cultivated) surface Ap horizons commonly ranges from 8 – 15 (median ~12) and is generally lower within soil profile (*Brady and Weil,* 2010). Soil microbes like other organisms require a balance of nutrients from which they build their cells and extract energy (C & N). The microbes need to find about 1g of N for every 24 g of C in their food. If C/N is too high microbes search available N and this can lead to depletion of soil soluble N in different forms. As a result of that process N deficiency can occur and decay of OM can be delayed. Moist soils contain from 1-10 % (10-100 g/kg) of C in surface horizon, with the majority having C content from 1-3 %. The most notable exceptions are organic soils (Histosols) formed under waterlogged conditions which restrict the flow of oxygen to soil organisms and thus reducing the rates of SOM decay. According to ***Paustian*** (2002) they may contain 10 -30 % of C.

One of particularly interesting questions is how nitrogen fertilization influences SOC. In the literature there are numerous findings about influence of mineral nitrogen fertilization to soil organic carbon content. Very often, results are controversial. Some authors confirm positive effects, but there are some papers where negative influence of nitrogen fertilization on total soil organic carbon content. Positive correlations are observed by ***Halvorson and Reule*** (1999) in semi arid, dry land areas in Colorado, than by ***Blevins et al.,*** (1983) in ***Kentucky and Raun et al.,*** (1993) in Oklahoma. On the other hand, some US scientists (***Khan et al.,*** 2007) observed negative correlation after analyses of numerous long term cropping experiments in the USA and elsewhere (Denmark and England). In addition, there are some results that point to to the conclusion that there is no influence of N fertilization on SOC (***Hofmann et al.,*** 2009).

Beside nitrogen fertilization, soil tillage and crop rotation also significantly contribute to the soil organic carbon balance. ***Birkás et al.*** (2007) studied organic material content in soils, including its response to land use. On soils originally rich in SOM they found five influencing factors, e.g.: (1) number and extent of soil disturbance (affecting CO_2 emission); (2) crop residue mass and handling (incorporate, mulch, or mix as recycle); (3) soil moisture storage or loss (affecting soil disturbance); (4) correct/incorrect-timing of primary tillage; (5) depth and method of soil disturbance in summer (affecting CO_2 emission). Based on results obtained both in experimental and field relations they concluded that less (optimal) soil disturbance should be applied to conserve organic matters effectively, and that frequent disturbance promotes the loss of humus in a long-term.

The results obtained by ***Meersmans J. et al.*** (2009) point to the conclusion that intensified land management practices seriously affect the SOC status of the soil. The increase in plough depth and a change in crop rotation result in a significant decrease of C near the surface for dry silt loam cropland soils. According to ***Birkás*** (2010) in the experiment with soil tillage the total of 12-17 t ha^{-1} organic carbon was recycled over a period of 7 years. The soil original C content (1.83 g kg^{-1}) was increased by 0.53 g kg^{-1} in the case of direct drilling, 0.19 g kg^{-1} in the case of tillage using cultivators, 0.08 g kg^{-1} at the disking, 0.19 g kg^{-1} at the loosening and by 0.27 g kg^{-1} in the case of ploughing. Factors contributing to the increase of organic C content include the adding of organic material to the soil, carbon conserving tillage and heat-stress alleviation.

As ***Álvaro-Fuentes et al.,*** (2011) concluded that there is little information about soil organic carbon (SOC) stocks and changes in Mediterranean areas at a regional scale. They modelled an area of 95 269 km^2 in northeast Spain using the Global Environmental Facility Soil Organic Carbon (GEFSOC) system to predict SOC stocks and changes in pasture, forest and agricultural soils. The greatest SOC gain was predicted in agricultural soils with 42 Tg C caused by changes in management, which led to increases in C inputs. Authors concluded that more research is needed in order to study the potential role of soils as atmospheric CO_2 sinks under different managements and climatic conditions.

These results clearly show the importance of different tillage and fertilization practices on soil organic carbon balance.

Conclusion

Management of agricultural fields, grasslands, meadows, orchards and forests has great influence on soil carbon content. Depletion of SOC is not an option for sustainable land use. For the need of monitoring of changes of carbon stocks in Pannonian and Mediterranean soils it will be necessary to carry out more detailed research programs.

References

Álvaro-Fuentes, J., Easter, M., Cantero-Martinez, C., Paustian, K. 2011. Modelling soil organic carbon stocks and their changes in the northeast of Spain. European Journal of Soil Science. 62. 5. 685–695.

Birkás, M. 2010. Results and findings of long term experiments aimed to help improve tillage practices. Acta Agronomica Hungarica 2010/1 Supplementum http://docs.agrisafe.eu/Publications/longterm/Birkas.pdf

Birkás, M., Kalmár, T., Bottlik, L., Takács, T. 2007. Importance of Soil Quality in Environment Protection. Agriculturae Conspectus Scientificus, 72. 1. 21-26.

Blevins, R.L, Thomas, G.W., Smith, M.S, Frye, W.W., Cornelius, P.L. 1983. Changes in soil properties after 10 years of continuous non-tilled and conventionally-tilled corn, Soil & Tillage Research 3 (2), 135-136.

Bohn, H.L., McNeal, B.L. O'Connor, G.A. 2001. Soil Chemistry, John Wiley & Sons, Inc., USA, pp. 155-172.

Brady, N.C., Wail, R.R. 2010. Elements of the Nature and Properties of Soils. Pearson Education, Prentice Hall, New Jersey, pp. 361-395.

Essington, M.E. 2004. Soil and water chemistry, An Integrative Approach. CRC Press, USA, pp. 129-180.

FAO: Food and Agriculture Organization of the United Nations. 2004. Carbon sequestration in dryland soils, World Soil Resources Reports No 102. Rome

Halvorson, A.D., Reule, C.A. 1999. Long-term Nitrogen fertilization benefits soil carbon sequestration. Better Crops, 83 (4), 16-20.

Hobley, E., Willgoose, G. 2010. Measuring soil organic carbon stocks – issues and considerations. Symposium 1.5.1. Quantitative monitoring of soil change. 62-65. 19th WCSS, Brisbane, Australia, Published on DVD

Hofmann, A., Heim, A., Gioacchini, P., Miltner, A., Gehre, M., Schmidt, M.W.I. 2009. Nitrogen fertilization did not affect decay of old lignin and SOC in a ^{13}C – labeled arable soil over 36 years. Biogeosciences Discussions 6, 1657-1675.

ISO 10390 – Soil quality - Determination of pH

ISO 10694 – Soil quality - Determination of organic and total carbon with dry combustion method («elemental analysis»)

ISO 11464 – Soil samples preparation for physical and chemical analysis

ISO 13878 – Soil quality - Determination of total nitrogen with dry combustion method («elemental analysis»)
Jagadamma, S., Lal, R., Heoft, R.G., Nafziger, E.D., Adee, E.A 2008. Nitrogen fertilization and cropping system impacts on soil properties and their relationship to crop yield in the central Corn Belt, USA, Soill & Tillage Research 98, 120-129.
Jenny, H. 1941. Factors of soil formation, Mcgraw-Hill, New York, pp. 52-88.
Khan, S.A., Mulvaney, R.L., Ellsworth, T.R., Boast, C.W. 2007. The myth of nitrogen fertilization for soil carbon sequestration, Journal of Environmental Quality 36, 1821-1832.
Meersmans, J., Van Wesemael, B., De Ridder, F., Fallas Dotti, M., De Baets, S., Van Molle, M. 2009. Changes in organic carbon distribution with depth in agricultural soils in northern Belgium, 1960–2006. Global Change Biology. 15. 11. 2739–2750.
Paustian, K. 2002. Organic Matter and Global C Cycle in Encyclopaedia of Soil Science (ed. Lal, R.), pp. 895-898.
Raun, W.R., Johnson, G.V., Phillips, S.B., Westerman, R.L. 1993. Effect of Long-Term Nitrogen Fertilization on Soil Organic Carbon and Total Nitrogen in Continuous Wheat, Oklahoma State University
SSSA, 1996. Soil Science Society of America Book Series No. 5. Methods of Soil Analysis, Part 3: Chemical Methods, Wisconsin, USA
Stolbovoy, V., Montanarella, L., Filippi, N., Jones, A., Gallego, J., & Grassi, G. 2007. Soil sampling protocol to certify the changes of organic carbon stock in mineral soil of the European Union. Version 2. EUR 21576 EN/2. 56 pp. Office for Official Publications of the European Communities, Luxembourg. ISBN: 978-92-79-05379-5.
Wang, Y., Li. Y., Ye, X., Chu, Y., Wang, X. 2010. Profile Storage of Organic/Inorganic Carbon in Soil: From Forest to Desert. Science of the Total Environment 408 p. 1925-1931.