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THE SOIL ORGANIC CARBON DENSITY OF HISTOSOLS

Telmen Turmunkh

Institute of Geography and Geoecology, Mongolian Academy of Science, Ulaanbaatar, Mongolia

telment@mac.ac.mn

Co-author: Batkhishig Ochirbat

Abstract: Soils are a major carbon reservoir. Also, soils can be a substantial source of greenhouse gas emissions into the atmosphere. Especially peatlands, occupies a small area and have high organic carbon content. The aim of this study was to determine Histosols (peatland soil) organic carbon density (SOCD) at 6 standard depth of soil (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm, 100-200 cm) for each soil subtypes. Some variables that needed to estimate soil organic carbon density such as organic matter content and bulk density data were incomplete. The number of these deficiencies were calculated by Pedotransfer functions. The estimation shows that the average SOCD of 2 m thick Histosols is 233.7 t/ha based on 9 soil profiles. The maximum organic carbon accumulated at a 30-60 cm depth with a value of 64.6 t/ha in Histosols. However, the highest SOCD contained per 1 cm layer is in topsoil, approximately 6.4 t/ha at first 5 cm and 5.6 t/ha at 5-15 cm. The minimum density of soil organic carbon is in the bottom layer of 100-200 cm.

Keywords: Histosols, Peatland, Soil organic carbon density.

Introduction

Soils are a major carbon reservoir containing more carbon than the atmosphere and terrestrial vegetation combined. Soil organic carbon (SOC) is an indicator of soil health, it is important for its contributions to food production, mitigation, and adaptation to climate change, and the achievement of sustainable development. In the presence of climate change, land degradation, and biodiversity loss, soils have become one of the most vulnerable resources in the world. Therefore, soils can be a substantial source of greenhouse gas (GHG) emissions into the atmosphere. Although the overall impact of climate change on SOC stocks is very variable according to the region and soil type, rising temperatures and increased frequency of extreme events are likely to lead to increased SOC losses. The soils within peatland in Mongolia are comparable to Histosols of WRB (World Reference Base for Soil Resources) classification (Batkhishig, 2016).

Although only 3% of the world's land surface, peatlands hold 30% of all soil carbon, an amount equivalent to 75% of all atmospheric carbon and twice the carbon stock in the entire forest biomass of the world (ADB, 2017). This carbon is released to the atmosphere when peatland is drained or when vegetation is (partly or totally) removed. The vegetation in peatland is much less resilient to the effects of livestock grazing compared to vegetation on mineral soil (Parish et al., 2008), therefore the risk of drainage and degradation is high in peatland soil due to drought, livestock growth, and other factors. When drained or degraded, peatlands release the carbon much faster than it has been sequestered (Couwenberg, 2011; Couwenberg et al., 2010). Emissions from drained peat soils are disproportionally large. Drained peatlands are responsible for 6% of total global anthropogenic CO_2 emissions (Joosten, 2010). According to Joosten (2010) and Bonn et al (2016), CO_2 emission from peatland in Mongolia was relatively higher among other countries. In 2017, Mongolian peatland spatial distribution was estimated based on around 250 descriptions of soil pits with soil profile descriptions, 11 reference drilling in permafrost, 14 GPR profiles, and 9 ERT profiles in 10 peatland study sites. Their results indicate that area of peatland has reduced by at least a half than that of 27000 km2 that estimated by Minayeva et al (2005) (ADB, 2017).

Soil organic content of Mongolian peatland was demonstrated several studies (Otgontuya, 2010; Murray et al., 2004; Fukumoto et al., 2014; Lu et al., 2009). However, organic carbon density of Histosols is remained unstudied.

The purpose of this study is to determine Histosols organic carbon density in its different types of soils. We calculated SOCD in 6 standard depth of soil (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm, 100-200 cm) for each soil types. It is assumed that topsoil carbon is important, however deep soil carbon is a really big deal for understanding the future of climate change.

Methodology

In this study, soil organic carbon density was calculated at 6 soil standard depths for each soil subtypes of Histosols. We used 9 soil profile information of Histosols for SOCD calculation from Mongolian Soil Information System – 5 (MOSIS-5) that developed by Institute of Geography and Geoecology, MAS. In this study, international WRB soil classification soil names were used.

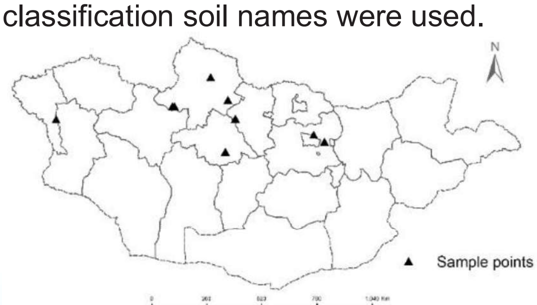

Figure 1. Soil samples location

Soil organic carbon density calculation:

$$SOCD = SOC \times h \times BD \times (1 - st) \quad (1)$$

Where *SOCD* - Soil organic carbon density, t/ha; *SOC* - soil organic carbon, %; *h* - soil layer height, cm; *BD* - bulk density, g/cm^3; *st* - stone content.

Van Bemmelen factor of 1.724 was used to convert soil organic matter (SOM) to soil organic carbon (SOC).

$$SOC = SOM(\%) \div 1.724 \quad (2)$$

Some soil information from MOSIS - 5 does not have soil bulk density result. Therefore, soil bulk density was expressed by available measurements. Adams (1973) pedo-transfer function was used to estimate some unknown soil bulk density.

$$BD = \frac{100}{\frac{1.72\times\%OC}{OBD} + \frac{100-1.72\times\%OC}{MBD}} \quad (3)$$

Where *BD*- bulk density, g/cm^3; *OC*- organic carbon; *OBD*- bulk density of organic matter – value is 0.223 g/cm3 when organic matter range 0-75 % (Adams, 1973). In our situation, all samples were within this range, therefore we used 0.223 g/cm^3 as a constant value.

MBD- bulk density of mineral matter – normally, 1.33 g/cm^3 is a constant value (Adams, 1973). However, if soil texture is available, MBD can be more accurately using Rawls & Brakensiek (1985) table.

Table 1. Bulk density of mineral matter (Rawls & Brakensiek, 1985)

		Sand									
	%	10	20	30	40	50	60	70	80	90	100
	10	1.4	1.2	1.25	1.27	1.4	1.52	1.58	1.69	1.65	1.53
	20	1.4	1.25	1.35	1.45	1.53	1.6	1.67	1.72		
Clay	30	1.4	1.3	1.4	1.5	1.57	1.63	1.68			
	40	1.4	1.35	1.44	1.55	1.61	1.68				
	50	1.4	1.35	1.44	1.53	1.62					

Samples were taken from soil genetic horizons by conventional way therefore we used weighted average ($\bar{x}$) to convert soil values to standard depths.

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad (4)$$

Where *wi*- thickness of genetic horizon; *xi*- value for horizon.

Depth prediction of soil organic carbon storage

Most of the OC is concentrated in the topsoil and in most soils its content decreases with depth. However, OC in subsurface horizons contributes to more than half of the total soil carbon stock. Global OC stock in the top 0.2-m layer is estimated to account for 615 Gt, whereas it may account for 1502 Gt at a depth of up to 1 m and 2344 Gt at a depth of up to 3 m (Jobbбgy & Jackson, 2000; Fontaine et al., 2007). The organic carbon in the topsoil is significant, however it is necessary to estimate the amount of organic carbon in deeper. Unfortunately, soil profiles were rarely dug and sampled to 2 m deep. Therefore, we used pedotransfer functions to predict deep soils properties. This is advantageous when dealing with soil databases such as MOSIS where the depths are not completely sampled and uniformly. We are able to predict the parameters of the function using more easily measured or more widely available data.

Soil carbon has been observed to decline rapidly with depth (Spain et al. 1983); the concentration of carbon with depth is usually expressed as an exponential decay function. In this study, we used Russell & Moore (1968) function to calculate unknown soil depth organic carbon.

$$C = C_a \exp(-kz) \quad (5)$$

Where *C* - Organic carbon, %; *Ca* - Organic carbon concentration at the soil surface, %; *z*- Depth, m; *k*- Rate of decrease. In our case, k value was between 2 and 5 in Histosols.

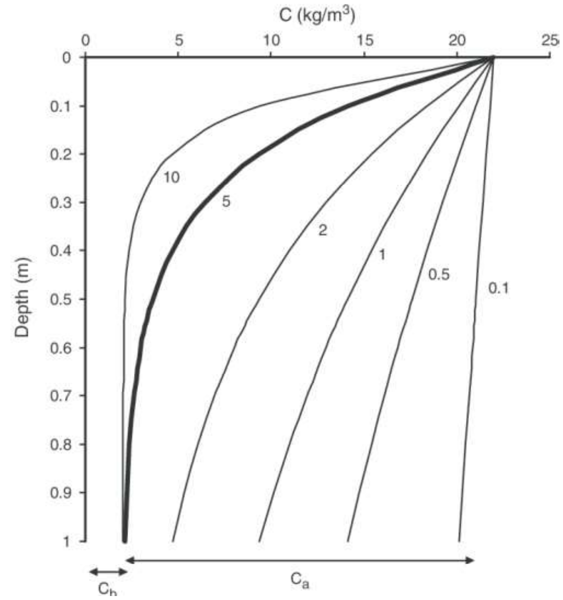

Figure 2. The negative exponential depth function for soil carbon content, *κ* (Minasny et al., 2006)

Results

In previous studies, attempts were made to estimate soil organic matter content or soil organic carbon content. In this work, we sought to determine Mongolian Histosols organic carbon density in its different subtypes at 6 standard depth of soil.

Key indicators that needed to estimate soil organic carbon density such as organic matter content and bulk density of some soil profiles from the MOSIS 5 database were incomplete. The number of these deficiencies were estimated by Pedotransfer functions in order to calculate SOCD at 6 standard depth.

Results are given in Table 2 illustrates the estimated soil organic carbon density of Histosols at 6 soil standard depths.

Table 2. Mean value of Histosols organic carbon density, t/ha

	Sub types	Depth, cm	Mean, t/ha	CV, %
Histosols	*Histosols, n=5*	0-5	32.8	46.4
		5-15	53.5	61.6
		15-30	45.2	45.1
		30-60	46.3	54.3
		60-100	17.4	97.4
		100-	3.2	64.5

	200		
Calcic Histosols, n=4	0-5	31.5	29.0
	5-15	58.7	40.8
	15-30	76.8	39.0
	30-60	82.8	41.0
	60-100	13.8	103.4
	100-200	5.3	105.4

Our results shows that the average SOCD at 2 m deep in the peatland is 233.7 t/ha based on 9 soil profiles. *Calcic Histosols* has the organic carbon of 268.9 t/ha, whereas *Histosols* has the 198.4 t/ha (Table 2). Future studies should increase the number of soil samples for both *Calcic Histosols* and *Histosols.*

In terms of depth, the maximum organic carbon accumulated at a 30-60 cm depth with a value of 64.6 t/ha in Histosols, the reason why it is not accumulated in topsoil is its thickness. Nevertheless, the highest SOCD contained in 1 cm thick is in topsoil, approximately 6.4 t/ha per 1 cm at first 5 cm and 5.6 t/ha at 5-15 cm. The minimum density of soil organic carbon is in the bottom layer of 100-200 cm. However, the SOCD values at this depth for all profiles are estimated by pedotransfer functions, not by the results of the field study.

The average coefficient of variation of all samples was 60.4 % (Table 2). This level of variability may have caused by the following reasons: an insufficient number of profiles, data from MOSIS-5 have been made by different people or the same types of soil have different characteristics depending on geographical zones/locations.

Discussion & Conclusions

Soil organic carbon is an important indicator for food production, mitigation, and adaptation to climate change, and the achievement of sustainable development. Also, soils can be a substantial source of greenhouse gas (GHG) emissions into the atmosphere. The soils within peatlands in Mongolia are comparable to Histosols of WRB (World Reference Base for Soil Resources) classification (Batkhishig, 2016). Although, peatlands distributed small area of the world's land surface, it holds high content of soil carbon. This carbon is released to the atmosphere when peatland is drained or when vegetation is removed. When drained or degraded, peatland release the carbon much faster than it has been sequestered (Couwenberg, 2011; Couwenberg et al., 2010). Emissions from drained peat soils (Histosols) are disproportionally large. Drained peatlands are responsible for 6% of total global anthropogenic CO_2 emissions (Joosten, 2010). Therefore, there is a need to know how much organic carbon contained in Mongolian peatlands.

In this study, organic carbon density of Histosols is presented at 6 depths for each soil subtypes. We used 9 soil profile information of mire and meadow for SOCD calculation from Mongolian Soil Information System – 5 (MOSIS-5). Some variables that needed to estimate soil organic carbon density such as organic matter content and bulk density of some soil profiles from the MOSIS 5 database were incomplete. These data were completed by Pedotransfer functions in order to calculate SOCD at 6 standard depth.

Our result shows that the average SOCD at 2 m deep in Histosols is 233.7 t/ha based on 9 soil profiles. *Calcic Histosols* has the organic carbon of 268.9 t/ha, whereas *Histosols* has the 198.4 t/ha. By depth, the maximum organic carbon accumulated at a 30-60 cm depth with a value of 64.6 t/ha in Histosols, the reason why it is not accumulated in topsoil is its thickness. However, the highest SOCD contained in 1 cm layer is in topsoil, approximately 6.4 t/ha at first 5 cm and 5.6 t/ha at 5-15 cm. The minimum density of soil organic carbon is in the bottom layer of 100-200 cm. However, the SOCD values at this depth for all profiles are estimated by pedotransfer functions, not by the results of the field study.

The average coefficient of variation of all samples was 60.4 %. This level of variability may have caused by the following reasons: an insufficient number of profiles, data from MOSIS-5 have been made by different people or the same types of soil have characteristics depending on geographical zones/locations.

Peatlands have higher organic carbon density. Therefore, it is important to increase the area of currently protected peatland in order to reduce its carbon emissions and to prevent future risks.

This research expands and merges prior works related to soil organic content and becomes the first SOCD estimation of Histosols in Mongolia. Few studies have been done in Mongolian wetlands and previous studies have focused mainly on organic content and little attention has been paid for Histosols and its organic carbon density because of its small distribution and difficulty of reaching and surveying. Due to the reasons mentioned above, the number of soil profiles in peatland is small and a 2 meter deep soil profile is rare in Histosols, making it difficult to estimate SOCD, however, it has been done by using pedotransfer functions in this study.

Pedotransfer functions can predict a certain amount of values, however, it is more reliable to estimate SOCD using real values (field work, laboratory analysis). Future studies should increase the number of soil samples, and take samples from 1-2 m deep for SOCD calculation.

References

Adams, W.A. 1973. The effect of organic matter on the bulk and true densities of some uncultivated podzolic soils. Journal of Soil Science 24(21): 10-17.

Asian Development Bank Technical Assistance TA-8802. 2017. Strategic planning for peatlands in Mongolia. Assessment report.

Batkhishig, O. 2016. Soil classification of Mongolia-2016. Mongolian Journal of Soil Science (1): 18-31. *(in Mongolian)*

Batkhishig, O., Nyamsambuu, N., Byambaa, G & Ganzorig, 2017. Mongolian Environment, Volume 4, Chapter 1: Soil.

Batkhishig, O et al. 2013. Updated soil classification and digital mapping of Mongolia. Research work report.

Bonn, A., Allott, T., Evans, M., Joosten ,H & Stoneman, R. 2016. Peatland restoration and ecosystem services: nature-based solutions for societal goals. Cambridge University Press: 404-419.

Dorjgotov, D & Dolzodmaa, S. 1989. Soil Stock and Application of Mongolian People’s Republic. Geographical Review of Mongolia (27): 59-68. *(in Mongolian)*

FAO. 2001. Lecture Notes on the Major Soils of the World. Rome: 19-21, 237.

Fukumoto, Y., Kashima, K & Ganzorig, U. 2014. The Holocene environmental changes in boreal fen peatland of northern Mongolia reconstructed from diatom assemblages. Quaternary International 348 (2014): 66-81.

Lu, Y., Zhuang, Q., Zhou, G., Sirin, A., Melillo & Kicklighter. 2009. Possible decline of carbon sink in the Mongolian Plateau during the 21st century. Environment Research Letters 4 (2009): 1-8.

Joosten, H. 2010. The global peatland CO2 picture: Peatland status and drainage related emissions in all countries of the world. Ede, The Netherlands: Wetlands International.

Minasny, B., McBratney, A.B., Mendonca-Santos, M.L., Odeh, I.O.A & Guyon, B. 2006. Prediction and digital mapping of soi carbon storage in the Lower Namoi Valley. Australian Journal of Soil Science 44: 233-244.

Minayeva, T., Sirin, A & Dugarjav, Ch. 2018. Highland Peathlands of Mongolia. The Wetlands book. Dordrecht, The Netherlands: Springer Science + Business Media.

Minayeva, T., Sirin, A., Dorofeyuk, N., Smagin, V., Bayasgalan, D., Gunin, P., Dugarjav, Ch., Bazha, S., Tsedendash, G & Zoyo, D. 2005. Mongolian Mires: From Taiga to Desert. Stapfia, 85, zugleich Kataloge der OЦ. Landesmuseen Neue Serie №35 (2005): 335-352.

Murray, M. 2004. Dynamics of biodiversity loss and permafrost melt in Lake Khovsgol national park, Mongolia. 2004. GEF Medium Size Project TF028988. Mid-Term Review Final Report. pp 7.

Otgontuya, B. 2010. Wetland soil of Khuvsgul. Geographical Review of Mongolia (6): 114-123.

Parish, F., Sirin, A., Charman, D., Joosten, H., Minayeva, T., Silvius, M & Stringer, L. (Eds.) 2008. Assessment on Peatlands, Biodiversity and Climate Change: Main Report. Global Environment Centre, Kuala Lumpur and Wetlands International, Wageningen.

Russell, J.S & Moore, A.W. 1968. Comparison of different depth weightings in the numerical analysis of anisotropic soil profile data. In 'Transaction of the 9th International Congress of Soil Science'. Adelaide, Vol. IV: 205–213.