Vertical Distribution of 137Cs and Organic Matter and Their Relationship in Wind Erosion Areas: A Case Study of Eastern Junggar, Xinjiang (Postprint)

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Abstract

Through soil sampling of sandy land, bare land, Gobi, cultivated land, and grassland in the Zhundong region of Xinjiang, this study analyzed the distribution characteristics of soil 137Cs and organic matter, estimated and validated soil erosion amounts for various land use types, and explored the relationship between 137Cs and organic matter. The results showed that 137Cs in non-cultivated soils was primarily distributed within 15 cm of the surface, whereas 137Cs in cultivated soils was mainly distributed in the plow layer. 137Cs in non-cultivated land exhibited a decreasing trend with increasing soil depth, while it was uniformly distributed in cultivated land. Soil organic matter in grassland decreased with increasing soil depth, organic matter content in Gobi and bare land showed no significant variation, and organic matter content in cultivated land was uniformly distributed. The 137Cs content across different land use types generally followed the order: grassland > fixed sandy land > Gobi > cultivated land > bare land > semi-fixed sandy land, while organic matter content followed: grassland and cultivated land > Gobi > fixed sandy land > semi-fixed sandy land and bare land. The discrepancies in soil erosion rates estimated using the 137Cs tracer method at various sampling points indicated that the 137Cs tracer technique is not reliable for measuring soil wind erosion in wind-eroded regions. 137Cs and organic matter in Zhundong soils exhibited weak correlation or no correlation, and the use of 137Cs to monitor soil organic matter dynamics in the Zhundong wind erosion area was not effective.

Full Text

1. Study Area and Methods

1.1 Study Area

The study area is located in the eastern part of the Junggar Basin, Xinjiang, with an elevation ranging from 800 to 1473 m. The region features a temperate arid climate. Sampling sites were selected across five different land use types: fixed sandy land, semi-fixed sandy land, Gobi desert, steppe, and cultivated land.

1.2 Sample Collection and Analysis

Soil samples were collected at 2 cm depth intervals. The 137Cs content was measured using a gamma spectrometer with a high-purity germanium detector at 661.6 KeV, with a counting time of 80,000 seconds. Soil organic matter (SOM) content was determined by the potassium dichromate oxidation method.

1.3 Vegetation Characteristics

The main vegetation types in the study area include Haloxylon ammodendron (C.A. Mey.) Bunge, Anabasis salsa (C.A. Mey.) Benth. ex Volkens, Reaumuria songonica (Pall.) Maxim., Salsola collina Pall., Ceratoides latens (J.F. Gmel.) Reveal et Holmgren, and Iijinia regelii (Bunge) Korov.

2. Distribution Characteristics of 137Cs and Soil Organic Matter

2.1 Vertical Distribution of 137Cs

The 137Cs was basically distributed within 15 cm of soil depth in non-arable land, and mainly concentrated in the plough layer of cultivated land. In non-cultivated land, 137Cs content decreased with increasing soil depth, while in farmland it showed a uniform distribution.

2.2 Relationship Between 137Cs and Land Use Types

The total 137Cs content followed the order: steppe > fixed sandy land > Gobi desert > cultivated land > bare land > semi-fixed sandy land. The soil organic matter content showed the order: steppe and cultivated land > Gobi desert > fixed sandy land > semi-fixed sandy land and bare land.

2.3 Correlation Analysis

Correlation coefficients between 137Cs and SOM in different land use types are shown in Table 3. The results indicate a weak or no significant correlation between soil 137Cs and organic matter content in the east Junggar Basin.

2.4 Soil Erosion Rates

Soil erosion rates estimated by the 137Cs tracer method varied significantly among different sampling sites. The differences between wind erosion rates determined by the 137Cs tracer technique and actual measured results were significant. The erosion rates ranged from -15.66 to 840.69 $t \cdot hm^{-2} \cdot a^{-1}$, with an average of 142.04 $t \cdot hm^{-2} \cdot a^{-1}$.

2.5 Soil Particle Size Distribution

The particle size distribution in soil samples is presented in Table 4. The results show that 137Cs is primarily associated with fine particles, and its distribution is significantly affected by soil particle composition.

3. Discussion

The relationship between 137Cs and soil organic matter is influenced by multiple factors including land use type, vegetation cover, and soil erosion intensity. Previous studies have shown that 137Cs is mainly adsorbed on fine soil particles, particularly on clay and silt fractions. The weak correlation between 137Cs and SOM in this study may be attributed to the specific environmental conditions of the wind erosion zone, where wind sorting processes redistribute soil particles and associated 137Cs differently than in water erosion environments.

4. Conclusions

The study demonstrates that 137Cs is an effective tracer for soil erosion in wind erosion zones, but its relationship with soil organic matter is complex. The distribution patterns of both 137Cs and SOM are strongly controlled by land use type and soil depth. The weak correlation between 137Cs and SOM suggests that caution should be exercised when using 137Cs as a proxy for SOM distribution in arid wind erosion regions.

Table 2. Characteristics of 137Cs content, soil erosion rate and soil organic matter content in soil samples

<table>
<tr><th>Sampling Site</th><th>137Cs Content (Bq · kg^{-3})</th><th>137Cs Inventory (Bq · m^{-2})</th><th>Soil Erosion Rate (t · hm^{-2} · a^{-1})</th><th>Slope Length (m)</th><th>SOM Content (g · kg^{-1})</th></tr>
<tr><td>Steppe (Reference)</td><td colspan="5">1062.27$±74.06a|1669.79|872.22|27.07|40.9025|9.93a||FixedSandyLand|1318.03|1057.7|1079.19±44.96ab|592.34|27.03|0.0025|
fixedSandyLand|1167.94±91.61b|479.44|90.89|0.0078|2.47c||GobiDesert|1467.73±188.32c|1710.58|−
0.20| −
0.0000|6.62a||BareLand|1491.87±140.23c|171.52|172.04|0.012|1.99c||CultivatedLand|1538.70±107.0
5.53| −
0.0004|3.71ac||WindErosionZone|1476.47±100.01c|2308.02|−
15.66| −
0.0011|13.64d||ReferenceSite|991.04±$82.42a</td></tr>
</table>

Note: Different letters indicate significant differences at P<0.05 level.

Table 3. Correlation coefficients between 137Cs and SOM in soil samples

Land Use Type	Correlation Coefficient
Wind Erosion Zone	0.7525*
Fixed Sandy Land	0.1567
Semi-fixed Sandy Land	0.6736*
Gobi Desert	-0.3473
Bare Land	0.0704
Cultivated Land	0.3778
Steppe	0.4407
Monsoon Region	-0.0365
Reference Site	0.0004

*Significant at P<0.05 level.

Table 4. Distribution of soil particle size in soil samples

Land Use Type	Clay (%)	Silt (%)	Sand (%)
Wind Erosion Zone	91.52	93.01	52.58
Fixed Sandy Land	88.03	63.83	81.21
Semi-fixed Sandy Land	99.99	37.83	10.91
Gobi Desert	33.45	18.05	-

References

[1] Hessel R, vandenBosch R, Vigia O, et al. Evaluation of the LISSEM soil erosion model in two catchments in the East African Highlands[J]. Earth Surface Processes and Landforms: The journal of the British Geomorphological Research Group, 2006, 31(4): 469-486.

[2] Creamer RE, Brennan F, Fenton O, et al. Implications of the proposed soil framework directive on agricultural systems in Atlantic Europe: A review[J]. Soil Use and Management, 2010, 26(3): 198-211.

[3] Pu Lijie, Han Shucheng, Jin Pinghua, et al. Relationship between 137Cs content and composition of soil particles in red soil region: A case study of Fengcheng City[J]. Soil and Water Conservation Science, 2006, 26(4): 11-15.

[8] Walling DE, He Q. Improved models for estimating soil erosion rates from caesium-137 measurements[J]. Journal of Environment Quality, 1999, 28(2): 611-622.

[9] Lowrance R, Mclntyre S, Lance C. Erosion and deposition in a field/forest system estimated using caesium-137 activity[J]. Journal of Soil and Water Conservation, 1988, 43(2): 195-198.

[10] Li Y, Zhang QW, Reicosky DC, et al. Using 137Cs and 210Pbex for quantifying soil organic carbon redistribution affected by intensive tillage on slopes[J]. Soil and Tillage Research, 2006, 86(2): 176-184.

[11] Zhang Mingli, Yang Hao, Wang Xiaolei, et al. Soil 137Cs background values in Monsoon region of China[J]. Journal of Nuclear Agricultural Sciences, 2009, 23(4): 669-675.

[12] Qi Yongqing, Zhang Xinbao, He Xiubin, et al. 137Cs reference inventories distribution pattern in China[J]. Nuclear Techniques, 2006, 29(1): 42-50.

[13] Yan Ping, Dong Guangrong. Characteristics of soil microorganisms and soil nutrients in different sand-fixation shrub plantations in Kubuqi Desert, China[J]. Chinese Journal of Applied Ecology, 2017, 28(12): 3871-3880.

[14] Xu Hong, Wei Jiguan, Zou Wenliang, et al. 90Sr and 137Cs levels in soil around Xinjiang nuclear test site[J]. China Journal of Radiology and Protection, 1986, 6(6): 395-398.

[15] Walling DE, Quine TA. Use of Caesium-137 as A Tracer of Erosion and Sedimentation: Handbook for the Application of the Caesium-137 Technique[M]. Department of Geography, University of Exeter, Exeter, 1993: 15-34.

[16] Cao Yue' e, Zhang Tingting, Yang Jun, et al. Grain size analysis and estimation on wind erosion amount in different land-use types of Zhundong Area[J]. Journal of Xinjiang University (Natural Science Edition), 2017, 34(2): 140-145.

[21] Wang Jian, Wu Faqi, Meng Qinqian. Benefits of tillage measures for soil and water conservation[J]. Bulletin of Soil and Water Conservation, 2004, 24(5): 39-41.

[22] Li Zijun, Yu Xingxiu. Characteristics of surface runoff and its influencing factors on slope scale in rocky mountain area of northern Hebei province[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(17): 109-116.

[23] Zhang Lixin, Duan Yuxi, Wang Bo, et al. Application of the caesium-137 technique on wind erosion in the Gonghe Basin, Qinghai Province[J]. Chinese Journal of Applied Ecology, 2013, 24(11): 3300-3310.

[24] Xu Hong, Wei Jiguan, Zou Wenliang, et al. Effects of environmental factors on litter decomposition in arid and semi-arid regions: A review[J]. Chinese Journal of Applied Ecology, 2013, 24(11): 3300-3310.

[25] Aoyama M, Angers DA, N' Dayegamiye A. Particulate and mineral-associated organic matter in water-stable aggregates as affected by mineral fertilizer and manure applications[J]. Canadian Journal of Soil Science, 1999, 79(2): 295-302.

[26] Yu Shuting, Zhao Yali, Wang Yuhong, et al. Improvement effects of rotational tillage patterns on soil in winter wheat-summer maize double cropping area of Huang-Huai-Hai Region[J]. Scientia Agricultura Sinica, 2017, 50(11): 2150-2165.

[27] Tang Xinyi, Guan Dongsheng. 137Cs inventories and soil organic carbon content in soils of three typical terrestrial ecosystems[J]. China Environmental Science, 2012, 32(4): 710-714.

[28] Yan Ping, Zhang Xinbao. Prospects of caesium-137 used in the study of aeolian processes[J]. Journal of Desert Research, 1998, 18(2): 87-92.

[29] Zhang Chunlai, Dong Guangrong, Dong Zhibao, et al. Time problem in calculating soil wind erosion rate with tunnel experiment[J]. Journal of Desert Research, 1996, 16(2): 200-203.

[30] Fang Haiyan, Sheng Meiling, Sun Liying, et al. Using 137Cs and 210Pbex to trace the impact of soil erosion on soil organic carbon at slope farmland in the black soil region[J]. Chinese Journal of Applied Ecology, 2013, 24(7): 1856-1862.

Abstract

The effect of soil organic carbon (SOC) loss caused by soil erosion has become a focus in the study of carbon cycles in arid areas. The relationship between 137Cs and soil organic carbon can be used to monitor SOM and provide references for preventing and controlling nutrient loss in arid regions. Soil samples were collected at 2 cm depth intervals from sandy land, bare land, Gobi desert, steppe, and arable land in the east Junggar Basin, Xinjiang. The SOM and 137Cs of soil samples were measured, and the 137Cs tracer method was used to estimate the soil erosion rates of five different land use types. Synchronously, the relationship between SOM and soil 137Cs in different land use types was discussed. The results showed that 137Cs was basically distributed within 15 cm of non-arable soil depth, and mainly in the plough layer of cultivated land. The 137Cs was decreased with the increase of soil depth in non-cultivated land, and there was a uniform distribution in the farmland. The SOM of steppe was in a decrease trend with the increase of soil depth. The change of organic matter content in Gobi desert and bare land was not significant, and the organic matter content in cultivated land was distributed uniformly. The total 137Cs content was in an order of steppe > fixed sandy land > Gobi desert > cultivated land > bare land > semi-fixed sandy land, and the organic matter content was in an order of steppe and cultivated land > Gobi desert > fixed sandy land > semi-fixed sandy land and bare land. The soil erosion rates estimated by 137Cs tracer method were quite different from the different sampling sites. The differences between the values of wind erosion determined by the 137Cs tracer technique and the actually measured results were significant. There was a weak or no correlation between soil 137Cs and organic matter content in the east Junggar Basin.

Keywords: wind erosion zone; 137Cs; SOC; land use type; soil erosion rate; arid area

Note: Figure translations are in progress. See original paper for figures.