**The dynamics and spatial variability of soil organic carbon content under grasslands in Southern Karelia**

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Abstract: Soil organic carbon is a soil property of major importance for soil quality and global carbon cycle. The distribution of soil organic carbon (SOC) in the landscape is governed by multiple factors and processes occurring at various scales. In this paper classical statistics and geostatistics analysis methods were used to quantitatively assess the spatial characteristics of the soil organic carbon and their relation to the topographic factors and land use. The classical statistics analysis results indicated that the variability of SOC was strong. The geostatistics analysis showed that SOC had strong spatial correlation. The map of SOC dynamics as a difference between two sets of data for the years 2003 and 2013 was constructed. The map showed that the organic matter loss was observed at the major part of the area, and the rate of the loss was strongly heterogeneous.

Key words: soil organic carbon, grassland, dynamics, spatial variability, geostatistics

In early studies on the impact of agriculture on soil, the positive effect of plowing, liming and fertilizing was emphasized. Soil management led to the formation of plow horizons enriched in carbon. In recent years, the focus is on the loss of soil organic carbon (SOC) and its emission to the atmosphere, which is believed to have a negative impact on soil and environment. The balance of biophylic elements in soil after amelioration depends on the natural zone, specific soil and environmental conditions, and the practices of land use (Mann, 1985; Smith et al., 2001; Takata, 2010; VandenBygaart, 2006; VandenBygaart et al., 2003; VanWesemael et al., 2005; Wei et al., 2008).

The aim of this work was to assess quantitatively the spatial characteristics of the SOC and their relation to the topographic factors and land use, and to estimate the influence of the change in agricultural practices on SOC content. We intend to obtain objective data on the impact of human activity on carbon balance in the soil and to identifying the role of northern agro-ecosystems in global carbon cycles.

The investigation was carried out in Southern Karelia (North-West of Russia, 61о49'N, 33o10’E). The studies were carried out in summer of 2003 and 2013. The within-field variability of SOC content was examined.

The total area of the studied field was 50 ha. The dominant soils at the plots included Agric Podzols, Histic Gleysols and Histosols. The field has been drained in 1963, and till 2005 it was used as a hayfield. The main grass species was *Dactylis glomerata.* At present this field is not cultivated and develops as natural grassland. The major plant species are *Dactylis glomerata, Elymus repens* and *Cirsium arvense*. The part of the field on Histosols is subjected to secondary swamping. The dominant species at these wet plots are *Salicaceae* and *Chamaenerion*.

We collected soil samples of a plough layer following a random-regular pattern with a lag distance of 100 m. The soil samples were analysed for organic carbon content using wet oxidation method. The dependence of the organic C content on the sampling point coordinates was examined by regression analysis. Spatial variability of organic carbon content was subjected to variogram analysis. Both omnidirectional variograms and variograms for the directions along and across the drains were plotted. Where a trend was found, variograms were built both for source and detrended data.

The classical statistics analysis results indicated that the variability of the SOC was high (table 1). The range of values was quite broad and the coefficient of variation was above 60%. The high level of variability could be caused by uneven content of mineral and peaty materials in plough layer of cultivated soils. The comparative analysis of plots showed that there was not a statistically significant difference between the means, standard deviations and medians of organic carbon content in different years.

Table 1: Statistical indices of SOC content of surface soil horizons

|  |  |  |
| --- | --- | --- |
| **Statistical index** | **C, % (2003)** | **C, % (2013)** |
| Range of values | 30,88 | 26,16 |
| Min | 2,18 | 2,06 |
| Lower quartile | 6,42 | 6,51 |
| Median | 10,38 | 11,07 |
| Upper quartile | 18,69 | 20,68 |
| Max | 33,06 | 28,22 |
| Mean | 13,64 | 12,77 |
| Variance | 90,45 | 64,78 |
| CV, % | 69,71 | 63,05 |
| Kurtosis | -0,74 | -1,13 |
| Skewness | 0,78 | 0,41 |

The simplest way to model large-scale spatial heterogeneity is to draw the regression line or surface using empirical data from individual points (trend surface analysis). This method is a particular case of multiple regression in which empirical values of the variable in question are related to independent variables – locations of sampling points. A trend is an increase (or decrease) in the value along a certain direction gradient.

We applied the least squares method to the data for both years to select the quadratic surface (2nd order trend) in the form(Jongman et al., 1995) :

z = b0 + b1x + b2y + b3x2+b4y2+b5xy.

The surfaces accounted with quite high probability (95%) for the variation in carbon content (53.4% in 2003 and 49.7% in 2013). This change corresponds to the direction from the hill with prevailing mineral soils in the lowlands on peat soils. However, obvious correlation between the elevation of the sampling point and the soil organic content was not revealed.

The variograms for SOC for both years were represented quite well by the spherical model in the form (McBratney & Webster, 1986):



The geostatistical analysis showed that the soil organic carbon had a strong spatial correlation (table 2, fig. 1). The C0/(C0+C) relations were less than 25% in both cases. Parameters of ​​semivariograms were almost identical, but in the case of grassland all the parameters were less.

Table 2: Model parameters of semivariograms for the soil organic carbon content

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | C0 | C | Range, m | C0/(C0+C), % |
| 2003 | 16.72 | 70.39 | 280 | 19.2 |
| 2013 | 11.52 | 57.60 | 220 | 16.7 |

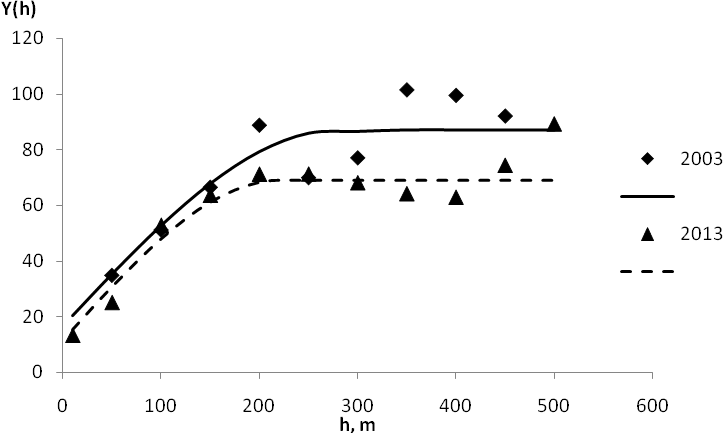


Figure 1:Semiariogram models for soil organic carbon content, %2. The dots indicate the semivariance, the lines are the corresponding models.

The difference between the anisotropic semivariograms for the organic carbon content was registered. In the semivariograms developed for the direction across the drains we observed a well expressed periodicity (fig. 2).

0

50

100

150

200

250

300

350

400

450

500

0

9

18

27

36

45

54

63

72

81

**h, m**

**(|h|)**

****

Figure 2: Anisotropic variograms of organic carbon content on the drained plot: the direction across the drains

Kriging was used to convert the punctual soil data into continuous fields of SOC contents. For the two sampling dates we constructed interpolated maps of organic carbon content and the map of SOC dynamics as a difference between two sets of data (fig.3).



Figure 3: Map of SOC dynamics 2003-2013

The map showed that the organic matter loss was observed at the major part of the area, and the rate of the loss was strongly heterogeneous. In the western part of the site in Agric Podzols and Histic Gleysols the organic carbon contend increased. The interpretation is that at meadow fallow the process of peat humification continues in these soils thus increasing the C:N ratio. In contrast, in Histosols in the eastern part of the site thepeat mineralized with an absolute loss of organic carbon.. So, the organic matter loss was observed at the major part of the area.

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