Organic carbon in Russian soils: A specified spatially explicit assessment

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Abstract

There are several estimations of soil organic carbon of Russia (Orlov et al., 1996; Rozhkov et al., 1996; Alexeyev, Birdsey, 1998; Nilsson et al., 2000; Stolbovoi, 2002; Chestnyh et al., 2004; etc.) which presented a large range of reported stock of carbon, particularly for individual land classes (forest, wetland etc.). In order to provide the most reliable estimate, we developed an aggregated model which attempts to apply advantages of methods used in the mentioned above publications. We used all available information at the country's scale: soil and other maps, remote sensing products, in situ measurement database, land statistics and others. A number of modeling clarifications have been introduced (corrections for the method used for empirical assessment of soil carbon, land use type, regional and vegetation specifics). The method is realized in a form of a dynamic system, which is able to assimilate any new information on soil, vegetation type and land use.

Methodology

The initial data we used for the soil organic carbon were following.

- Soil map of Russia 1:2.5M (Fridland, 1988) with soil profile database (Stolbovoi, McCallum, 2002) – the most detailed soil spatial distribution dataset , covered all Russian territory. It has been digitize by Dokuchaev Soil Science institute. We update the database with new information.
- Soil organic carbon measurements in situ (IIASA in-house database). It was used to update the soil map description and take into account particularities of region, land use, vegetation and disturbances.
- Hybrid land cover of Russia (Schepaschenko et al., 2010) represents the most up-to-date spatial distribution of vegetation and land use at resolution of 1 km.
- Vegetation zone map (Stolbovoi, McCallum, 2002).
- Administrative division map.

Using the typical soil profiles discription and soil organic carbon database we calculate the range (min and max value) of possible carbon content for each soil type by the equation.

$$C = \sum_{i=1}^{n} \left(H\, K_C\, D\, L\, K_S\, K_{meth} \times 10 \right) \qquad (1)$$

where C – soil carbon, kg m^{-2}; n – number of soil horizons in profile; H – carbon content, %/100; D – bulk density, g cm^{-3}; L – thickness of horizon, cm; K_s – correction for stoniness; K_{meth} – correction for the measurement method; 10 – conversion factor : g cm^{-2} into kg m^{-2}.

The actual carbon content for each grid sell was adjusted depend on region, land use, disturbances regime, main tree species by following equation.

$$C = \left(C_{\min} + \frac{C_{\min} - C_{\max}}{2} K_{reg}\, K_{sp} \right) K_{LU} \qquad (2)$$

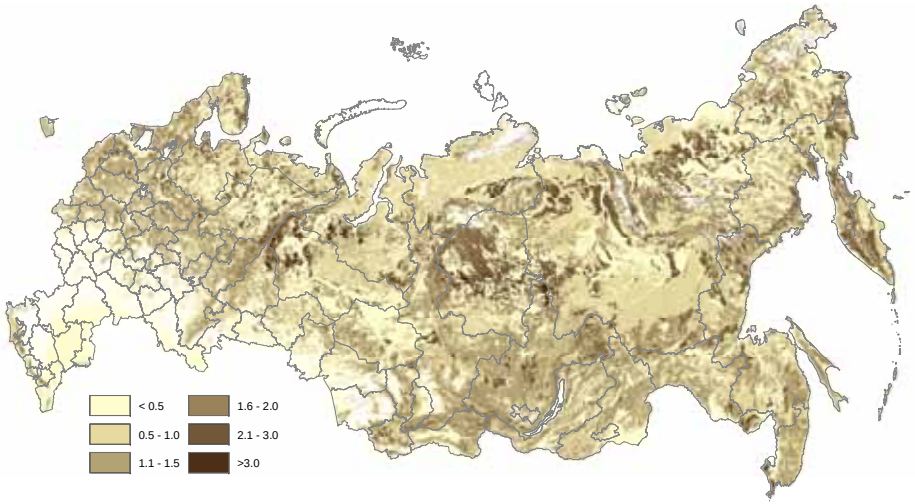
where C_{min} and C_{max} – minimum and maximum carbon content in the certain soil, calculated by the equation (1); K_{reg} – correction for the region; K_{sp} – correction for the main tree species; K_{LU} – correction for land use and disturbances.

Results

The results are represented by soil organic carbon map, which is parameterized by each 1 km pixel. It contains two layers: on-ground organic layer (OL) and 1 meter of soil below. Total amount of organic carbon accumulated in Russian soil assessed as 317.1 Pg C. The most dynamic part – on-ground organic layer comprises 14.4 Pg C. The average carbon content is 19.2 kg C m^{-2} (0.87 in the OL). Forest soils have less average carbon content (17.6 kg C m^{-2}), but higher OL (1.01 kg C m^{-2}) compare to other land use type.

Distribution of soil organic carbon by region, zone and land use class are presented at the table 1. Comparison with other estimations are shown in the table 2. Our overall result is in the range of others. It distinguishes among others by high spatial resolution and it based on all available, most up-to-date information.

On-ground organic layer, kg C m^{-2}



Soil organic carbon (onground organic layer + 1 m below), kg C m^{-2}

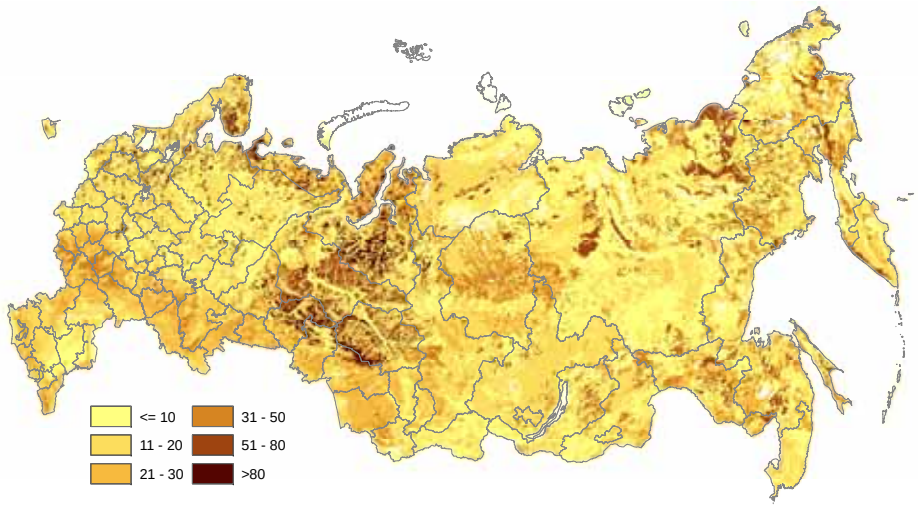


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Table 1. Distribution of average soil organic carbon by region, zone and land use

Region / Zone	Average soil organic carbon content, kg C m^{-2} by land use type									Total
	no veg.	forest	sparse forest	burnt area	arable	hayfield, pasture	fallow	wetland	grass- & shrubland	
European part										
Arctic	0.05								1.74	0.11
Tundra	0.61	28.85	33.41	4.17	0.00	18.15	6.12	44.48	17.06	27.57
Sparse & northern taiga	4.26	19.68	19.09	14.97	10.59	9.95	8.91	40.19	18.07	24.22
Middle taiga	2.42	13.75	15.96	9.97	34.65	9.66	13.47	38.67	14.19	15.59
Southern taiga	3.06	14.59	13.66	12.85	10.85	9.93	9.21	64.64	14.96	14.74
Moderate forest	7.02	17.12	17.90	20.43	19.80	16.67	19.01	38.18	19.65	18.39
Steppe	7.71	25.42	27.16	25.72	24.49	21.52	24.30	26.86	21.73	23.58
Semi desert	2.95	17.95	23.01	14.21	7.18	7.42	7.92	7.49	7.96	7.69
Subtotal	**0.52**	**16.21**	**20.25**	**13.87**	**22.19**	**15.16**	**15.73**	**43.24**	**17.51**	**18.99**
Asian part										
Arctic	0.41								9.47	1.14
Tundra	2.06	18.16	20.71	13.84	0.00	10.40	7.22	38.98	13.82	16.73
Sparse & northern taiga	5.25	22.00	27.11	11.06	9.27	12.50	12.95	44.83	14.26	24.52
Middle taiga	2.78	15.87	14.88	15.22	13.65	11.96	15.01	45.71	14.41	17.23
Southern taiga	5.00	22.31	29.44	27.72	17.50	14.76	17.44	62.95	24.73	26.19
Moderate forest	5.21	16.73	35.66	25.85	21.08	17.97	18.41	36.17	24.16	18.66
Steppe	5.47	22.70	28.43	24.10	23.93	19.91	24.06	19.01	20.86	21.86
Semi desert	1.01	17.15	8.14	11.33	18.65	15.84	19.66	13.69	10.24	14.72
Subtotal	**2.07**	**17.96**	**19.94**	**14.93**	**22.50**	**17.10**	**19.52**	**44.39**	**14.35**	**19.24**
Russia total										
Arctic	0.20								6.54	0.56
Tundra	1.96	20.24	24.31	13.72	0.00	11.92	6.71	39.99	14.02	17.83
Sparse & northern taiga	5.22	21.44	26.24	11.07	9.75	12.16	10.90	43.40	14.37	24.45
Middle taiga	2.78	15.62	14.91	15.19	18.95	11.64	14.77	44.92	14.41	17.07
Southern taiga	4.09	19.38	15.65	25.86	13.11	11.64	11.01	63.26	20.91	21.22
Moderate forest	6.39	16.90	20.08	25.02	20.02	17.09	18.75	36.50	20.98	18.50
Steppe	6.26	23.61	27.44	24.63	24.33	20.70	24.21	19.79	21.49	22.87
Semi desert	1.83	17.39	19.12	12.27	13.31	8.95	10.24	12.08	8.33	9.36
Total	**1.82**	**17.60**	**19.99**	**14.92**	**22.28**	**16.05**	**17.14**	**44.17**	**14.63**	**19.19**

Table 2. Comparison of our estimations with others

Average soil organic carbon content (Total Russia / Forested area)				References
on-ground organic layer		1 m of soil		
kg C m^{-2}	relation to our estimation, %	kg C m^{-2}	relation to our estimation, %	
1.03 / –	118 / –	22.1 / –	115 / –	Vinson, Kolchugina, 1993
		17.3 / 17.0	90 / 97	Orlov et al., 1996
		20.6 / 20.3	107 / 115	Rozhkov et al., 1996
– / 1.80	– / 178	– / 9.6	– / 55	Alexeyev, Birdsey, 1998
1.04 / 1.50	119 / 148	18.0 / 11.5	94 / 65	Nilsson et al., 2000
		– / 14.8	– / 84	Utkin et al, 2001
		18.3 / 11.5	95 / 65	Stolbovoi, 2002, 2006
		– / 15.9	– / 90	Shvidenko et al., 2003
– / 0.72	– / 71	– / 16.2	– / 92	Chestnych et al. 2004, 2007
		– / 15.9	– / 90	Zamolodchikov et al., 2005
0.87 / 1.01	100 / 100	19.2 / 17.6	100 / 100	our current estimation

References

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