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Distributed GIS for Estimation of Soil Carbon Stock of West Siberia Boreal Zone

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Distributed GIS developed to assess the soil carbon resources includes digital maps "Vegetation" and "Soil" of boreal zone of West Siberia, middle-scale soil maps of the key sites of landscape provinces that have been created on the basis of interpretation of satellite images, and the software for updating and management of the database "Carbon in soils of Siberia". According to preliminary estimates the resources of C_{org} in the soil of the boreal zone is 83.6×10^8 t which is 28.2% of the resources of C_{org} in soils of Russia or 15.2% of its world reserves.

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Validity of study importance. Estimation of functional role of soil cover is of high priority and pressing in solving problems of global climate change. Soils as also ground vegetation are found the most sensitive to climate change and, in its turn, can have an influence on climate change [1]. These links are substantially realized through biogenic turnover which is shown in carbon cycle. According to present-day information the C_{org} stocks in terrestrial biocoenoses of the world are estimated as 550 Gt and in ecosystems of Russia as 40 Gt. The C_{org} reservoirs of Russia make 39.8 Gt in the forest phytomass and 296 Gt in soil humus—this is 7.2% of the phytomass carbon and 19.7% of soil carbon in the world.

On the Russian area as also in other countries of the Eurasian north the highest carbon sink is noted in soils and forests of boreal zone. By overall estimation of the Centre on problems of forest ecology and productivity of RAS over 70% of phytomass carbon and about 80 % of soil carbon fall on coniferous forests (Table 1).

The boreal biome of West Siberia plays a great role in the presented balance. Its soil cover is characterized by wide development of peat and peat-bog soils with high and superhigh (180–800 t/ha by the scale of C_{org} stock levels) amount of organic carbon. Equally with high organogenic soils a great contribution to formation of total C_{org} stocks of the region is brought by shallow-peatified and mineral soils which take large areas and contain under peat horizon from 4 to 10% of organic carbon what forecasts its rather high stocks in mineral soil horizons of boreal biome as a whole.

Generally the C_{org} stocks in soils and phytomass of boreal zone can be presented according to calculations of carbon pool in bogs of West Siberia or by available cartographic and thematic data banks. However, the most these estimations were performed using small-scale maps for territories where administrative regions are as structural units or only for bog areas with no taking into account mineral soils [3–7]. Therefore the major objective of this research is making the integrated cartographic base of vegetation and soil cover as well as creation of software, compatible with cartographic base, to process specialized data banks of C_{org} stocks in soil and phytomass. The following blocks can be conditionally named in the structure of distributed GIS: 1, digital (electronic) maps "Vegetation" and "Soil" of boreal zone in West Siberia; 2, software for updating and managing the data bank "Carbon in soils of Siberia"; 3, mid-scale soil maps of key sites of the main landscape provinces of West Siberia; 4, the model of digital map "C_{org} stocks in soils of boreal zone of West Siberia". Single blocks of spatially distributed GIS are presented in this paper.

Digital maps "Vegetation" and "Soil" of boreal zone in West Siberia. Vegetation is as the main source of organic part of soil. In the most terrestrial ecosystems the C_{org} stock in soils depends greatly on productivity of ground vegetation. The C_{org} stock naturally increases in soils of boreal zone from podzolic (2–3%) to soddy-podzolic and grey forest (4–6%) of coniferous-small leaved forests to 30–40% in peaty and peat soils of paludified forests and moss bogs. Since there is a close dependence of formation of C_{org} stocks in soils on types of phytocoenoses then the cartographic and thematic maps were made based on generalized legend of the "Vegetation of West Siberian plain" map, 1976, that was presented by Central Siberian Botanical Garden of SB RAS. At developing the legend of this small-scale map (1 : 7 500 000) two basic hierarchical

Table 1. Carbon reserves in soils of different climatic zones of Russia (G. A. Zavarzin and V. N. Kudeyarov, 2006)

Zone	Area, million ha	C_{org} stocks in 0–100 cm soil layer	
		t/ha	Gt
Polar- tundra	181	106	19.2
Forest tundra-northern taiga	233	168	39.4
Middle taiga	238	219	52.0
Southern taiga	237	262	61.9
Forest steppe	126	304	38.4
Steppe	80	267	21.3
Dry steppe	28	100	2.8
Semidesert	15	73	1.1
Total	171.4		296.1

levels were used: subzonal peculiarities of forest vegetation growing on plains and low plateau as well as units of regional dimension which present dominating ecological-geographical vegetation types or typical combinations of several ecologically different types. The complete legend embraces 29 elements which are combined into 5 categories. The digital map "Soil" (1 : 7 500 000) is coupled with the map "Vegetation" of boreal zone of West Siberian plain and is made in common principles of creating a legend, its structure, size and content of the main mapped units in the vegetation map.

Types of vegetation and biological turnover are close connected with the types of soil formation in the study area as in other bioclimatic zones. Geographically such regularity shows that soil zones with soils of prevalent certain zonal type agree well with vegetation zones. Similar regularity can be traced when comparing the content of digital soil and vegetation maps (Table 2).

Within zonal-subzonal division a high compatibility level of borders and information content of soil and vegetation cover contours is highly recognized. Combined typological map units of soils obtained in the result of compilation agree well with the types and groups of types of plant associations. For instance, large areas of forest tundra-northern taiga zone which are taken by disordered- patchy, mound- tussock, flat- and large palsa (hilly) soil complexes are in good spatial compatibility with stunted low paludified forests and open forests coupled with vast massifs of moss bogs. In the same zone the illuvial-humus-iron, also peaty- and peat-gley podzols are formed on drained sites under dark-coniferous forests. Large-contour combinations of ridge-bog hollow, ridge-pool complexes of peat soils as well as vegetation complexes of oligotrophic pine-dwarf shrub-sphagnum bogs are widely represented in middle taiga subzone. In southern taiga the soddy-deep podzolic soils with the second humus horizon, typical of this region, correspond to local contours of dark coniferous and pine-birch with grass moss forests and the small contour combinations and complexes of grey forest soils with birch and aspen grassy forests are characteristic of subtaiga. The established correspondence of borders and information content of soil and vegetation contours on these electronic maps is supposed to be used later for describing the present-day geographic and temporal distribution of carbon stocks and fluxes in ecosystems of boreal zone.

Updating the data base "Carbon in soils of Siberia". C_{org} stocks were calculated based on data bank "Organic carbon". This data bank involves values of humus amount in 5850 and bulk weight in 2300 soil pits of Siberia. Additionally a specialized data block on humus amount in soils of boreal zone was formed which includes a great massif of literature and own data for the last 15 years of studies. The data bank "Organic carbon in soils of boreal zones" involves presently 480 values of humus amount and bulk weight in 70 soil pits in boreal zone of West Siberia. Every pit has a coordinate binding to the proper contour of soil and vegetation cover.

Mid-scale soil maps of key sites of the main landscape provinces of West Siberia. Materials of detailed interpretation of typical landscapes and natural complexes taking into account also spatial characteristics of the area and soil properties have a great importance in assessing C_{org} stocks. Usage of remote sensing information for assessing C_{org} stocks was improved on key sites located within landscape provinces of boreal zone. Typological regions were marked off taking into account principles of landscape regioning. The essence of the method is in the coupled analysis of regional structures which are fairly shown on satellite images and recorded on landscape- typological maps. Individual geomorphological units were marked off on satellite images as detached ones by the regular composite of structural elements and also by clearly interpreted natural and anthropogenic factors of soil cover differentiation.

Mid-scale soil maps of key sites were made according to interpretation data of satellite images Landsat with the following ArcGis vectorization. The land-

Table 2. Correlation of legend units of digital maps "Vegetation" and "Soil" of West Siberian boreal zone

Legend units	In vegetation map of West Siberian plain, 1976	In soil map of RF, 1989, in synonyms Soil classification of RF, 2004
1.	Larch and spruce-larch open forests	Complexes of mound-tussock tundra gley peat-humus soils and soils of patches
2.	Yernik tundra with larch open woods and flat palsa bogs	Complexes of disordered-patchy tundra and taiga gley peaty-humus, gley non-differentiated soils and soils of patches
3.	Dwarf shrub-sedge-moss-lichen and roller-polygonal complex bogs	Complexes of polygonal- roller peat-bog, tundra gley peaty and peat soils and frost-fissured soils
4.	Larch-spruce and spruce green moss-lichen and green moss open forests with yernik-sphagnum-lichen flat-palsa bogs	Gleyzems of taiga and gleyzems weak gley differentiated
5.	Larch-spruce-Siberian pine lichen-green moss-dwarf shrub forests with Siberian pine-birch secondary forests	Gleyzems and weak gley differentiated peaty and podzolized taiga gleyzems
6.	Pine-Siberian pine-larch lichen forests with dwarf shrub-sphagnum bogs	Illuvial-iron and illuvial-humus podzols
7.	Larch and spruce-larch open forests with flat- and large palsa bogs	Peaty- and peat gleyzems
8.	Larch and spruce-larch lichen-moss-dwarf shrub green moss forests and open forests	Complexes of disordered-patchy taiga gley peaty-humus, gley-differentiated soils and soils of patches
9.	Larch-pine lichen- green moss-dwarf shrub forests combined with pine lichen forests and dwarf shrub-moss-lichen large palsa bogs	Illuvial-iron podzols
10.	Dwarf shrub-moss-lichen flat palsa complex bogs	Flat- and large palsa complexes of peat bog raised and transitional bog degrading (being mineralized) soils
11.	Lichen-sphagnum-plateau like oligotrophic bog-pool complexes	Ridge-bog hollow and pool bog complexes of raised and transitional peat bog soils
12.	Spruce-Siberian pine-polytric and dwarf shrub-sphagnum forests with dwarf shrub-sphagnum oligotrophic bogs	Peat- podzolic- gley soils
13.	Pine and birch-pine forests with oligotrophic bogs	Peat oligotrophic and eutrophic soils
14.	Sphagnum pine-dwarf shrub oligotrophic domed bogs with pine and Siberian pine on ridges and sphagnum bog hollows as well as pine-dwarf shrub-sphagnum oligotrophic bogs	Peat oligotrophic soils
15.	Sedge-hypnum and grassy eutrophic bogs	Peat eutrophic soils
16.	Fir-spruce forests with birch, aspen and nemoral species combined with moist broad-grass forests	Soddy-podzolic with second humus horizon and soddy-podzolic-gley soils
17.	Forest-shrub-meadow vegetation of the Ob River flood lands	Alluvial soils and complexes of flood land bogged soils

scape- indication method of interpretation was applied for the purpose of mid- scale cartographying (mapping). On its base the interpretation (deciphering) signs were obtained: direct signs—a sketch drawing which shows structural topography (relief) forms, and indirect ones—spectrozonal characteristics of a sketch which show the character of ground vegetation (Table 3).

In the sketch drawing the contours of soil complexes or soil combinations were outlined which have clear borders. At interpreting (deciphering) the bog formations the specificity of which is close related with landscape structure of area the following direct interpretation signs were used: configuration of bogs, the degree of unity or apartness of mesolandscapes of

Table 3. Indication signs of soil interpretation in boreal zone

Type of topography	Type of vegetation	Prevailing soils
Drained watersheds of rivers	Larch-yernik-lichen open forests	Podzolized tundra gleyzems
Tops of ouvals	Dwarf shrub- lichen	Illuvial-iron tundra gleyzems
Drained mesouplands	Yernik-moss-lichen	Humus gleyzems
Thermokarst mesodepressions	Dwarf shrub- moss	Peat bog raised
Interouval depressions	Dwarf shrub-lichen-moss	Peat gleyzems
Valleys of rivers	Grassy-moss	Alluvial soddy-gley

bog systems which are shown on classified image as separate counters, etc.

Soil maps of key sites in the distributed GIS structure are as a basic information layer where regularities of functional and correlation links of natural objects (in our paper soils—vegetation) remain identical when passing from one scale to another one. Established indication links topography-vegetation-soils enabled to interpret distribution of soils on key sites of landscape provinces of boreal zone (Fig. 1).

In accordance with principles of landscape-geographical regioning the 17 landscape provinces located in forest tundra, forest bog and pine-small leaved zones have been selected. Landscape provinces, within which the key sites are located, relate to the northern, middle and southern taiga landscape subzones of the forest bog zone [8, 9].

The northern taiga subzone covers the following key sites: Ob-Taz—larch, also larch-spruce-Siberian pine and Scots pine forests, not seldom open forests with vast massifs of flat palsa and ridge-bog hollow bogs on tundra-gley soils and gleyzems; Sibirskie Uvaly (the Surgut forested lowland)—fir-spruce and larch-spruce forests with domed-palsa, bog hollow-ridge and grassy bogs on podzols and podzolic-gley soils; Upper Taz—large bog massifs are absent, gley-cryogenic-taiga and gley-podzolic soils have been formed under larch forests and larch-spruce-Siberian pine taiga.

The following key sites were selected in the middle taiga subzone: Severnaya Sos'va—large areas are occupied here by raised bogs, gley-podzolic soils have been formed under larch- pine forests and riam open forests; Konda—vast areas are taken by woodless peatlands with pine riams, ridge-bog hollow and lowland bogs, illuvial-iron podzols have been formed under pine forests; Middle Ob—raised sphagnum ridge-bog hollow and lowland bogs are most typical of this site, podzolic soils have been formed under pine- and dark coniferous forests.

And finally, key sites of southern taiga subzone are: Lower Tobol—raised and lowland bogs take large areas, soddy-podzolic and grey forest soils have been formed under birch forests; Vasyugan—the raised and transitional ridge-bog hollow bogs occupy vast areas, soddy-podzolic and podzolic-bog soils have been formed under dark coniferous taiga and paludal birch forests; Chulym–Yenisei—under dark coniferous southern taiga forests and pine forests the soddy-podzolic soils have been formed and under the park birch and birch-aspen forests the grey and grey forest gley soils have been formed.

In the opinion of many researchers studying carbon budget in ecosystems of boreal forests both in our country and abroad the main factors, which result in large vagueness in describing the carbon cycle, are uncertainties in determining the typology and areal correlation of differentiation units of soil-vegetation cover [10–13]. Therefore, the correction of borders and information content of soil contours based on satellite images at the local level as well as within landscape zones, subzones and provinces was a particular aim of our study.

Use of remote sensing data for assessing C_{org} reserves. Formation peculiarities of C_{org} stocks in soils of boreal zone are greatly determined by its ecosystem structure. Automorphic landscapes occupy somewhat about 40% of total area of the region, and on the rest of area the soil-vegetation cover has been formed under hydromorphic or relatively drained conditions. As a dominant component of boreal zone the soil complexes are. They are the most complicated structures of soil cover where the alternation of sharply differed soils is observed which are interconnected in genesis and create specific landscape formations. Data of digital processing of soil map and interpreting satellite images of studied area show forest tundra-taiga, taiga, alluvial-flood land and bog complexes of soils (Fig. 2). They occupy more than 20 % of the region area, however within separate map units the areas of soil contours, being a part of these map units, range widely (Table 4).

To obtain the areas of soil contours two methodical approaches are, mainly, used at assessing C_{org} stocks: division by trapezia and digitization. There are lot of estimations of C_{org} stocks for various biomes of the world and of our country. These estimations were obtained by distributing the cartographical base in trapezia, the network of which has a various degree of graininess depending on study tasks [14, 15]. At this approach simple or homogeneous contours are selected only when dominating soil type takes more than 85 % of the contour area. However, the contours showing the heterogeneous soil cover where dominating soil takes less

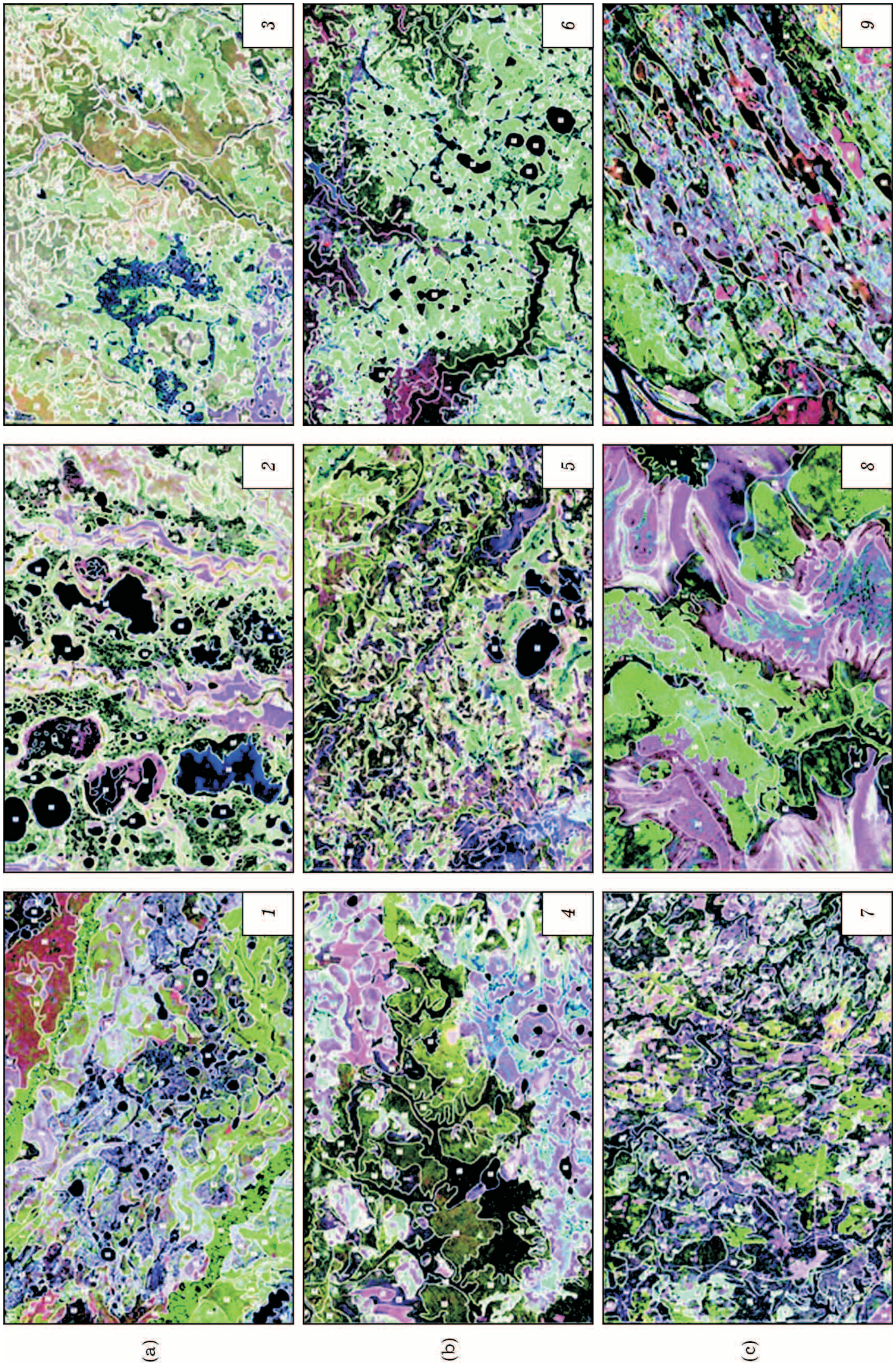
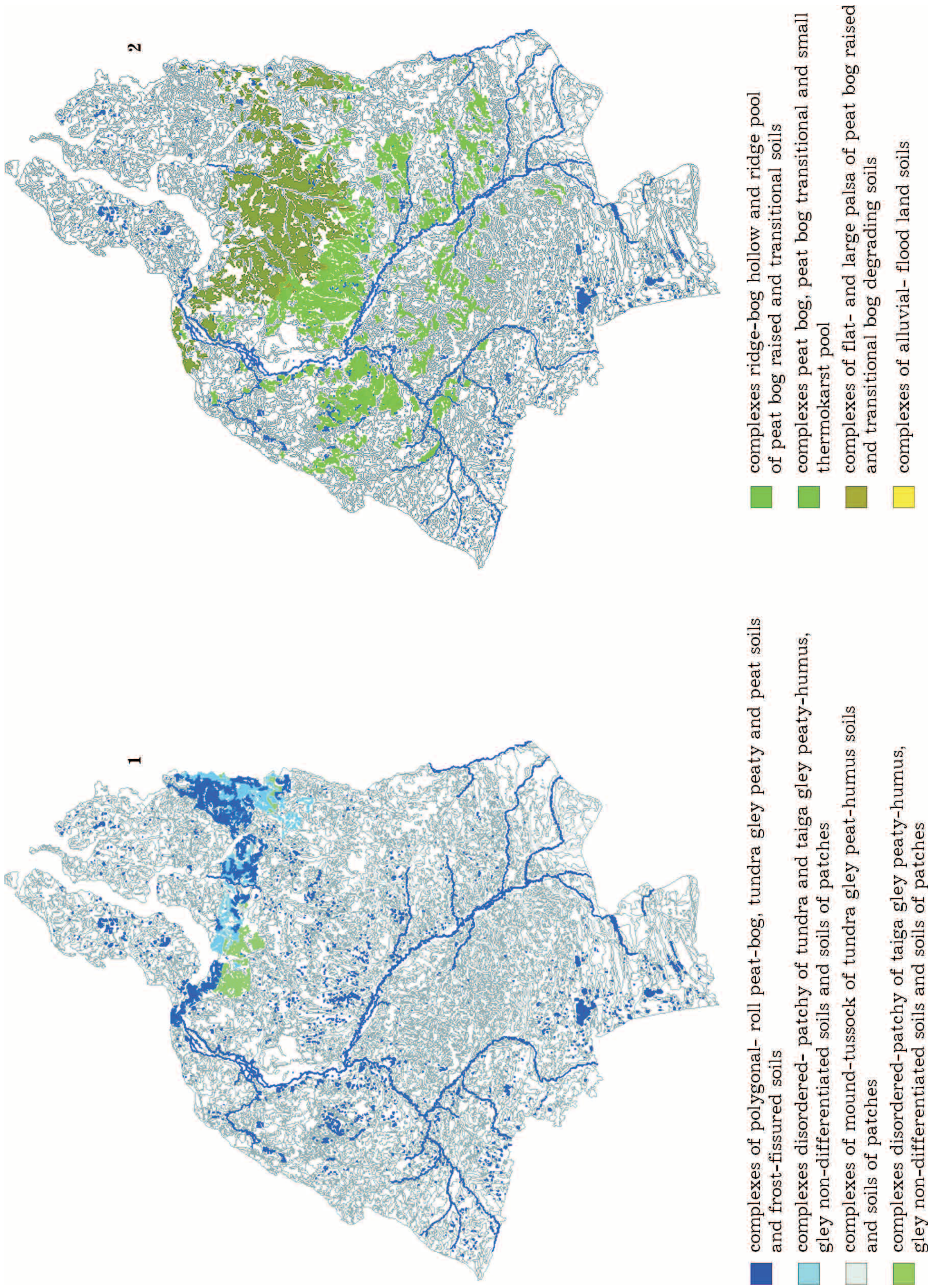


Fig. 1. Mid-scale soil maps of key sites of landscape provinces of West Siberian boreal zone based on remote sensing research. (a), Northern taiga: *1*, Ob–Taz; *2*, Sibirskie Uvaly; *3*, Upper Taz. (b), middle taiga: *4*, Severnaya Sos'va; *5*, Konda; *6*, Middle Ob. (c), southern taiga: *7*, Lower Tobol; *8*, Vasyugan; *9*, Chulym–Yenise.


1
complexes of polygonal- roll peat-bog, tundra gley peaty and peat soils and frost-fissured soils
complexes disordered- patchy of tundra and taiga gley peaty-humus, gley non-differentiated soils and soils of patches
complexes of mound-tussock of tundra gley peat-humus soils and soils of patches
complexes disordered-patchy of taiga gley peaty-humus, gley non-differentiated soils and soils of patches
2
complexes ridge-bog hollow and ridge pool of peat bog raised and transitional soils
complexes peat bog, peat bog transitional and small thermokarst pool
complexes of flat- and large palsa of peat bog raised and transitional bog degrading soils
complexes of alluvial- flood land soils

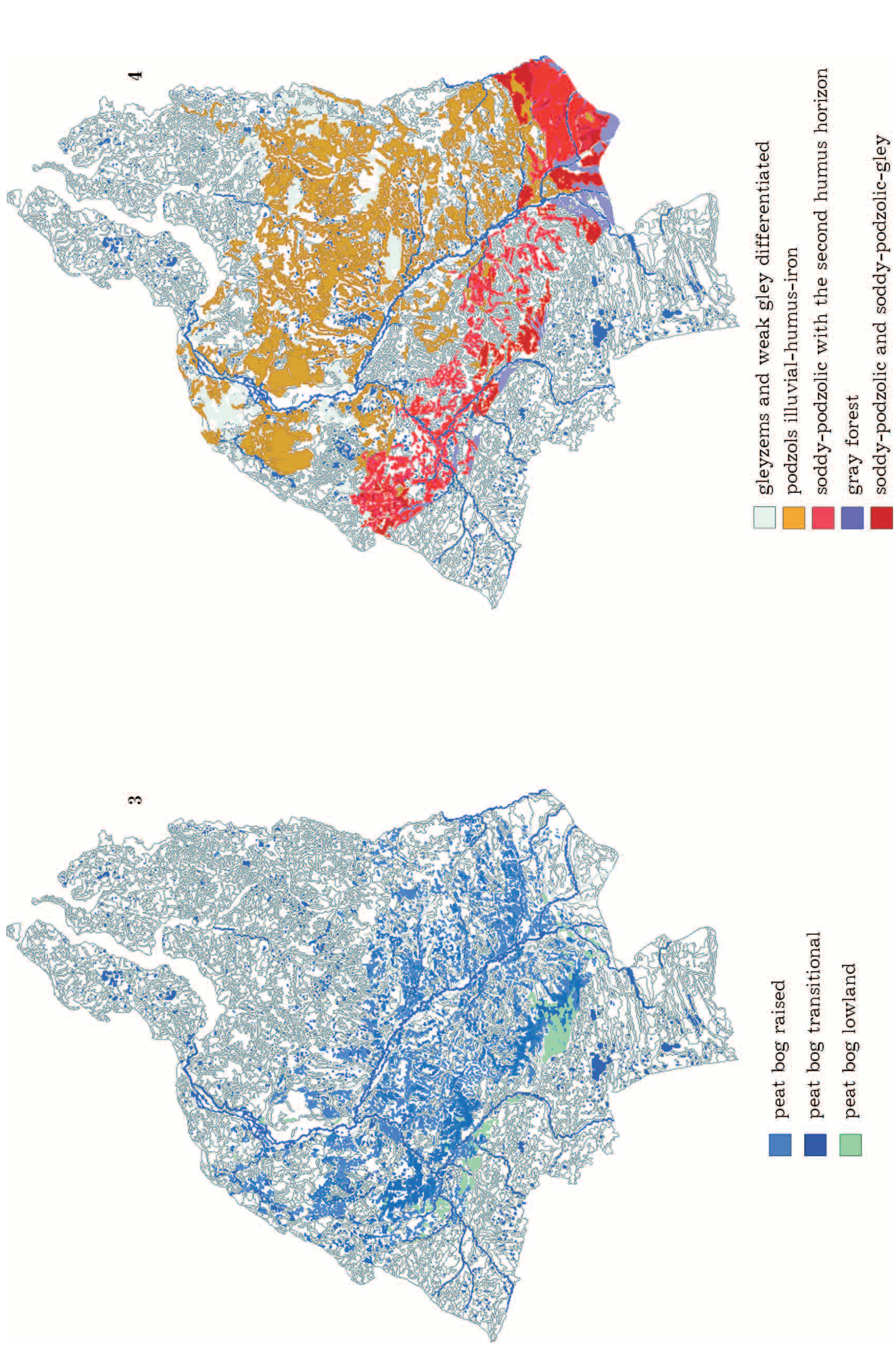


Fig. 2. Spatial distribution: *1*, complexes of forest-tundra taiga soils; *2*, complexes of taiga soils; *3*, complexes of peat-bog soils; *4*, complexes of auto- and semihydromorphic soils within boreal zone of West Siberia.

Table 4. Areas of soil complexes and the range of areas covered by soil contours

Soil complexes shown on the soil map of RF, Scale1:2 500 000	Contour areas by digitization	
	thousands ha	min–max
Forest tundra taiga		
Mound-tussock complexes of tundra gley peat-humus soils and soils of patches	3902.9	186.6–1819.3
Disordered-patchy complexes of tundra and taiga gley peaty-humus, gley non-differentiated soils and soils of patches	3133.2	361.5–1447.3
Disordered-patchy complexes of taiga gley peaty-humus, gley-differentiated soils and soils of patches	1572.1	161–9162.8
Bog		
Flat- and large palsa c. of peat bog raised and transitional bog degrading (being mineralized) soils	10 711.3	161–9162.8
Ridge-bog hollow and ridge-pool c. of peat bog raised and transitional soils	16 181	283.1–8137.8

than 85% of contour area are subdivided into soil combinations, and respectively their area is distributed proportionally. When using this calculation method the large part of soil contours which have an independent ecological importance but take small areas will not be taken into account in the total estimation. According to data of the Table 4 the small and middle contours of peat- and peaty-humus as well as peat bog transitional soils should be referred to the tundra-gley and tundra-gley differentiated ones which visibly differ in horizon thickness, bulk weight, carbon amount what introduces a certain error to the estimation of total C_{org} stock.

The second approach for calculation of areas with using GIS technologies enables to obtain the more precise estimations and presently is widely used for studying the carbon budget [16–18]. In our paper based on digital processing and interpreting satellite images the soil areas of forest tundra-taiga complexes were obtained which are not brought in the summary to the Soil map of RF scaled as 1:2,500,000. Besides, the contour borders and content of some soil contours which take vast areas were corrected (Table 5). For example, peat-bog transitional and peat-bog degrading soils being a part of the complex of large-palsa bogs, owing to the fact that their areas were not determined, were referred to the bog raised soils of flat-palsa complex which areas are not large by digitization data.

The obtained areas will be later used for assessing the contribution of soil complexes and of single soil types to the total C_{org} reserves. By preliminary data the highest contribution to the total C_{org} stock is made by soil complexes of ridge-bog hollow and ridge-pool peat raised and transitional bogs as well as of large-palsa and degrading peatlands that give more that 30% of total C_{org} stock of the region.

Explanation is needed when we compare soil areas which were not included to the complexes. The areas of boreal biome, obtained by overlay grid method and by digitization data, differ quite a little, therefore the distinctions in estimating the areas are, mainly, connected with principles of dividing or combining the soil contours. A special attention should be paid to the high organogenic soils, just which form the main C_{org} reserves. Data of the Table 6 shows that the areas of peat bog transitional and peat bog raised soils, obtained by overlay grid method and by digitization, differ essentially, although all in all they are rather close. As for zonal soils then the most distinctions were found in illuvial-iron low-in-humus podzols. By digitization their area is practically two times larger than that one in summary, although the areas of illuvial-humus and illuvial-iron rich-in-humus podzols by summary data and obtained by digitization don’t differ practically. Zonal podzols take somewhat about 10% of boreal zone, and although they have a low amount of organic carbon their importance is rather large in the carbon budget of the region. Estimations of C_{org} stocks in natural complexes of middle taiga have shown that from 4 to 10% of its stock has been formed due to podzols.

Estimation of C_{org} in soils of landscape provinces. Within landscape provinces the C_{org} stocks have been formed in close dependence on typology and area correlation of soil types. The contribution of single landscape provinces to total C_{org} stock of the region is determined by its area size. By digitization data the areas of landscape provinces of boreal zone can differ 5–8 times (Table 7).

Conditionally, according to occupied area the landscape provinces can be divided into the following groups: 1, Lower Ob, Nadym–Pur, Yenisei–Taz, Ural which area makes from 2.4 to 3.6% of total area; 2, Sibirskie Uvaly, Lower Tobol, Severnaya Sos’va—their area is 5.3–5.5%; 3, Konda, Chulym–Yenisei, Upper Taz, the area makes 6.1–8.8%; and 4, Yenisei, Ob–Taz, Vasyugan, Middle Ob, the area 10.7–16.2%.

Table 5. Areas of soil complexes of boreal zone according to data from the overlay grid method and digitization

Nos.	Soil complexes given		Area, thousands ha	
	on the soil map of RF, scale 1 : 2 500 000	In synonyms of Classification of soils of Russia, 2004	by the overlay grid method	by digitization
1	Arctic -tundra humus-gley, soils of patches and tundra-gley peaty and peat	Complexes mound-tussock of tundra gley peat-humus soils and soils of patches	No data	571.0
2	Tundra gley peat, peaty-and peat-gley, bog soil and soils of patches		No data	1819.3
3	Tundra gley peaty-humus, tundra gley peaty and peat		No data	927.1
4	Tundra surface-gley differentiated peaty-humus and tundra gley peaty and peat		No data	398.9
5	Podburs (subbrown) tundra (with no dividing), tundra gley peaty and peat and soils of patches		No data	186.6
Total			No data	3902.9
6	Tundra surface-gley differentiated tundra gley peaty-humus and soils of patches	Complexes disordered-patchy of tundra and taiga gley peaty- humus, gley non-differentiated soils and soils of patches	No data	1324.4
7	Taiga gley and gley non-differentiated and soils of patches		No data	1447.3
8	Taiga gley humus-mull soils and soils of patches		No data	361.5
Total			No data	3133.2
9	Peaty- and peat-gley bog, tundra gley peaty and peat soils and frost-fissured soils	Complexes polygonal-roll of peat-bog, tundra gley peaty and peat soils and frost-fissured soils	No data	264.7
10	Taiga gley peaty-humus and soils of patches	Complexes disordered -patchy of taiga gley peaty-humus soils of patches	98.5	403.9
11	Taiga gley-differentiated and soils of patches		23.8	1168.2
Total			122.3	1572.1
12	Peat bog raised and peat bog degrading (being mineralized)	Complexes flat- and large palsa of peat bog raised and transitional bog degrading (being mineralized) soils	6297.4	161.0
13	Peat bog transitional and peat bog degrading (being mineralized)		11,687	9162.8
14	Peat bog transitional and peaty bog degrading being mineralized		No data	1387.5
Total			17 984.4	10 711.3
15	Peat bog raised and transitional	Complexes of ridge-bog hollow and ridge- pool peat bog raised and transitional soils	7176.5	7411.3
16	Peat bog transitional and lowland		259	283.1
17	Peaty bog transitional and lowland		258	348.8
19	Peat bog and transitional, small thermokarst pools		7693.5	8137.8
Total			15 387	16 181

Table 6. Areas of organogenic semihydro- and automorphic soils prevailing in the boreal zone by the overlay grid method and digitization data

Nos.	Soil complexes given		Area, thous. ha	
	on the soil map of RF, scale 1 : 2 500 000	In synonyms of Classification of soils of Russia, 2004	by the overlay grid method	by digitization
	Peat bog transitional	Peat oligo- and eutrophic	9481.2	14 809.5
	Peat bog raised	Peat oligotrophic	10 725.8	6709.6
	Peat lowland bogs	Peat eutrophic	2516.5	2333.5
1	Taiga gley humus-mull (gleyzems weak-gleysolic humus-mull taiga)	Humus and podzolized gleyzems	No data	2488.6
2	Taiga gley and weak gleysolic non-differentiated(taiga gleyzems)		6116.1	612.6
3	Taiga gley- differentiated (weak gley differentiated gleyzems including taiga podzolized)		No data	8575.6
Total			6116.1	11 676.8
5	Podzols illuvial-humus (podzols illuvial- rich in humus)	Podzols illuvial- iron and illuvial-humus	6535.6	5524.4
6	Podzols illuvial-iron and illuvial-humus with no dividing (podzols illuvial- low humus- and rich in humus)		4008.6	5370.3
Total			10 544.2	10 894.7
7	Podzols illuvial- iron (podzols illuvial-low humus)	Podzols illuvial- iron	5592.9	10 399.6
8	Peaty- and peat-bog (gleyzems peaty and peat)	Peaty and peat gleyzrms	4366.1	2492
12	Peat- and peaty-podzolic-gley	Peat-podzolic-gley	6027.3	8652.3
13	Podzols gley-peaty and peat, illuvial-iron		7872.6	9711.9
Total			13 899.9	18 364.2
18	Soddy-podzolic, shallow – and not deep podzolic	Soddy- podzolic and soddy-podzolic-gley	No data	35.7
19	Soddy- podzolic, not deep podzolic		No data	119.9
20	Soddy- podzolic with the second humus horizon, mainly, deep		1402.6	2390.6
21	Soddy- podzolic with the second humus horizon, deep- gley deep		2056.1	4340.0
22	Soddy- podzolic-gley with the second humus horizon		3526.3	5019.9
23	Light- grey with the second humus horizon		No data	117.8
Total			6985	12 023.9
	Grey forest	Dark-grey and grey	2022	1357.7
	Dark-grey forest		No data	1008.9
	Grey forest solodic		1137.3	551.4
	Grey forest with the second humus horizon		No data	122.8
	Grey forest gleyed and gley		No data	14.6
Total			1137.3	3055.4

Table 7. Areas of landscape provinces of boreal zone

Landscape provinces of boreal zone	Area	
	million ha	% of total area
Lower Ob	4.6	2.4
Nadym–Pur	4.7	2.4
Yenisei–Taz	4.7	2.4
Ural	7.1	3.6
Sibirskie Uvaly	10.3	5.3
Lower Tobol	10.5	5 .4
Severnaya Sos'va	10.7	5.5
Konda	11.8	6.1
Chulym–Yenisei	14.1	7.2
Upper Taz	17.2	8.8
Yenisei	20.8	10.7
Ob–Taz	22.4	11.5
Vasyugan	24.3	12.5
Middle Ob	31.5	16.2
Total	194.7	100.0

Maximum C_{org} stocks are concentrated in provinces, which are the greatest in the area, they are Vasyugan and Middle Ob (63% of C_{org} stock of landscape provinces). For assessing the C_{org} reserves we will consider the potential use of areas of soil contours resulted from digitization and interpretation on example of the key site in Sredneobskaya landscape province. Peat bog raised soils of different thickness are widely represented in the soil cover of the key site (Table 8). Total carbon stock in soils of the key site makes 751.2 ton per map unit. Soils of raised peatlands occupy 53% of total area. Their contribution to carbon budget makes more than 82%. Peat and peaty soils of fens give 11% of total C_{org} stock. The other soil types contribute about 3% only.

In the soil cover of landscape province as also on the key site the main areas are occupied by peat-bog soils (26%) which are, mainly, represented by thick (1–5 m) raised peatlands with 25% of C_{org} stock. From the mineral soils the rich-in-humus (up to 10% of humus) soddy-gley soils are characterized by the highest C_{org} stock, these soils take 6% of total area and contain 12% of total soil carbon. Large areas (7.3%) are occupied by zonal illuvial-humus and illuvial-iron podzols, where in spite of relatively low humus amount, the 7% of total C_{org} stock is formed. Other soil types which take less than 3% of total area contribute from 1.5 to 5% to the total organic carbon stock.

Summarizing the validity of potential use of distributed GIS for assessing C_{org} stocks in soils and phytomass of boreal zone, described in this paper, it is

Table 8. Areas of soil contours of the key site in Middle Ob landscape province

Soils	Area of soil contours, ha		
	total	min	max
Podzolic surface-gley	3859.74	32.70	1420.7
Bog raised peat thin	6144.41	47.66	1624.9
Peat-podzolic gley illuvially-Hm-Fe	10 097.45	13.50	3660.0
Bog raised peat mean	16 067.90	4.40	1812.79
Bog transitional peat	17 756.60	4.57	5590.1
Podzolic ground- gley illuvially-Fe-Hm	19 771.01	9.15	2677.8
Bog raised peat thick	20 534.61	2.80	1429.97
Total	94 231.72		
Lakes	4965.06	1.35	488.79

needed to pay once more attention to compatibility of borders and information content of integrated cartographic base of soil and vegetation cover at different levels of landscape differentiation.

Mid- scale soil maps of key sites based on materials of remote sensing study, also on principles of landscape regioning and methods of landscape-indication interpretation can be used as an information basis for assessing C_{org} stocks in soils of landscape provinces and the boreal region as a whole.

Distributed GIS has been elaborated together with the Institute of computing technologies of SB RAS and Central Siberian Botanical Garden of SB RAS within the framework of the Interdisciplinary integration project of fundamental research SB RAS N 50 "Models of Changing the Biosphere Based on Carbon Balance (by field and satellite data, taking into account the contribution of boreal ecosystems.)"

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