Ecological Assessment of Dynamic Soil Parameters in the Megapolises Protected Areas

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Introduction

21 century is characterized by sharp increase of anthropogenic impact on environment and active development of degradation process. Environmental quality decreasing processes are most intensively developed in the urbanized areas. Natural reserves are created for environmental conservation and natural resource use. These territories generate ecological bases for sustainable development of natural-technogenic landscapes. It's actual especially in megapolises, which are characterized by maximum accumulation of population, factories, pollutants and most intensive level of human impact on ecosystem.

Reserves, located in megapolises have the greatest environmental importance. Moscow is the largest megapolis in Eastern Europe, where the mentioned environmental problems are most topical. Sustainable functioning and development of the megapolises is impossible without advanced framework of reserves and first of all without forest, which implements numerous important function, such as absorb noise, vibration, dust and atmospheric pollution, fix of atmospheric CO_2, O_2 producing therefore carrying out functions of «capital lungs».

There are a lot of wood protected territories in Moscow. One of the most interesting among them is reserve «Petrovsko-Rasumovskoe», representing a big value for nature conservation and more then 150 years history of researches. The eldest Russian agricultural and nature management educational institution is situated in its territory - Russian State Agrarian University - Moscow Timiryazev Agriculture Academy. The Academy strategies of development include methodical and personnel support of a sustainable development of rural region, environmental conservation and natural resource use.

Megapolises reserves play important role not only as natural framework, but also as a key object of basic environmental monitoring, which allows to forecast main development trend and environment quality of urbanized area in 21 century. 150 years monitoring observation history after forest stand of central forest massive creates a good basis for further development and improvement system of current environmental monitoring.

Soils as "a mirror of landscape" (Dokuchaev 1952) are traditional element of monitoring of human impact on ecosystem, executing memory function ("soil-memory", Torgulian 2004). Especially interesting are dynamic soils parameters, which most intensively show current anthropogenic impact and influence on main processes in these ecosystems.

Urban soil cover performs various ecological and environmental functions. Their main properties are fertility, soil suitability for plant growth and absorptive capacity of pollutants to prevent their penetration to subsoil and ground waters and, with dust, into urban air.

The soil cover plays the significant and diverse role in urban areas. First of all it significantly determines quality of surface and ground water. It is the universal biological source, sink, and regulator of CO_2, O_2 and NO_x in the atmosphere. Therefore urban soil conservation is a very important issue in condition of megapolises, which can not be successfully solved without good-quality results of soil ecological monitoring.

The main **goal** of this paper is analysis spatial-temporal variability of basic parameters of investigated soddy-podsolic soil, with special emphasis on its influence on soil basic environmental function.

Subject and methods

Principal object of the research

Reserve «Petrovsko-Rasumovskoe» (with total area around 540 hectares and central forest massive around 240 hectares) is situated in North Administrative district of Moscow. According to its natural condition, «Petrovsko-Rasumovskoe» enters into a southern mixed forests subzone of a taiga-forest zone (Figure 1). The reserve is located in the most southern part of the big slope of the Klinsko-Dmitrovsky ridge of hill, its relief is represented by moraine hilly plain. The reserves territory is composed of quaternary sediments and layer of Jurassic clays, thickness of clays is 20-22 m. The dominant parent material is moraine loam. Soddy podsolic soils are the most typical for this territory.

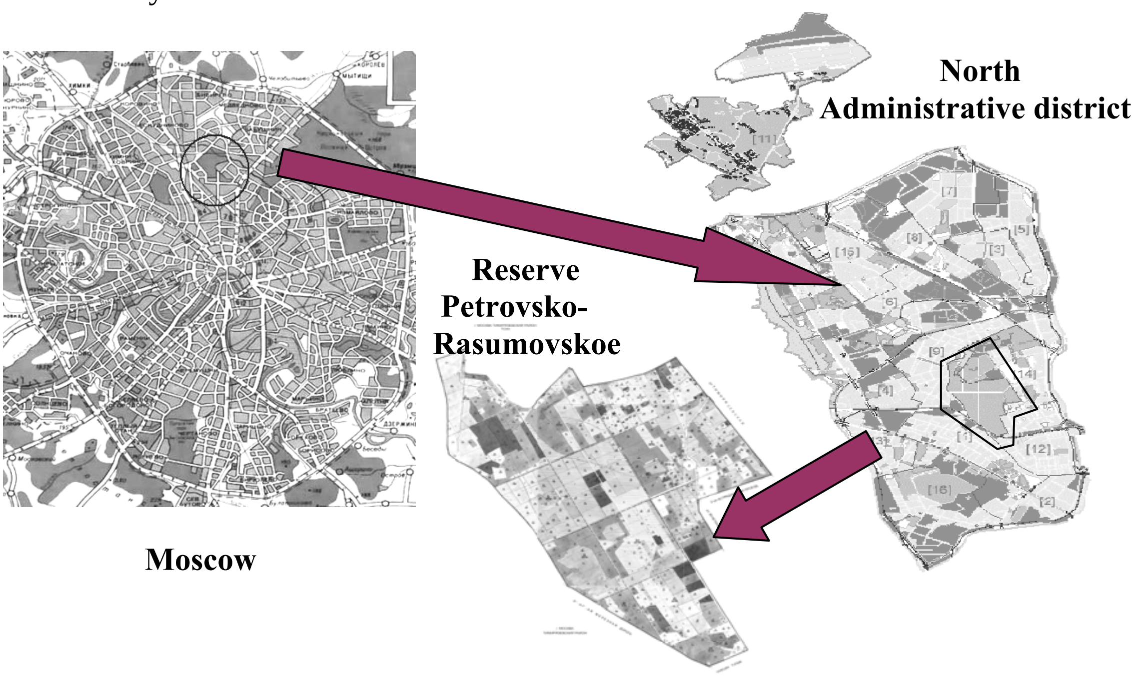


Figure 1: The arrangement scheme of the Petrovsko-Rasumovskoe Reserve in Moscow territory

The climate of the area is characterized by the average July temperature of 19,1 °C, and average January temperature of - 14 °C , with the average annual precipitation close to 550 mm. Most widespread wood species are pine, lime, birch, maple, oak, elm, larch. Rowan, chestnut, bird cherry tree, euonymus, hazel and gaiter-tree prevail in underbrush. Since 1862 regular supervision over a condition of wood plantings and natural biogeocenosises are conducted in the reserve. Early studies of soils were hold in the 70th in XIXth century. The systematized descriptions of soils have been performed by S.D. Solovev in 1889, I.V. Arbuzov in 1935 and I.P. Grechin in 1955. Last years are characterized by activization of versatile soil-ecological researches.

Reserve territory is used for recreation as well as for investigation. That's why this area equally with air contaminant impact is exposed to intensive recreation impact.

Key sample plots description

For our investigation we chose five key sample plots. These sample plots are situated along the transect line passed through the watershed hill and are located at the top of the hill with its slopes with different exposition, form and steepness (Figure 2).

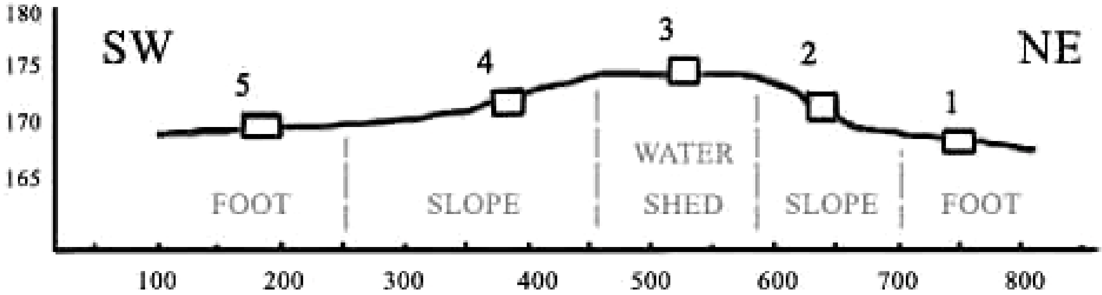


Figure 2: The profile of the transect line.

Investigated forest massive is characterized by undistrict relief with prevalence of moraine hill overlaid from surface by 40–cm layer of tegumental loam (top hill plot – table 1). There are medium-soddy deeply podsolic surface low gley slightly loam soils on drift clay (soddy-podsolic soils subtype of podsolic type).

Northeast part of the hill could be divided into slope (steepness 3 °) and foot of straight short slightly inclined slope of moraine hill (key sample plot 2 and 1, respectively). There are medium-soddy deeply podsolic surface low gley slightly loam soils on moraine clay (soddy-podsolic soils subtype of podsolic type).

Southwest part of the hill is represented by gentle weakly concave slope with the increased length. This slope gradually passed into the foot of hill. There are medium-soddy deeply podsolic surface gley slightly loam soils on drift clay (soddy-podsolic surface-water gleys subtype of podsolic type).

The form of a relief and the exposition are especially important for our investigation, because we have found out that the form of a relief influence on soils properties and mesostructure of soil cover more than exposition. This observation is true for areas with feebly marked relief.

The structure and type of forest plantation essentially varies in different sample plots (Table 1). Vegetation on the top of hill is characterized by domination of oak and lime in 1-t synfolium, 2-d sinfolium which are represented by lime and maple. Rowan and chestnut are underbrush. There is the highest value of common projective covering of grasses (70%).

Northeast part of the hill is characterized by prevail in 1-t synfolium of maple and lime on the slope and pine and lime on the foot of the hill. In 2-d synfolium dominate lime. Most part of underbrush is represented by rowan, hazel and bird cherry tree. Common projective covering of the grasses is 50 %.

Southwest part of the hill is characterized by prevail in 1-t synfolium of pine and elm emergent on slope. In 2-d synfolium dominate elm. Rowan, bird cherry tree, hazel are typical for underbrush. Common projective covering of the grasses is differ on slope and foot of the hill and has value 60 and 40 percent, respectively.

Table 1. Brief characteristic of key sample plots

Key sample plot	Relief	Vegetation
hill top (KSP **3)	watershed part of moraine hill	**The deciduous plantation with compound form. Forest type: hazelwort-gill oak-lime forest** The 1-t SNF.* is represented by oak and lime, in 2-d SNF. dominate lime and maple; in underbrush prevail rowan, chestnut, significant regrowth of lime and maple is noticed; common projective covering of the grasses is 70 %, the mine grass association is hazelwort-gill association.
NE slope (KSP 2)	center of straight short slightly sloping slope of northeast exposition	**The deciduous plantation with compound form. Forest type: shield-fern-carex compound lime forest** The 1-t SNF. is represented by maple; lime and elm are dominate in 2-d SNF., underbrush includes prevail rowan, bird cherry tree, hazel and honeysuckle, significant regrowth of maple, elm and lime are noticed; common projective covering of the grasses is 50 %, the mine grass association is shield-fern-carex association.
NE foot (KSP 1)	foot of straight short slightly sloping slope of northeast exposition	**The mixed plantation with compound form. Forest type: gill-shield-fern pine forest** The 1-t SNF. is represented by pine and lime, in 2-d SNF. dominate lime and birch; in underbrush prevail rowan, bird cherry tree, euonymus, hazel, significant regrowth of lime is noticed; common projective covering of the grasses is 50 %, the mine grass association is gill-shield-fern association.
SW slope (KSP 4)	center of gentle weakly concave slope of the increased length southwest exposition	**The mixed plantiation with compound form. Forest type: herb-carex pine forest.** The 1-t SNF. is represented by pine and birch, in 2-d SNF. dominate lime and elm; in underbrush prevail rowan, bird cherry tree, gaiter-tree, hazel, significant regrowth of lime and birch is noticed; common projective covering of the grasses is 60 %, the mine grass association is herb-carex association.
SE foot (KSP 5)	foot of gentle weakly concave increased length southwest exposition	**The mixed plantation with compound form. Forest type: carex-shield-fern pine forest.** The 1-t SNF. is represented by pine , in 2-d SNF. dominate elm and maple; in underbrush prevail rowan, bird cherry tree, euonymus, hazel, significant regrowth of lime is noticed; common projective covering of the grasses is 40 %, the mine grass association is carex-shield-fern association.

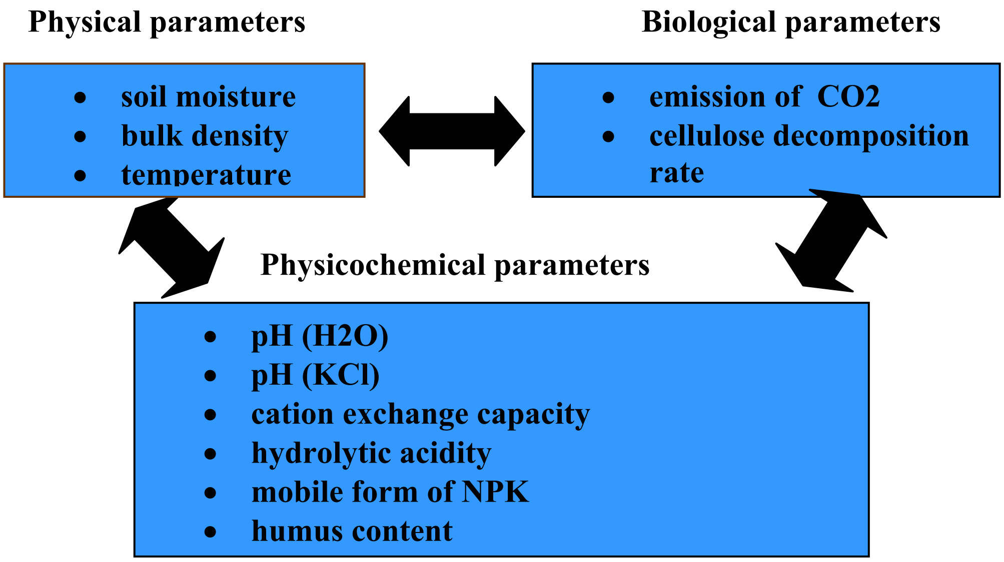
* SNF – synfolium (forest layer), **KSP – key sample plot

The methods of the research

Method of representative key sample plots was a principal method of the research. The basis of monitoring observation was five experimental plots with the area of 400 square meters situated on different elements of a relief (watershed part of hill, slopes and foots of hill with different exposition), described in Vasenev, Naumov and Raskatova paper (2006).

The method of the regime supervision was also used in this research. This method includes three blocks of characteristic: physical, physicochemical and biological parameters. The group of physical parameters consists of soil moisture, bulk density and temperature. Physicochemical parameters include pH, mobile form of PK (Machigin), humus content (Turin), cation-exchange capacity, and hydrolytic acidity (Kappen) (Vorobyova, 2006). Emissions of CO_2 (method of Karpachevskyi) and cellulose decomposition rate are integral biological parameters (Shein, Karpachevskiy, 2007).

Figure 3: The regime supervision scheme



These parameters can be divided into three groups: base parameters – a stable parameters not varying on a yearly basis (soil mesostructure, morphological structure, plantings characteristics); dynamic parameters - essentially varying from year to year (humus contain, mobile form of NPK, cation exchange capacity, hydrolytic acidity) and regime parameters – which are highly dynamical within a year (pH, soil moisture, bulk density, temperature, emission of CO2, cellulose decomposition rate).The last group of characteristics have been observed every month from May till August during 3 years.

Results and discussion

The stable parameters

As it has already been told the most wide-spread type of soils is soddy podsolic. But on different key sample plots they vary in physicochemical parameters (Table 2).

Table 2. Results of soil physicochemical analysis

Characteristic	KSP 3 top hill	KSP 2 NE slope	KSP 1 NE foot	KSP 4 SW slope	KSP 5 SW foot
humus (%)	3,0	2,9	3,3	3,55	3,3
H_{ex}	0,98	1,9	1,82	1.67	1,78
Al mob.	8,3	17	13,3	12,28	15,17
Hh	10,8	10	12,43	19	16,7
S	10,7	10,3	9,24	5,75	6,3
Nah	90,3	98	155	113,05	128,8
P_2O_5	24,5	15	25,5	27,8	30
K_2O	320	205	120	180	100
bulk density	1,14	1,15	1,20	0,97	0,96

Soils are characterized by relatively high humus content. The soils on all key sample plots are very acid and have a low value of the cation exchange capacity. The content of main nutritious elements (N and P) is low which is typical for soils of the given zone. K high content is noted due to more heavy texture in part of investigated soils. High contents of exchange ions of hydrogen and aluminum (at the high contents they are particularly toxic for plants) are observed. Highest value of bulk density is noticed on the north-east slope of the hill.

Dynamic soil parameters

Dynamic soil parameters were observed in 2008 from May to August. We have found out well-marked changes following soils characteristics: temperature, soil moisture, pH and integral soil biological activity parameters such as CO_2 emission and cellulose decomposition rate.

Soil temperature and moisture

The temperature was determined with the use of soil-moisture-meter in the first dates of every month (from May to August) for each of five key sample plots.

Table 3. Soil temperature and moisture

Key sample plot	May		June		July		August	
	t°C	W	t°C	W	t°C	W	t°C	W
KSP 3 Top hill	16,5	30,42	14,5	38,33	15,0	45,17	15,0	58,00
KSP 2 NE slope	16,5	32,40	15,1	35,12	15,2	40,91	15,2	46,85
KSP 1 NE foot	16,4	30,84	14,7	45,22	15,3	55,13	15,5	54,60
KSP 4 SW slope	15,6	34,93	14,6	41,18	15,1	64,62	15,5	53,30
KSP 5 SW foot	15,8	40,56	14,4	45,28	14,7	65,40	14,9	54,20

According to the received data the observation period was very moist. May was unusually warm, but other summer months were rather cold, what is atypical for this season. Moister content in soil have increased by the end of summer while usually it should decrease; it is connected with the weather conditions. The end of summer was characterized by considerable precipitation. The distribution of soil temperature and moisture wasn’t identical in different key sample plots. The soils in key sample plots with north-east exposition are warmer and less dump. This pattern can be connected with specifics of soil cover. Soils in experimental plots with south-west exposition are characterized by the presence of gleization and due to heavy texture can longer keep moisture.

Actual acidity

According to the research results soils in the experimental plots shows essential variability of pH values. pH is the most dynamical parameter within investing season, The soils in key sample plots with north-east exposition are more acidic. By the end of summer the pH value decreases. Their changes come up to 1,5 unit, that may be connected with appearance of tree waste and the beginning of its decomposition.

Table 3. Soil pH dynamics at the key sample plots

Key sample plot	pH_{H2O}				pH_{KCl}			
	May	June	July	August	May	June	July	August
KSP 3 top hill	5,3	4,03	4,26	3,90	3,9	3,74	3,90	3,90
KSP 2 NE slope	5,23	4,56	4,59	3,82	3,89	3,60	3,82	3,97
KSP 1 NE foot	4,76	4,12	4,22	3,94	3,73	3,60	3,82	3,97
KSP 4 SW slope	4,35	3,96	4,11	3,82	3,47	3,98	3,99	4,21
KSP 5 SW foot	4,49	4,04	4,12	3,94	3,51	3,86	4,01	3,86

Soil biological activity

A special attention was paid to analysis of integral soil biological activity parameters such as CO_2 emission and cellulose decomposition rate. These parameters have close connected with ecosystem CO_2 and O_2 fluxes, are determinated as typical for 21 century global atmospheric changes.

The weather conditions during the observation period were very moist and rather cool. It has apparently influenced on biological activity of soils. Consequently we can see decrease of soil biological activity. In comparison to preceding year cellulose decomposition rate receded on 5-10 percent on the average. CO_2 emission strongly depends on soil moisture. June was very rainy therefore we did not receive correct data. Data received in June reflects reduction of "soil respiration" in 2 - 3 times. In August CO_2 emission raised and approximated to its usual level (according data received in 2006-2007 it is 15 kg/ha/h). This increase may be connected with beginning of forest floor decomposition.

Table 4. Cellulose decomposition rate (%)

Key sample plot	May	June	July	August
KSP 3 top hill	8,8	2,6	2,5	2,5
KSP 2 NE slope	4,76	7,1	1,4	4,9
KSP 1 NE foot	3,3	4,2	2,1	2,4
KSP 4 SW slope	3,1	7,02	4,9	1,4
KSP 5 SW foot	2,8	3,8	2,4	2,1

Table 5. CO_2 emission (kg/ha/h)

Key sample plot	July	August
KSP 3 top hill	4,6	6,98
KSP 2 NE slope	5,3	8,54
KSP 1 NE foot	6,0	8,18
KSP 4 SW slope	6,05	9,3
KSP 5 SW foot	5,3	8,18

Conclusion

The conducted researches have shown high spatial variability of soil cover parameters even within low-contrast elements of relief that probably is typical for mature forest ecosystem. Under condition of transient landscape type (between taiga and temperate broadleaf forest) even not so significant changes of slope steepness (1-2°), its form (from straight to weakly concave) and length (from 200 to 400-500 meters) lead to qualitative changes in forest type (from lime-tree forest to boreal pine forest) and soil subtype (at subtype level of podsolic soils) and in mode of its dynamic parameters.

The monthly regime supervision held within summer season have shown essential distinctions of seasonal changes of temperature, moisture and biological activity (CO_2 emission and cellulose decomposition rate) of soils at the representative key sample plots. The steepness and length of a slope exert more essential influence on soil's microclimate and biological activity of soddy-podsolic soil then its exposition. It's obvious that anthropogenic impact essentially influences dynamic soil parameters too, but this statement requires supplementary investigations.

The presence of evident responses and logically explainable interrelations between investigated parameters of monitoring, weather and microclimate conditions, and form of a relief allows conducting well-founded extrapolation of obtained at the key plots monitoring results on similar elements of a landscape. It helps to detail process interpretation of spatial variability of a soil cover and to predict changes of soils and ecosystems.

Considerable spatial-temporal variability of investigated soils dynamic parameters argue that these factors should be considered at the organization and interpretation of monitoring observation in case of similar objects. It allows obtaining more precise assessments and predictions of consequences of man-made impacts on megapolises forest ecosystems as basic subjects of framework environmental monitoring.

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