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СОДЕРЖАНИЕ

МАТЕРИАЛЫ МЕЖДУНАРОДНОЙ КОНФЕРЕНЦИИ «МЕГАПОЛИСЫ 2050: ЭКОЛОГИЧЕСКИЕ ПОСЛЕДСТВИЯ ЕВРОПЕЙСКОЙ УРБАНИЗАЦИИ»

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MEGACITIES 2050: FROM URBANIZATION THREATS TO SUSTAINABLE URBAN DEVELOPMENT

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Urbanization is a global land-use change tendency, responsible for substantial environmental changes. At the same time urban ecosystems are vulnerable to global changes, and their adaptation is necessary to maintain sustainable functionality and important ecosystem services. Sustainable urban development demands for integration of innovative green technologies and natural-based solutions in urban management, which is only possible through a collaboration of scientists, landscape designers, civil engineers and policy-makers.

Key words: urbanization, green areas, urban soils, ecosystem services, green technologies, natural based solutions

Globally, urbanization is growing rapidly with more than two thirds of the world population expected to live in cities by 2050 [9; 1]. Urbanization influences the environment and human well-being by e.g. contributing to climate change, soil degradation and biodiversity reduction. At the same time, urban ecosystems are very sensitive to global changes, and their adaptation is necessary to maintain sustainable functionality and the most important ecosystem services [5].

Historically, urbanization was mainly studied as a potential environmental threat, resulting in such as soil, water and atmospheric, forest degradation and biodiversity loss. Numerous evidences of the unfavorable ecological state of urban environments accumulated by the beginning of 21st century [8; 3]. Urbanization alters vegetation, soil and fluxes of substances and energy. An established urban ecosystem strongly differs from a natural or agricultural ecosystem when urbanization converts it to serve urban purposes. Urban ecosystems are characterized by the man-changed and artificial landscapes with considerable anthropogenic disturbances (e.g. environmental pollution, soil sealing, waste disposal). Cities generally consume much more energy than they generally provide, resulting in intensive emissions of heat, air and water contaminants and greenhouse gases.

Together with the continued increase of the global urban populations, this motivated the development of novel concepts like 'sustainable cities'. The concept of sustainability resulted in the design of, for example, 'emission free' cities [6] and 'climate adapted' cities [7] which investigate urban areas as source of unique natural and urban-specific resources, rather than an environmental threat.

The international conference Megacities 2050 aimed to search for solutions of the environmental problems of modern megapolises and to maximize the capacity of urban ecosystems to support specific ('natural') functions and services. Urban green areas provides a set of key ecosystem services, e.g. climate mitigation, biodiversity, water and air quality control [2]. The role of green infrastructure in sustainable urban development was clearly illustrated in papers, focused on the restoration of the historical parks of Saint Petersburg and studying interrelationships between soil quality and plantations' state in Moscow. Urban soils are key for regulating healthy urban ecosystems. Reserving minerals and nutrients (provisioning service), carbon sequestration contributing to climate mitigation, runoff and flood control (regulating service) and archiving historical artefacts (cultural service) are widely recognized ESs of urban soils. Currently, urban soils face a paradox of being of the highest value regarding property and building issue, and being almost totally ignored with regard to the ES they can provide [4]. Different aspects of monitoring and assessment of urban soils at the multiple scales from local (e.g. urban soil constructions) to regional (mapping basal respiration in the Moscow region) were also discussed in the papers of the issue. Finally, practical applications of green infrastructure, for example, for dust control were presented and an economic value of green areas and natural-base solutions was analyzed.

The conference allowed receiving a multi-disciplinary feedback from a broad audience, including scientific and research community, municipal services, environmental protection agency and stakeholder working in urban management and greenery. Such a multi-disciplinary discussion is an essential step towards sustainable urban development, since implementation of innovative technologies and natural-based solutions gets feasible only when all interested stakeholder' group collaborate for the purpose of smart urban management.

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REFERENCES

[1] FAO. 2013. Climate-smart agriculture. Sourcebook. E-ISBN 978-92-5-107721-4.

[2] Gómez-Baggethun, E. and D.N. Barton 2013 Classifying and valuing ecosystem services for urban planning. 2013. Ecological Economics 86: 235—245.

[3] McKinney, M.L. 2006. Urbanization as a major cause of biotic homogenization. Biological Conservation 127: 247—260.
[4] Morel J.L., C. Chenu, K. Lorenz. 2014. Ecosystem services provided by soils of urban, industrial, traffic, mining, and military areas (SUITMAs). Journal of Soil and Sediments (article in press).
[5] Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Boone, C.G., Groffman P.M., Irwin E., Kaushal S.S., Marshall V., McGrath B.P., Nilon C.H., Pouyat R.V., Szlavecz K., Troy A. and Warren P. 2011. Urban ecological systems: scientific foundations and a decade of progress. Journal of Environmental Management 92: 331—362.
[6] Pickett, S.T.A., Cadenasso M.L., Grove J.M., Groffman P.M., Band L.E., Boone C.G., Burch W.R., Grimmond C.S.B., Hom J., Jenkins J.C., Law N.L., Nilon C.H., Pouyat R.V., Szlavecz K., Warren P.S. and Wilson M.A. 2008. Beyond urban legends: an emerging framework of urban ecology, as illustrated by the Baltimore Ecosystem Study. BioScience 58: 139—150.
[7] Raciti, S.M., Groffman P.M., Jenkins J.C., Pouyat R.V., Fahey T.J., Pickett S.T.A. and Cadenasso M.L. 2011. Accumulation of Carbon and Nitrogen in Residential Soils with Different Land-Use Histories. Ecosystems 14: 287—297.
[8] Stroganova M.N., Myagkova A.D. and Prokofieva T.V. 1997. The role of soils in urban ecosystems. Eurasian Soil Science 30: 82—86.
[9] UN. 2008. World urbanization prospects: the 2007 revision. United Nations Department of Economic and Social Affairs, Population Division., New York, USA. http://www.un.org/esa/population/ unpop.htm.

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МЕГАПОЛИСЫ 2050: ОТ УГРОЗ УРБАНИЗАЦИИ К УСТОЙЧИВОМУ РАЗВИТИЮ ГОРОДОВ

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Урбанизация — глобальная тенденция изменения современного землепользования, фундаментально изменяющая окружающую среду. В свою очередь, урбоэкосистемы подвержены воздействию глобальных (в том числе климатических) изменений. Адаптация городских экосистем к глобальным изменениям — необходимое условие сохранения их устойчивого функционирования и предоставляемых ими экосистемных сервисов. Устойчивое развитие городов подразумевает внедрение современных технологий зеленого строительства и рационального природопользования в систему городского менеджмента, что достижимо только при взаимодействии всех заинтересованных сторон, включая научное сообщество, ландшафтных архитекторов, инженеров-градостроителей, городскую и муниципальную администрацию.

Ключевые слова: урбанизация, зеленые зоны, городские почвы, экосистемные сервисы, ландшафтно-адаптивные решения

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ANALYSIS OF CARBON DIOXIDE EMISSION FROM LAWN ECOSYSTEM WITH CONTRASTING SOIL PROFILES

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Land-use change is among the main factors contributing to climate change. Urbanization is a land-use change pathway, conjugate with a rapid growth of urban territory and irreversible change of soil features and functioning. Greenhouse gases' emissions (primarily CO_2 emission) and carbon sequestration are among important soil functions. Ecological risks of increased CO_2 emissions in urban soils are determined by different factors of anthropogenic impact. This paper aims to analyze the impact of different soil constructions on CO_2 emissions from urban lawns. The research plot is situated in northern Administrative district of Moscow (NAD) and included urban soil constructions with organic layers of different genesis (turf, sand-turf mixtures and soils-sand mixtures) and of different depth (5, 10 and 20 cm). As a result an average CO_2 emission from turf (20 cm dept of organic layer) was 22 g/m^2 day, whereas the sand-turf mixture (10 cm of the organic layer) emitted 16.15 and peat soil (5 cm of organic layer) — 19.23 g/m^2 day respectively. Therefore, was observed dependence of CO_2 emissions on genesis and depth of soil organic layers. Also was revealed dependence of CO_2 emissions on climate conditions for nine-months of observations.

Key words: CO_2 emission, urbanization, urban land use, greenhouse gas, soil respiration

INTRODUCTION

Soil is a key natural resource with major ecological functions [1—3]. Current realities include continuous expansion of urban areas. Urban soils have recently attracted the attention of researchers [9; 5; 4; 8]. Artificial urban soils with prevalence of turf grass in their vegetation, account for a considerable part of the urban soils. This particular soil type is becoming the main object when studying the soils of urban ecosystems [28; 7]. However, the functioning of urban soils is evidently subject to drastic changes owing to human impact, as any other component of the urban ecosystems [6; 10].

It is estimated that artificial changes in land-use have, until now, produced a cumulative global loss of carbon from the land of about 200 thousand million tones. Widespread deforestation has been the main source of this loss, estimated to be responsible for nearly 90 percent of losses since the mid-nineteenth century. Losses primarily occur due to the relatively long-term carbon sinks of forests being replaced by agricultural land. Land-use change is driven by a host of social, political and economic factors around the world. Increased awareness of the most sensitive way to manage land and the better agricultural practice, combined with political agreement on food trade and avoidance of deforestation, are required if land-use change is not to continue being a net global source of carbon to the atmosphere in years to come. Indeed, having degraded large areas of the terrestrial carbon sink, sensitive land-use change may in fact provide a sink for atmospheric greenhouse gases in the future.

Carbon dioxide is released from the soil through soil respiration, which includes three biological processes, namely microbial respiration, root respiration and faunal respiration primarily at the soil surface or within a thin upper layer where the bulk of plant residue is concentrated [18], and one non-biological process, i.e. chemical oxidation which could be pronounced at higher temperatures [19]. Soil micro-flora contributes 99% of the CO_2 arising as a result of decomposition of organic matter [22], while the contribution of soil fauna is much less [20]. Root respiration, however, contributes 50% of the total soil respiration [21].

Temperature has a marked effect on CO_2 evolution from the soil. Edward found a strong relationship between CO_2 evolution and mean daily litter temperature [23]. Wiant observed no CO_2 evolution at 10 °C followed by a logarithmic increase in CO_2 evolution between 20 and 40 °C; above 50 °C, it declined rapidly [24]. At higher temperatures partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems. But Bunt and Rovira [19] found increased CO_2 evolution with a rise in temperature above 50 °C as well. Maximum CO_2 evolution rate was noted in mid-July (190 kg CO_2 ha–1d–1), which is attributed to the increasing role of root activity and organic matter decomposition with the increase in temperature. Increase in CO_2 emission with temperature is a matter of concern, as the possible global warming would increase CO_2 evolution from the soil that would accelerate the depletion of soil carbon and soil fertility [25].

Soil moisture affects soil respiration and hence CO_2 evolution [26]. In general, increasing soil moisture would increase CO_2 evolution up to an optimum level, above which it would reduce CO_2 evolution. Periodic drying and wetting of soil has a pronounced influence on CO_2 evolution. When the soil is moisten the activity of the microbes, which were in a latent state in the dry soil, increases accompanied by releasing of air trapped in the soil pore contributing to an increase in CO_2 evolution [27].

The research work aimed to analyze the carbon dioxide emissions from the artificial soil construction under urban lawns. To achieve the aims the following research steps were taken:

1) to analyze the emissions of carbon dioxide for the contrasting soil structures;

2) to analyze the dynamics of the flow of carbon dioxide, temperature and moisture of contrasting soil structures;

3) to assess the impact of the genesis and depth of organic substrates on carbon dioxide flows and temperature of urban lawns.

MATERIALS AND METHODS

The research field is situated in Moscow Timiryazev Agricultural Academy. On the field there are 28 different containers with different substrates of different depth. All the containers have the size of 100 cm × 100 cm × 50 cm and were made from plastics (Fig. 1A). The containers contained different soil constructions were divided into groups according to the type of the organic substrate and the depth of the organic layer. The organic layer is the first layer from the top, containing the substrate used for the experiment; the second layer is sand and the third is the native sod-podzolic soil (B horizon) (Fig. 1B).

Figure 1. The research field of Moscow Timiryazev Agricultural Academy (A) and an artificial soil construction with three different layers (B)

The following substrates have been chosen for the experiment: control (C), turf-sand mixture (Ts), turf (T) and peat-soil mixture (Pso) with two different depths (5 cm and 20 cm). In order to measure the CO_2 flux, moisture, soil temperature and air temperature, an infrared gas analyzer (IRGA) Li-820, chamber, soil thermometer (HI98501) and soil moisture meter (HH2) were used. The observations of CO_2 emissions were held from March to September 2014. The dynamics of total soil respiration (9 times for the whole period) was analyzed for each container. The IRGA chambers (diameter 20 cm, height 15 cm) were installed on the bases (diameter 20 cm, depth 4 cm) on top of soil construction and hermetically fixed. The chambers were connected with the IRGA with flows of incoming and outgoing air. With the integrated air pump an air sample from chamber was pumped into the IRGA, whereby the device registered the rise of CO_2 concentration in the chamber at a frequency of 1 Hz. Based on the data obtained from the concentration of growth, taking into account the temperature and pressure of the air inside the chamber, CO_2 flux (g/m^2 day) was calculated using ideal gas equations.

RESULTS AND DISCUSSION

The dynamics of CO_2 fluxes between turf-sand (20 cm depths), turf-sand (5 cm) and control (turf-sand; 10 cm) were compared to understand the variation of the CO_2 fluxes from different soil constructions. The results show that in July 2014 the carbon dioxide efflux from the turf-sand (20 cm) was 12.91 (g/m^2 day) and for the control construction it was 6.3 (g/m^2 day), whereas CO_2 efflux from turf-sand (5 cm) was 6.95 (g/m^2 day). The CO_2 flux from turf-sand (20 cm) was 7.43 more than from turf-sand (5 cm) and 0.82 more than from control. Therefore, it can be claimed that CO_2 efflux was higher from the urban soil constructions, containing more organic carbon (Fig. 2). Analysis of the peat-soil samples with different depths gave the following results: an average CO_2 efflux from the control site was 24.64 (g/m^2 day), whereas the amount of CO_2 emitted from the peat soil (5 cm) was 20.68 g/m^2 day. In average the 20 cm peat soil mixture emitted 15 and 30% more CO_2 that the 5 cm peat soils and the control soil mixture respectively (Fig. 3). This outcome confirms a positives correlation between the amount of emitted CO_2 and carbon contents in substrate.

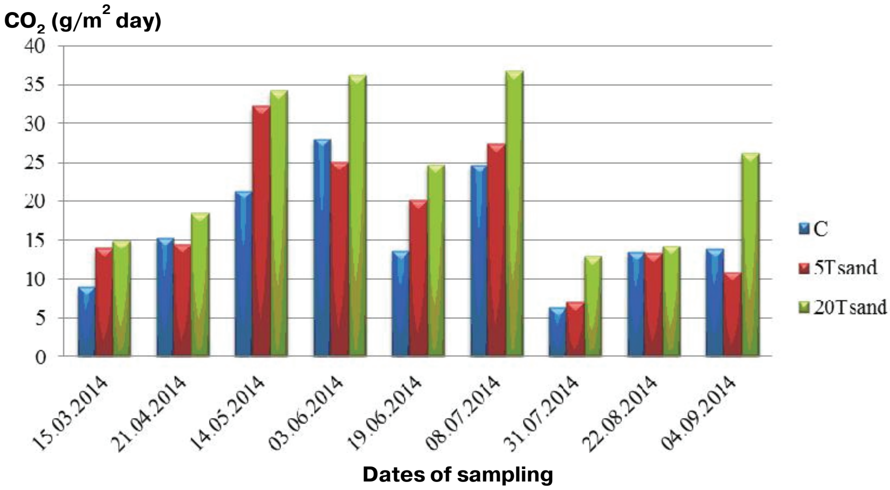

Figure 2. CO_2 fluxes from control (C), 5 cm turf-sand (5Tsand) and 20 cm turf-sand (20 Tsand) for the period March 15 — September 4 2014

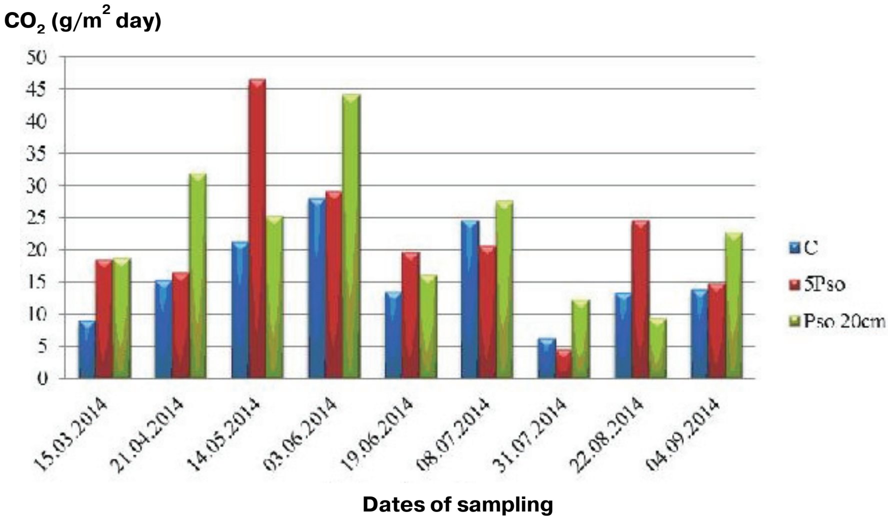

Figure 3. CO_2 fluxes from control (C), 5 cm peat-soil (5Pso) and 20 cm peat-soil (20 Pso) for the period March 15 — September 4 2014

Comparisons of the dynamics of CO_2 fluxes between turf-soil (20 cm), turf-soil (5 cm) and control (turf-sand; 10 cm) for one day — 14th of July 2014 — resulted in following: the highest CO_2 emission was found for the turf-soil (5 cm) and was 53.95 (g/m^2 day), whereas and a 20cm turf-soil and control emitted just half of this value — 25 and 21 (g/m^{2}day) respectively. In average for the season 20 cm turf-soil mixture emitted more CO_2 than other, whereas CO_2 emission from the control site was the lowest (Fig. 4).

In order to analyze the seasonal dynamics of CO_2 fluxes the three soil constructions with the same depth (5 cm) were monitored along the nine month of the experiment. The lowest emission was obtained for the 31th of July 2014, whereas the highest amount was monitored on 14th of May 2014 (Fig. 5).

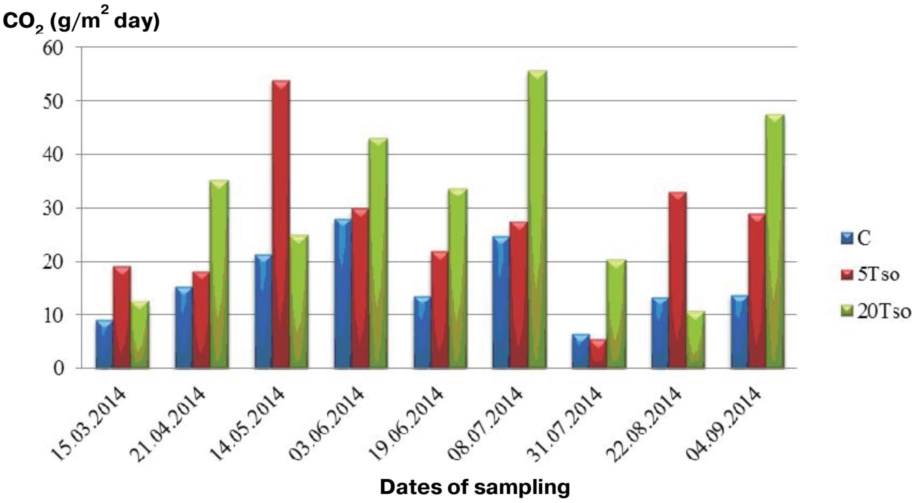

Figure 4. CO_2 fluxes from control (C), 5 cm turf-soil (5Tso) and 20 cm turf-soil (20 Tso) for the period March 15 — September 4 2014

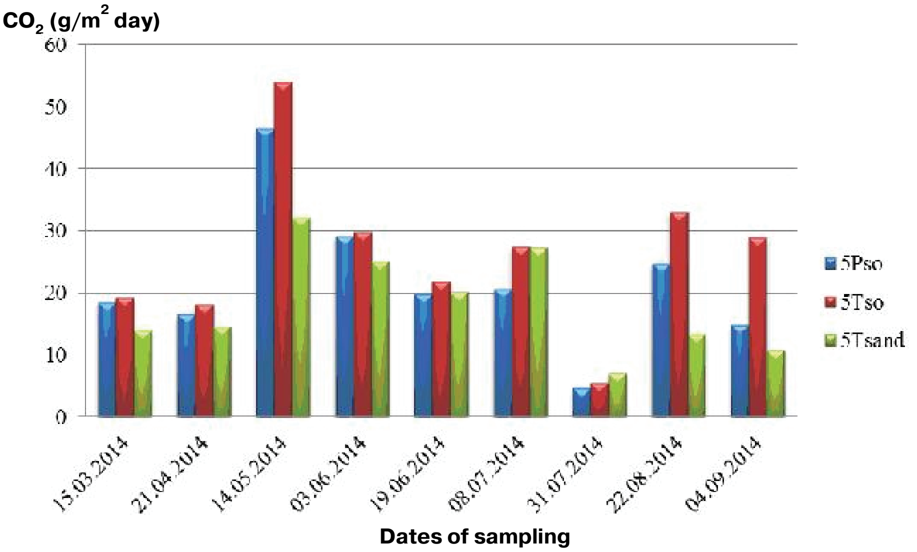

Figure 5. Seasonal dynamics of CO_2 fluxes from three construction with the same depth of organic layer (5 cm), but different substrates: peat-soil (5Pso), Tso (5Tso) and turf-sand (5Tsa)

The experiment has demonstrated the evaluation of carbon dioxide from different artificial soil construction with different soil sample for lawn ecosystem and as a result we have got to understand how the carbon dioxide from the soil is related to the moisture and the temperature. This outcome is necessary to estimate the total losses of organic carbon from urban soil constructions from the intensive emission. soil management practices like increasing soil organic carbon content. Obtained results show that there is dependence between CO_2 emission and type of soil. The CO_2 emission can be reduced by sequestering C in the soil for those that lost high amount of organic carbon due to mineralization of organic carbon.

CONCLUSIONS

As a result of the research data of CO_2 emissions from lawn ecosystem with a contrasting structure of soil profile has been obtained. The lowest CO_2 emissions was shown for the soil constructions on the basis of peat soil mixture show, which is obviously related with the lowest average temperature and soil moisture. It is observed that artificial soil construction based on a mixture of peat soil lost less total carbon stocks due to CO_2 emissions. The most optimal functioning has been shown for the peat soil sample (a mixture of soil and land capacity 5 cm), for which the low rates of decorative lawns combined with a high positive value of the carbon balance. In this paper, it was clearly shown how 'fragile' can be a mixture based on turf sand, turf-soil. These soils are very unstable. The optimal designs of lawn ecosystems remain a priority for urbanized research and for applications of landscape construction.

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REFERENCES

[1] Dobrovolskii, G.V. and Nikitin, E.D. Soils functions in biosphere and ecosystems Funktsii pochv v biosfere i ekosistemakh (Functions of Soils in the Biosphere andEcosystems), Moscow: Nauka, 1990.
[2] MEA: Millennium Ecosystem Assessment. Ecosystems and Human WellBeing: Synthesis, Washington, DC: Island Press, 2005.
[3] Blum, W.E.H. Functions of soil for society and environment, Rev. Environ. Sci. Biotechnol., 2005, vol. 4: 75—79.
[4] Lorenz, K. and Kandeler, E. Biochemical characterization of urban soil profiles from Stuttgart, Germany, Soil Biol. Biochem., 2005, vol. 37: 1373—1385.
[5] Madrid, L., Diaz Barrientos, E., and Madrid, F. Distribution of heavy metal contents of urban soils in parks of Seville, Chemosphere, 2002, vol. 49: 1301—1309.
[6] Svirejeva Hopkins, A., Schellnhuber, H.J., and Pomaz, V.L. Urbanized territories as a specific component of the global carbon cycle, Ecol. Model., 2004, vol. 173: 295—312.
[7] Vasenev, V.I., Anan'eva, N.D., and Makarov, O.A. Specific features of the ecological functioning of urban soils in Moscow and Moscow oblast, Euras. Soil Sci., 2012, no. 2: 194—205.
[8] Pouyat, R.V., Yesilonis, I.D., and Nowak, D.J.Carbonstorage by urban soils in the United States, J. Environ. Quality, 2006, vol. 35: 566—575.
[9] Stroganova, M.N., Myagkova, A.D., and Prokof'eva, T.V. The role of soils in urban ecosystems, Eurasian Soil Sci., 1997, no. 1: 82—86.
[10] Imhoff, M.L., Bounoua, L., DeFries, R., et al.The consequences of urban land transformation on net primary productivity in the united states, Rem. Sens. Environ., 2004, vol. 89: 434—443.
[11] Alberty, C.A., H.M. Pellett, and D.H. Taylor. 1984. Characterization of soil compaction at construction sites and woody plant response. f. Environ. Hort. 2(2): 48—53.
[12] Blume, H.P. 1986. Characteristics of urban soils. In Man and the Biosphere, edited by the German National Committee. International scientific workshop on soils and soil zoology in urban systems as a basis for management and of green/open spaces. Berlin: UNESCO: 23—46.

[13] Craul, P.J. 1985a. Urban soils. METRIA 5: 45—61.
[14] Craul, P.J. and C.J. Klein. 1980. Characterization of streetside soils of Syracuse, New York. METRIA 3: 88—101.
[15] Gilman, E.F., I.A. Leone, and F.B. Flower. 1987. Effect of soil compaction and oxygen content on vertical and horizontal root distribution. Environ. Hort. 5(1): 33—36.
[16] Hillel, D. 1980. Fundamentals of Soil Physics. NewYork: Wiley.
[17] Zemlyanitsky, L.T. 1963. Characteristics of the soils in the cities. Sov. SoilSci. (5): 468—475.
[18] de Jong, E., Schappeart, H.J.V. and Macdonald, K.B., Can. J. Soil Sci., 1974, 54, 299— 307.
[19] Bunt, J.S. and Rovira, A.D. Nature, 1954, 173, 1242.
[20] Macfadyen, A. in Soil Organisms (eds Docksen, J. and Van der Drift, J.), North Holland, Amsterdam, 1963:3—16.
[21] Macfadyen, A. in Methods of Study in Soil Ecology (ed. Phillipson, J.), IBP/UNESCO Symp., Paris, 1970:167—172.
[22] Reichle, D.E., McBrayer, J.F. and Ausmus, B.S. in Progress in Soil Zoology (ed. Vanek, J.), Academic Publishing, Czechoslovakia, 1975:283—292.
[23] Edward, N.T., Proc. Soil Sci. Soc. Am. J., 1975, 39: 361—365.
[24] Wiant, H.V. Jr., J. For., 1967, 65: 489—490.
[25] Bouma, J., Kai, L.N., David, M.E. and Jonathan, P.L. Plant Soil, 1997, 195: 221—232.
[26] Johnson, D., Geisinger, D., Walker, R., Newman, J., Vose, J., Elliot, K. and Ball, T. Plant Soil, 1994, 165:129—138.
[27] Orchard Valerie, A. and Cook, F.J., Soil Biol. Biochem., 1983, 15: 447—453.
[28] Bandaranayake W., Y.L. Qian, W.J Parton, D.S Ojima. and R.F. Follett. 2003. Estimation of Soil Organic Carbon Changes in Turfgrass Systems Using the CENTURY Model. Agronomy Journal 95: 558—563.

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АНАЛИЗ ЭМИССИИ УГЛЕКИСЛОГО ГАЗА В ГАЗОННЫХ ЭКОСИСТЕМАХ В УСЛОВИЯХ КОНТРАСТНЫХ ПОЧВЕННЫХ ПРОФИЛЕЙ

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Изменение землепользования является одним из главных факторов, способствующих изменению климата. Урбанизация является землепользованием, которое связано с быстрым ростом городских территорий, вследствие чего происходят необратимые изменения особенностей почвы и ее функционирования. Эмиссия парниковых газов (преимущественно эмиссия CO_2) и депонирование углерода являются одними из важнейших функций почв. Экологические риски увеличивающейся эмиссии CO_2 в городских почвах определяются различными факторами антропогенного воздействия. Целью данной статьи является анализ воздействия различных почвенных конструкций на эмиссию CO_2 в газонных экосистемах. Объект исследования расположен в северном административном округе (САО) г. Москвы и включает в себя почвенные конструкции с различными по происхождению (торф, торфяно-песчаная смесь и почво-песчаная смесь) и мощности (5, 10, 20 см) органическими горизонтами. По полученным данным, средняя эмиссия CO_2 в варианте с торфяным органогенным горизонтом мощностью 20 см составила 22,00 г/м^2 в день, в то время как в варианте с торфяно-песчаной смесью мощностью 10 см эмиссия составила 16,15 г/м^2, а торфяной почвы мощностью 5 см — 19,23 г/м^2 в день. Следовательно, наблюдается зависимость эмиссии углекислого газа от таких показателей, как генезис органического вещества почвы и мощность органогенного горизонта. Также в течение 9 месяцев наблюдений была выявлена зависимость эмиссии углекислого газа от климатических условий.

Ключевые слова: эмиссия CO_2, урбанизация, экологические риски, парниковые газы, почвенное дыхание

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SOIL-ECOLOGICAL CHARACTERISTICS OF THE RECREATIONAL FOREST ECOSYSTEMS IN MOSCOW

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To understand the soil ecology of the forest ecosystem, the dynamics of soil-ecological indicators in the soil-plant system were studied through physical, chemical and biological parameters at various sites of the Forest Experimental Station of the Russian State Agrarian University of Moscow Agricultural Academy; a unique forest ecosystem known for its heavy metal pollution and unregulated recreation. The results showed that soil compaction had the strongest ability to increase risk of heavy metal mobility. Recreational activity caused a 2—3-fold increase in the density of the soil, resulting in poor aeration and significant heavy metal contamination, affecting the stability and functioning of the green spaces. Moreover, the proximity of the urban environment had a negative effect on the state of the stand. The maximum heavy metal migration capacity determined by biological uptake was found in the root systems of 70—80-year-old oak tree stands and the minimum, in the roots of pine and birch phytocoenosis. The systems' normal functions were hindered due to reduction in microbial activity.

Key words: heavy metals, compaction, microbiological activity, soil ecological functions, living conditions of a forest stand, recreational load

INTRODUCTION

Soil plays an important ecological role in maintaining plants' life cycle. Soil is a mixture of different mineral particles, organic matter, and living organisms. Thesoil management influence on dynamic of physical, chemical and biologicalsoil properties [10]. Due to sorption properties, soil has become a sink for many contaminants, and is, therefore, an important source of anthropogenic contamination in urban environments [1]. This fact can have serious consequences considering humans receive about 95—97% of all food products from soil resources [4].

A large quantity of particulate matter and pollutants settle/accumulate on the soil surface from atmospheric deposition [2]. In 2012, nearly 32 million tons of pollutants, including heavy metals, were released into the atmosphere and these emissions have continued to increase [11]. Lead (Pb) is of particular concern in urban environment due to both its prevalence and toxic effects. Lead can affect nearly all bodily systems and is mostly noted for its neurotoxic effects [9]. Interesting to note, at the beginning of the last century in Moscow (1909—1910), total Pb soil concentration was 6 mg kg^{-1}. By the end of the century, its concentration increased by more than 20 times [7].

Unlike in air and water, where heavy metal purification processes occur, soil is an active sink for heavy metals. Biogeochemical processes and storing properties of soil have long-term negative impact on contaminated soils. For example, the period of removal for Pbin the soil is from 740 to 5900 years, Zn — 70 to 510 years, Cd — from 13 to 1100 years, Cu — from 31 to 1500 years [7]. An accumulation of pollutants in soils, particularly heavy metals, disrupts the proper functioning of the environment, which is a serious threat for organisms, including humans [13].

This study was conducted at the forest experimental station (FES) of the Russian State Agrarian University of Moscow Agricultural Academy (RSAU-MAAT). This forest occupies 232.6 hectares of land and was previously designated as a conservation area both in 1939 and in 1953. Research has been conducted at the FES for over 100 years. This fact provides the baseline and unique opportunity to conduct further research in this large, diverse forest that is situated in an urban environment. The FES is surrounded by a ring of the roads, whose effect imposes a certain imprint on the soil conditions and subsequently, the state of vegetation [8].

In addition to heavy metal pollution posing a risk to the environment, another negative factor is unregulated recreation. In a large portion of the FES, there is a network of trails cutting through and in nearby residential areas, soil cover is practically absent. The wood plantations of the FES that are exposed to these recreation conditions, are extremely depressed, resulting in dieback of the stands, suppressed growth, and substantial damage [6].

In this context, an assessment of the ecological status of the soil and a preservation of its ecological functions requires an integrated research approach to identify the factors affecting the ecological system, especially in terms of environmental pollution. The aim of our study was to conduct comprehensive research on the major soil-ecological characteristics to assess the ecological condition of soils. Environmental indicators were studied through the physical, chemical, agrochemical and biological (including microbiological) parameters in the soil-plant system with a focus on the effect of heavy metal contamination and increased recreational load.

METHODOLOGY

Soil samples were collected from the experimental plots (the size of 0.5 ha), in the suburban areas and in the middle of the forest (450 to 500 mapart). Assemblages of plant species and the ground cover on the investigated areas were similar. The controls were located in the Krasnaya and Istra forest in the northern and north-western parts of the Moscow region on the watershed plateau, far from the influence of industrial facilities and highways [7].

The effects of humus and soil acidity as basic soil characteristics were determined by the conventional methods to assess theireffect on the migration of heavy metals and the degree of their mobility in the soil-plant system [5]. Microbial communities were seeded to grow on solid nutrient media in cups in four replications. The quantitative and qualitative compositions of aerobic heterotrophic microorganisms were studied along with the intensity of mineralization processes and the structure of microbial cenosis [5].

Group affiliation of actinomycetes were determined with the N.A. Krasilnikova' Finder and A.S. Bondartseva' Scale Colors. The living conditions of the stands were studied as a risk criterion (J) determined by degradation factors. The worse the condition of the stand resulting in dieback, damages, low foliation, the higher the value of J.

To measure the effect of unregulated recreation, bulk density and soil density were sampled every season from the 0—3 cm, 3—7 cm, and 7—11 cm depth intervals as well as from a full 0—10 cm depth profile. Compaction of the soil layers determines water-air and temperature regimes, redox conditions, and biochemical processes [3]. It also influences basic soil ecological functions, such as growth, development and productivity of plants, microbial activity, and soil fauna [12]. Studyingthe processes that cause changes in the densities of soil horizons is extremely important for understanding the dynamic shifts in the soil environment and forest stands, especially in terms of heavy metal pollution and unregulated recreation.

RESULTS AND DISCUSSIONS

The studied forest plots located within 5 meters of the urban area were characterized by increased dieback and crippled trees. Such plantations were determined as being on the verge of disintegration and in a weakened state. Soil-ecological characteristics studied under the plantations are presented in Table 2. The living condition indices (J) were estimated to be between 2.8—2.1 (Table 1). The maximum values of J were 2.7—2.8 in the forest areas under oak stands. The pine-birch stands were characterized by a greater tolerance to environmental factors with living condition of 2.1. Similar plantations located away from the urban environment, the middle of the forest and in the control areas were leafier and exhibited less damage. The J values for these stands were 1.3 and 1.25 at the Istrinskyand Krasnaya Polyana Forestry experimental plots, respectively. This data shows that the proximity of the urban environment, mainly highways, has a negative effect on the state of the stand.

Table 1

The anthropogenic load as an indicator for the ecological status of the stand — a case study of the forest experimental station (FES) of the Russian State Agrarian University of Moscow Agricultural Academy (RSAU-MAAT)

Number of the experimental plot	Mainspecies, ageclass	Index of the living condition (J) of the forest stand	Assessment of an ecological state
Sites with the minimum anthropogenicimpact			
6	TheOak X—XII	2.1	weakened condit on of a plant
8	The Oak VII—VIII	2.5	weakened condition of a plant
9	The Pine with the birch IX—XI	1.5	healthy state
Sites with the increased anthropogenicimpact			
11	TheOak X—XII	2.8	On the verge of disintegration
7	TheOak VII—VIII	2.7	On the verge of disintegration
10	The Pine IX — XI with the birch	2.1	weakened condition of a plant
IstrinskyForestry (control)	The Pine with the birch. VIII— IX	1.3	healthy condition of a plant
Krasnaya Polyana forestry (control)	TheOak VIII — IX	1.25	healthy condition of a plant

Table 2

Soil-ecological characteristics under the experimental forest plantation at the forest experimental station (FES) of the Russian State Agrarian University of Moscow Agricultural Academy (RSAU-MAAT) with various anthropogenic load

Number of the experimental plot	Bulk density, g cm^{-3}	pH KCl	Organic substance, %	The content of heavy metals (%) in different extracts					
				Pb		Zn		Cu	
				$Ca(NO_3)_2$	1N HCl	$Ca(NO_3)_2$	1N HCl	$Ca(NO_3)_2$	1N HCL
Sites with the minimum anthropogenic impact									
6	0.84	4.10	4.06	47	53	47	53	50	50
8	0.82	4.25	4.67	47	53	63	37	50	50
9	0.83	3.90	5.49	36	64	29	71	51	49
Sites with the increased anthropogenic impact									
7	1.22	4.20	10.12	64	36	73	27	51	49
10	1.26	3.75	8.98	60	40	84	16	56	44
11	1.30	4.35	6.3	54	46	74	26	56	44
Wood sites with the minimum removal from an urban environment									
8 «О»	0.81	4.20	4.45	31	69	58	42	56	44
4«Ю»	0. 80	3.95	4.15	44	56	65	35	37	63

Significant differences in organic matter content were observed among the studied soil-ecological factors between the sites. The organic matter content in the soil under the plantations growing on the city border (experimental plots #11, 7, 10) was significantly higher (about 50%) than the organic content from the distant plots. This could indicate that there is potentially are duction of the most available forms of heavy metals (the exchangeable form sextracted with $Ca(NO_3)_2$) not a reduction of the less available (potentially available) forms (extracted with 1N HCl). However,these correlations were not observed. Thus, theratio of the exchangeable to potentially available forms of heavy metals varies according to soil compaction. Our observations show that the higher the bulk density value, the greater the proportion of mobile forms of heavy metals, including an increasein the ratio of exchangeable forms. Therefore, it can be stated that the compaction factor is more significant than the humus content.

The soils were characterized as acidic with a pH range of 4 and 5. The pH value varied in the upper humus horizon from 4.10 to 4.35; approximately a 7% difference. This difference, however, did nothave a significant impact on the degree of heavy metals mobility. The soils under the pine and birch stands growing in the middle of the forest (experimental plot # 9) had pH of 3.9 and were classified as highly acidic (determined by a pH range of 3—4) (Table 2). It was expected that the presence of organic matter and increased soil acidity would have also increased the degree of heavy metal mobility; however, this was not the case. The results showed that the mobilitywasactually largely affected by the compaction.

To confirm the importance of soil compaction as the driving factor of heavy metals mobility,soilsamples weretaken from the native stands growing on the city borderand analyzed for bulk density.The average value of bulk density was 0.8 g cm^{-3} (experimental plots # 4 "Ю" and 8 "O"). The different phases of the heavy metals were also analyzed in these samples. In the forest plotswhere was minimal anthropogenic load, the content of the most available (exchangeable) forms (extracted with $Ca(NO_3)_2$) was significantly lower than the less mobile (potentially available) forms (extracted with 1N HCl) (for Pb — 44 and 56%, Zn — 35 and 65%, Cu — 37 and 63%, respectively). A similar ratiowas observed for Pb — 31 and 69%. Zn — 58 and 42%. Cu — 44 and 56% at the experimental plot # 8 “O”. Obtained results show, that in the absence of increased soil compaction,the percentage of the most mobile (exchangeable) form was significantly reduced.

The results show a significant reduction in the mobile forms of Pb in the forest areas that were subject tominimal recreational load in comparison with the high-density areas.This confirms that the soil compaction plays a dominant role in determining the degree of potentialcontamination hazard from the heavy metals. Soil compaction thus creates a sensitization effect, enhancing the impact of heavy metals; Pb contamination causing the greatest threat.

The increased heavy metal mobility in the soil affects the migration of contaminants into the plants. Considering that,the root system of a plant is the first biological barrier to toxins in polluted soils [12]; wehavestudied the heavy metal content in the roots of the tree species (Table 3).

Table 3

The heavy metal content in the tree roots depending on the degree of anthropogenic load (mg kg^{-1} of dry matter)

N of the trial area	Cd	Zn	Cu
Sites with the minimum anthropogenic impact			
6	0.20 + 0.02	22.35 + 1.05	3.15 + 0.10
8	0.11 + 0.02	7.12 + 0.10	3.15 + 0.10
9	0.40 + 0.01	47.25 + 2.80	8.10 + 0.30
Sited with the increased anthropogenic impact			
11	0.29 + 0.03	35.75 + 1.40	3.63 + 0.21
7	0.29 + 0.02	10.50 + 0.14	3.70 + 0.40
10	0.45 + 0.01	62.30 + 2.80	7.20 + 0.10
Control (Istrinsky Forestry) Birch	0.24 + 0.02	32.60 + 2.60	3.55 + 0.12
Pine	0.30 + 0.04	22.00 + 2.50	4.25 + 0.28

Increasing in anthropogenic load, heavy metal migration capacity (determined by biological uptake) in the plants also increased. The results ranged from 12 to 152% of plant heavy metal concentrations compared to the control plots, depending on the species composition of the stand. The maximum migration capacity was found in the root systems of 70—80-year-old oak tree stands (experimental plot #7) and the minimum, in the roots of pine and birch phytocoenosis(experimental plots #9, 10).

Soil properties undoubtedly affect the growth and condition of the plants. Soil-ecological characteristics studies adopted in forestry studies, such as humus content, soil acidity, and availability of nutrients, do not fully reflect the multifunction of forest and agricultural ecosystems; processes of transformation of organic matter in particular. It is therefore necessary to study the biological components with a strong focus on microorganismsalong with the compositional, physical and chemical properties of the soil.

The behavior of microbial communities determines the mechanism of formation of sustainable forest and forest park ecosystems susceptible to a high anthropogenic load. This is especially important to consider in terms of the biodiagnostics and bioindications of soil when dealing with the issues related to the prevention of soil contamination. The data obtained on the status of these soil microbial relationships can be used for further research and monitoring of the forest and forest park landscapes [6].

The study of microbial components shows significant changes as a result of anthropogenicload. In the forest plotssusceptible to high anthropogenic load, the aerobic heterotrophic microorganisms sampled during different periods of vegetative growth exhibited a 7—10-fold reduction in number. The number of ammonifiers from the oak plantations (X—XII age class) was reduced from 34.6 million of colony forming units (CFU) in 1 g of soil to 3.4 million. Similar reductions of biological activity were observed for other plantations in similar settings. Under the 70—80-year-olds phytocenoses of the same species, the numbers reduced from 37 million to 3.4 million of CFU. The pine and birch stands had reductions from 21.4 million to 2.5 million of CFU (Figure 1).

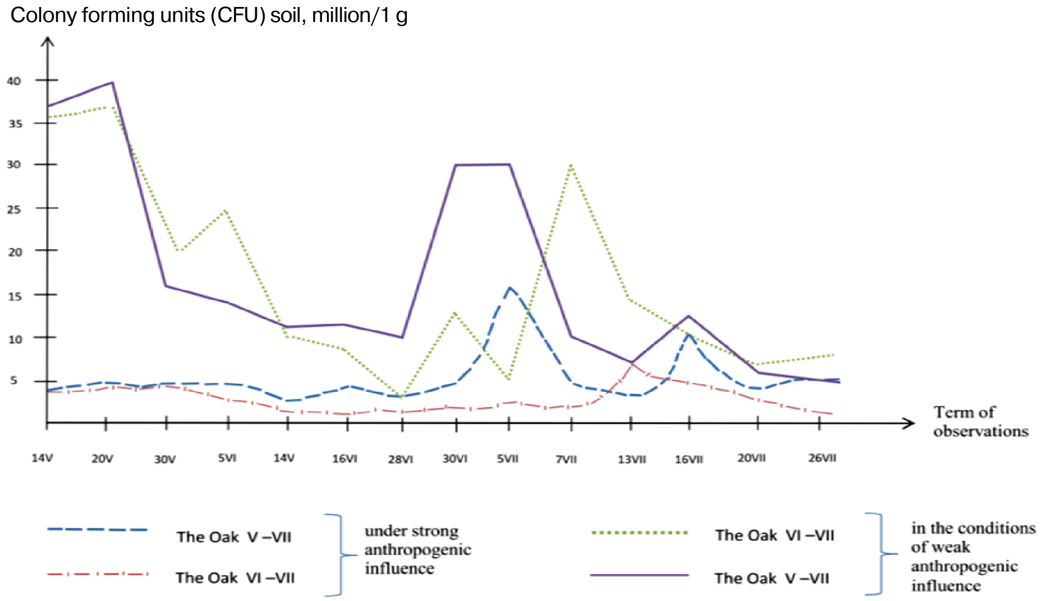

Figure 1. Changes in the number of microorganisms in the soil ammonifiers due to anthropogenic impacts (the upper 10 cm layer; million cells (g of dry soil)

With the reduction in microbial activity, the systems' normal functions are hindered. In plots, were impaired reproductive function of actinomycetes, this fact was indicated by the absence of aerial mycelium on the surface of the colony, and they remained sterile. In addition, the black (Niger) actinomycetes group was revealed, changing the structure of microbial cenosis (Figure 2).

Reduction of species diversity of bacilli resulted indisturbance of the normal functioning of the soil-plant systems. In the forest soil located far from the urban area, 7—8 heterotrophic aerobic spore-forming bacteria species were found whereas only 3—4 species occurred under the plantation near the urban environment (Figure 3).

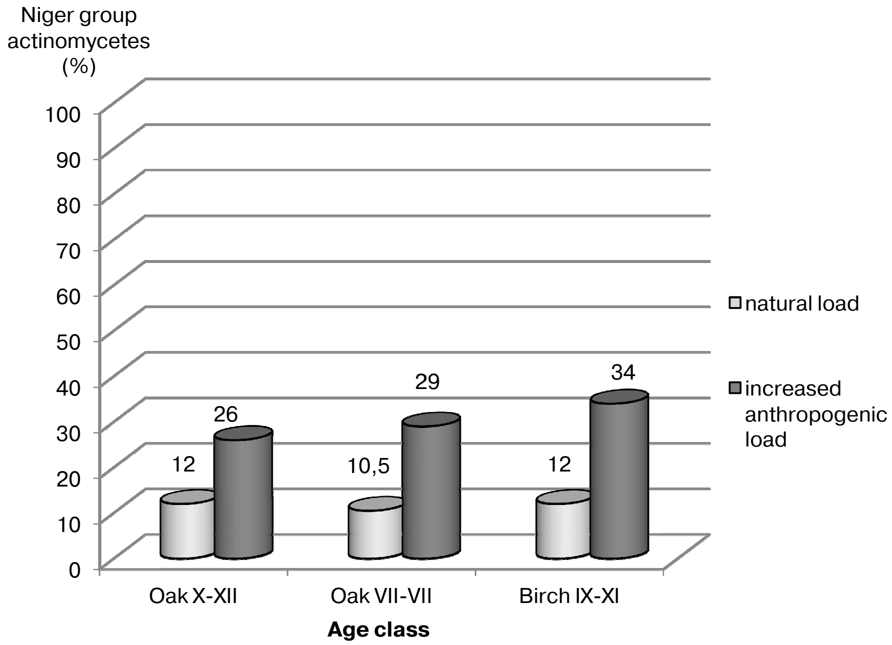

Figure 2. Percentage of the*Niger* groupactinomycetes
under the plantations with different anthropogenic loads

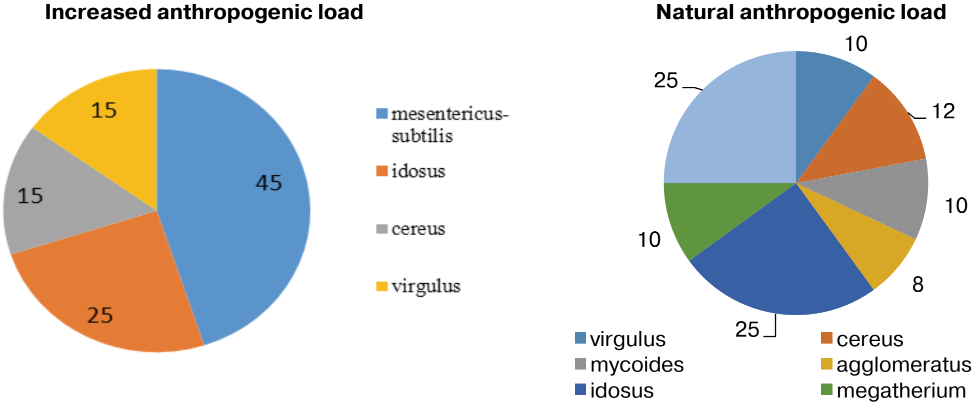

Figure 3. Species composition of bacilli in the soil
under the tree plantations with various anthropogenic loads

SUMMARY

1. The proximity of the urban environment, mainly highways, has a negative effect on the state of the stand.
2. The greater bulk density value, the greater the proportion of mobile forms of heavy metals was observed including an increase in the ratio of exchangeable forms.
3. The maximum heavy metal migration capacity determined by biological uptake was found in the root systems of 70—80-year-old oak tree stands and the minimum, in the roots of pine and birch phytocoenosis.

4. The systems' normal functions were found to be hindered due to reduction in microbial activity. Reduction of species diversity of bacilli resulted in disturbance of the normal functioning of the soil-plant systems.

5. Soil compaction is a strong factor in increasing risk of heavy metal mobility.

6. Recreational activity causes a 2—3-fold increase in the density of the soil, resulting in poor aeration and significant heavy metal contamination, affecting the stability and functioning of the green spaces.

7. In order to prevent irreversible degradation of green spaces in urban areas, it is nessary to optimize conditions for their growth to improve the performance of their environmental functions.

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REFERENCES

[1] Cheng Z., A. Paltseva, I. Li, T. Morin, H. Huot, S. Egendorf, Z. Su, R. Yolanda, K. Singh, L. Lee, M. Grinshtein, Y. Liu, K. Green, W. Wai, B. Wazed, R. Shaw. 2015. Trace Metal Contamination in New York City Garden Soils. Soil Science. Volume 180. Number 4/5. April/May.

[2] EPA 747-R-98-001a. Final report sources of lead in soil: a literature review. February 1998.

[3] From the Surface Down. An Introduction to Soil Surveys for Agronomic Use. 2010. Second edition. USDA Natural Resources Conservation Service.

[4] Healthy soils are the basis for healthy food production. 2015. Food and Agriculture Organization of the United Nations. I4405E/1/02.15.

[5] Mosina L.V. Fundamentals of Toxicology: Training manual. M.: Russian State Agrarian University of Moscow Agricultural, 2013.

[6] Mosina L.V., Dovletyarova E.A. Microbiological diagnostics of problematic environmental situations at the recreational natural facilities // RUDN Journal of Agronomy and Animal Industries. № 5. M.: PFUR, 2015. P. 130—140.

[7] Mosina L.V., Dovletyarova E.A., Andriyenko T.N. The Forest experimental station of Russian State Agrarian University — Moscow Timiryazev Agricultural Academy as object of environmental monitoring of forest and forest-park landscapes of the megalopolis of Moscow. M.: PFUR, 2014.

[8] Mosina L.V., Dovletyarova E.A., Petrovskaya P.A. Microbiological assessment of a condition of forest and forest-park ecosystems // RUDN Journal of Agronomy and Animal Industries. № 4. M.: PFUR, 2015. P. 42—51.

[9] Ryan, J.A., Scheckl, K.G., Berti, W.R., Brown, S.L., Casteel, S.W., Chaney, R.L., Hallfrisch, J., Doolan, M., Grevatt, P., Maddaloni, M., Mosby, D., 2004. Reducing children's risk from lead in soil. Environ. Sci. Technol. 38 (1), 18A—24A.

[10] Soil Quality — Introduction. Soil Quality Information Sheet. USDA Natural Resources Conservation Service. Revised June 2001. Available at: http://soils.usda.gov/sqi.

[11] Su Chao. LiQin Jiang. WenJun Zhang. 2014. A review on heavy metal contamination in the soil worldwide: Situation, impact and remediation techniques. Environmental Skeptics and Critics. 3(2): 24—38.

[12] Vorhees. W.B. 1992. Wheel-induced soil physical limitations to root growth. In i and B.O. Stewart eds. Adv. Soil Sci 19:73—92.

[13] Wong Coby S.C. Xiangdong Li. Iain Thornton. 2005. Urban environmental geochemistry of trace metals. Review. Environmental Pollution 142 (2006) 1e16. doi: 10.1016/j.envpol.2005.09.004.

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ПОЧВЕННО-ЭКОЛОГИЧЕСКАЯ ХАРАКТЕРИСТИКА РЕКРЕАЦИОННЫХ ЛЕСНЫХ ЭКОСИСТЕМ В МЕГАПОЛИСЕ МОСКВА

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В условиях уникального лесного массива — Лесной опытной дачи Российского государственного аграрного университета — МСХА имени К.А. Тимирязева изучен в динамике комплекс почвенно-экологических показателей в системе почва—растение с использованием физических, химических и биологических (микробиологических) параметров на фоне загрязнения тяжелыми металлами (ТМ) и нерегулируемой рекреации. Исследования показали, что уплотнение почвы выступает мощным негативным фактором, вызывающим сенсибилизационный эффект, при котором увеличивается опасность действия тяжелых металлов. Возросшая рекреационная нагрузка, вызывающая 2—3-кратное возрастание плотности почвы, а также ее аэрорегулируемость на фоне существенного загрязнения тяжелыми металлами, вызывает комплекс факторов, негативно влияющих на устойчивость и функционирование «зеленых легких». Кроме того, с увеличением антропогенной нагрузки миграция ТМ в растения увеличивается. Максимальная миграционная способность установлена в корневой системе 70—80-летних древостоев дуба, минимальная — в корнях сосново-березового фитценоза. Нормально функционирование экосистемы было нарушено вследствие снижения микробиологической активности.

Ключевые слова: тяжелые металлы (ТМ), уплотнение почвы, микробиологическая активность, экологические функции почвы, жизненное состояние древостоя, рекреационная нагрузка

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SOIL AND FOREST CHARACTERISTICS OF THE SAMPLE PLOTS IN THE CONDITIONS OF SOD-PODZOLIC SOILS OF THE FOREST EXPERIMENTAL GARDEN, RUSSIAN STATE AGRARIAN UNIVERSITY — MOSCOW TIMIRYAZEV AGRICULTURAL ACADEMY

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In this paper, the influence of sod-podzolic soils with different expression of sod and podzolic processes of soil formation the formation of pure coniferous and deciduous, and mixed forest stands in terms of educational scientific consulting center "the Forest experimental cottage". Identified the relationship of physico-chemical properties of soil from silvicultural and forest inventory indices of the studied stands. In this regard, was a complex of forests and soil studies, which include the laying of soil profiles with detailed description of the soil horizons, the holding of descriptions of woody vegetation with the establishment of the age, vertical and horizontal structure of forest stands growing.

Key words: silvicultural-taxation characteristics of forest sod-podzolic soil; humus; physico-chemical properties of soils; forest litter; soil moisture

Stance forest experiment RSAU-MAA named after Timiryazev is a unique natural research laboratory in which, beginning in 1862, regular monitoring of the condition, growth, structure, structure and productivity of forest vegetation. A great contribution to the conduct of silvicultural and forest research this area was made by A.R. Vargas de Bedemar (1863), M.K. Toursky (1893), N. With. Nesterov (1917, 1935), V.P. Timofeev (1965, 1966), A.N. Poles (1993, 2003).

On permanent sample plots, along with the taxonomic studies of forest stands are carried out and soil studies. The first assessment of soil was made A.R. Vargas de Padamara using as a basis data on the growth of pine plantations, it was proposed to establish three classes of quality of soils [9]. In the future soil of the Forest experimental garden has been the object of scientific research carried out under the leadership of such scientists as S.K. Soloviev (1889), I.P. Grechin (1954, 1955, 1957), B.D. Zaitsev (1964), V.D. Naumov (2005, 2009, 2015).

Influence of forest ecosystems on structure, composition and properties of sod-podzolic soils to date remains largely debatable. Karpachevsky (1977, 1996, 1997) in their works, constantly raised the question: what comes first. The change of soil under the influence of vegetation, or, on the contrary, differentiation of vegetation depending on soil properties. Numerous studies [2; 4; 7; 8] it was found that private forest plantations have different impacts on the emerging properties of soils. Gavrilov [4], and later Demin [6], confirmed that under other equal conditions (climate, position in the relief, Genesis and granulometric composition of soil-forming rocks) there is a significant difference in morphology and chemical properties of soil under different forest crops.

Largely unclear is the question of the role of sod and podzolic processes in the formation of sod-podzolic soils. According to Lebedeva, Tonkonogov [8], organogenic horizons are mostly carriers of a near memory associated with the capacity of modern external environment; and eluvial median horizon, keep, especially, information about the properties of Litomerice and transformed in the process of soil formation substrate and are native mostly a distant memory, associated with the peculiarities of soil formation in terms of climate and biota in past stages. The upper horizons of the soils to the greatest extent affected by changes in heat and moisture corresponding to the fluctuation of these parameters for seasons and years. Their formation is dependent on the receipt of litter and mortality, their number, nature and speed of decomposition of organic matter, the characteristics of the process of humification. Soil-forming processes affect primarily the upper strata of soils that are experiencing the most vivid reflection of the intensity and specifics of their manifestations, dynamics and orientation, also in the literature there is a reverse opinion. In studies of T.N. Minina (1992), conducted on sod-podzolic soils not confirmed the statement about high dynamic labile forms of humus. For received data, significant differences in the content of organic substances that go into the pyrophosphate extract during 3 months (May-July), was absent, this was observed in soils with different humus content.

Thus, the analysis of literature data showed that there are different points of view on the question of the role of the arboreal plantations of different composition on the properties of forest sod-podzolic soils. Insufficiently studied question on seasonal dynamics of organic matter in soils under different tree plantations. Of great interest is the question of changing productivity of forest stands in dependence on properties of soils in the urban environment. All this served as the basis for our research.

The aim of the study is to determine the mobility of various forms of humus under coniferous and pure deciduous, and mixed forest, establish the relationship between the capacity of the forest litter, field moisture content and qualitative composition of humus horizon. In this regard, was a complex of forests and soil studies, which include the laying of soil profiles with detailed description of the soil horizons, the holding of descriptions of woody vegetation with the establishment of the age, vertical and horizontal structure of forest stands growing.

As object of research was chosen permanent Stance forest experiment RSAU-MAA named after Timiryazev, 11M, 11E, 8H, 8O, 4O, 4N, 4M, 4L.

These data indicate the heterogeneity of the soil cover of the Forest experimental garden, which is due not only to heterogeneity in topography, but also different history and composition of woody vegetation.

The manifestation of such important properties as field soil moisture, in the present examples were specific. Identified a definite pattern under pure plantations (both under broad-leaved and coniferous), humidity was slightly higher than under mixed. Thus, it is possible to notice that such indicator as field soil moisture depends on the composition of wood plantations. This is because the woody vegetation creates a special microzone. Therefore, it is possible to notice that the climate, from the point of view of soil moisture, is specific under pure plantation in comparison with mixed plantations. Humidity is closely tied to microbiological processes in the soil, its value depends on their intensity. This indicator reflects the status of all modes. So we needed to watch this indicator in dynamics.

Table 1

Soil characteristics of the forest inventory sample plots

Room quarter	Plot	Age, years	Tier	The composition of the stand	Diametr, cm	Height, m	Class productivity	Completeness	Stockm3/he	Soil	Capacity Ao, cm	Capacity A1, cm	Capacity A1A2, cm	Capacity A2, cm
11	M	265	I	4Oak5Linden 1Birch single Elm, Maple	65,3 39,0 39,2	29,4 27,5	II	0,76	408,1	$П^{Дог-2}_{3/5}$ лс Мс	3	11	15	16
11	E	90	I	9Oak1Linden single Pine, Elm	32,1 39,6 26,1	25,3	II	0,79	314,0	$П^{Дог-1}_{1/3}$ сп Мп	2	8	13	18
8	H	110	1	8Oak2Linden single Pine	35,9 41,3 29,6	24,0 26,4	III	1,04	378,2	$П^{Дог-1}_{4/4}$ лс Мсп	5	13	13	17
8	O	120	I	6Oak4Linden	35,2 11,6	27,4	II	0,94 0,10	439,4	$П^{Дог-3}_{3/5}$ лс Мп	4	14	19	15
4	O	120	I	10Pine single Birch, Elm	30,9	25,3	II	1,07	465,8	$П^{Д}_{3/5}$ лс Млс	1	6	22	14
4	N	120	I	10Pine single Elm, Linden	28,4	25,0	II	0,91	340,4	$П^{Д}_{1/2}$ лс Млс	1	5	14	19
8	M	138	I	9Pine1Linden ед. Birch, Elm,Oak	27,6	24,4	II	1,09	432,9	$П^{Д}_{1/4}$ лс Мп	1	4	20	11
4	L	120	I	9Pine1Linden single Oak, Birch, Maple	25,6	25,2	II	1,01	414,3	$П^{Д}_{1/5}$ лс Млс	1	5	16	11

Was drawn up a diagram of distribution of values of field moisture of each month in the pilot areas and graphs of the distribution of this value separately for each area for 7 months (June—October, April—may).

It is noticed that the character of moisture distribution in the pilot areas in April, may, June and September were similar — large values of the field moisture was observed under pure oak and pine plantations for 5—10% less moisture was soil under mixed oak and pine forest. In July there was a slightly different picture — the difference in moisture in all areas was only 5% lower than the value observed under mixed pine and oak pure stands. In August, the driest month, the lowest moisture was in the soil samples under mixed and pure oak, but in mixed and pure pine plantations humidity was higher not by much. In October, a smaller value of field moisture was observed under the pure pine and mixed oaks.

Figure 1 presents the average values of field moisture.

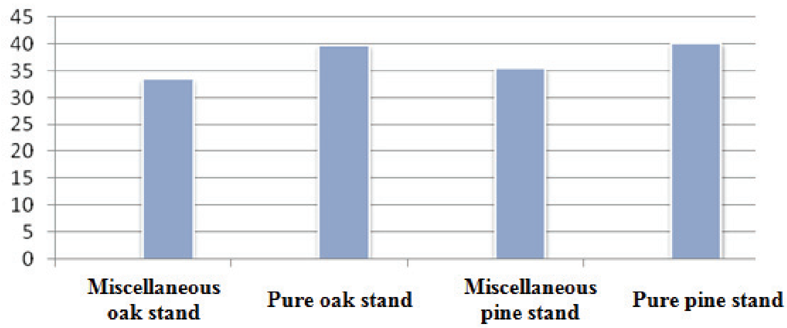

Figure 1. Average values of field moisture depending on the composition of wood plantations

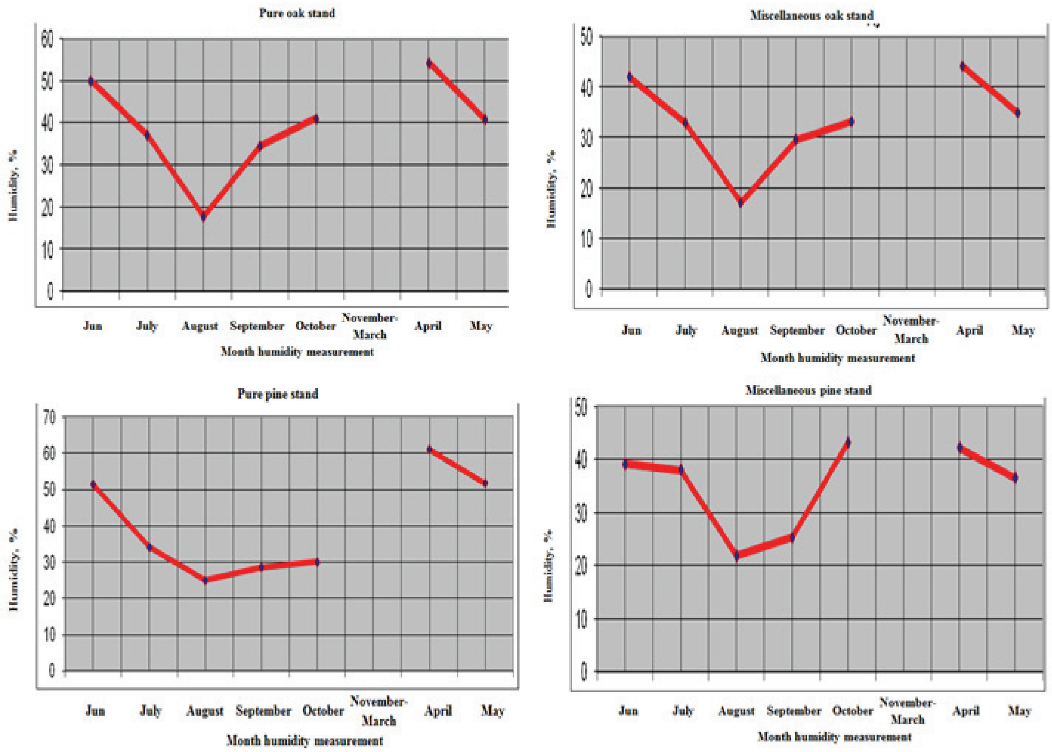

Figure 2. Change the field of humidity under pure and mixed oak and pine forest

The nature of the change of soil moisture under pure and mixed plantations is similar, maxima in spring months, and the lows in August, which is associated with the composition of plantations object of study. Under mixed and pure oak plantations change in the field of humidity occurred similarly, and under mixed pine plantations was observed, a slightly different picture in June and July humidity had a rather larger values and modified slightly in August, its value has decreased dramatically, little changed by September, and in October there was another high, and not very different in magnitude from the results taken in April of the following year. Under the pure pine plantations, the maximum value of humidity was observed in June and April, and the changes from July to October was pretty smooth.

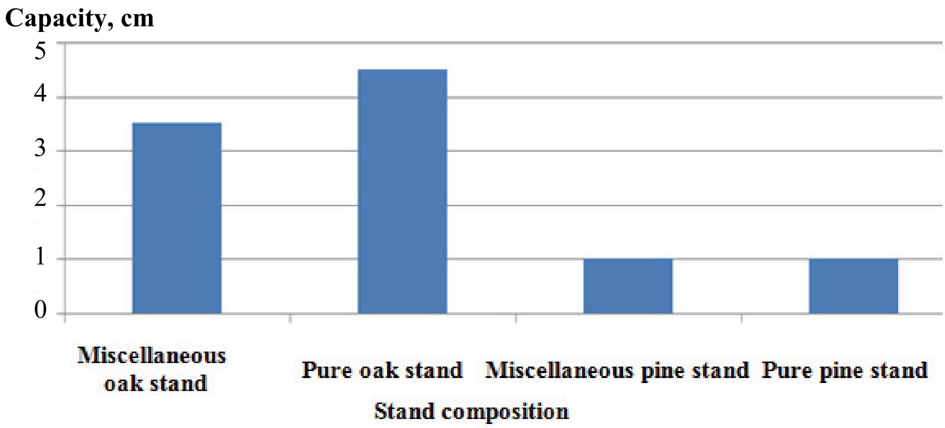

Figure 3. The capacity of the forest litter

According to Morozov (1912), litter plays a dominant role in the issue of forest impact on soil. Mats serve as the first battery and natural substances, the most important source of rolling organic substances, which migrate in the soil profile and within the profile of the litter is a sequential transformation of organic matter of the litter. The composition and structure of litter varies depending on the structure of forest stands, development of undergrowth, age, completeness, and sanitary condition. Properties of forest litter are in close genetic connection with the composition of plant residues, which formed a litter, and from the context in which the formation. A study of the forest litter showed that its capacity is closely linked with the composition of wood plantations (figure 3).

This diagram clearly shows that the capacity of the forest litter depends on the wood plantings presented on this space. The maximum value of power observed on the area of VIII H and VIII square O involved in pure oak plantations. Slightly less power is the A_0 horizon on the test areas M and E XI quarter, due to the fact that here in addition to oak, there are plantations and other tree species. The same power of the forest litter are plot O, N, M, L, IV block, located under the Mixed and pure pine plantations. The capacity of the A_0 horizon in these areas are minimal and make 1 cm, and are almost decayed and very thick. Hence it can be concluded that the litter of broad-leaved trees are more abundant and easier to transform.

Forest litter was collected in dynamics by months (June—October, April—may). Table 16 clearly describes the changes its power depending on the time of selection and composition of the woody planting plots.

The capacity of the forest floor, as can be seen from table 3, it is highly dynamic, which changes not only depending on the composition of plantations, but depending on the time of sampling.

As noted above, the largest capacity of the horizon A_0 was observed under deciduous stands, and lowest under conifers. However, this figure varies depending on the time of year. The maximum capacity of the litter observed in October, because at this time there is a leaf fall, and in the composition of litter is not only a waste of the past, but the litter of the current year. Under pure coniferous plantations changes the capacity of the forest litter was not observed, and under mixed coniferous — a slight increase in October, which is due to the litter of deciduous trees and underbrush.

Table 2

Capacity of the forest litter in the investigated test areas

Plot	A month sampling						
	Jun	July	August	September	October	April	May
	The capacity of the forest litter, cm						
11 M	2	2	2	3	6	3	3
11 E	3	2	2	4	6	4	3
8 N	5	4	5	5	6	5	5
8 O	4	3	4	4	5	5	5
4 O	1	1	1	1	2	1	1
4 N	1	1	1	1	1	1	1
4 M	1	1	1	1	1	1	1
4 L	1	1	1	1	1	1	1

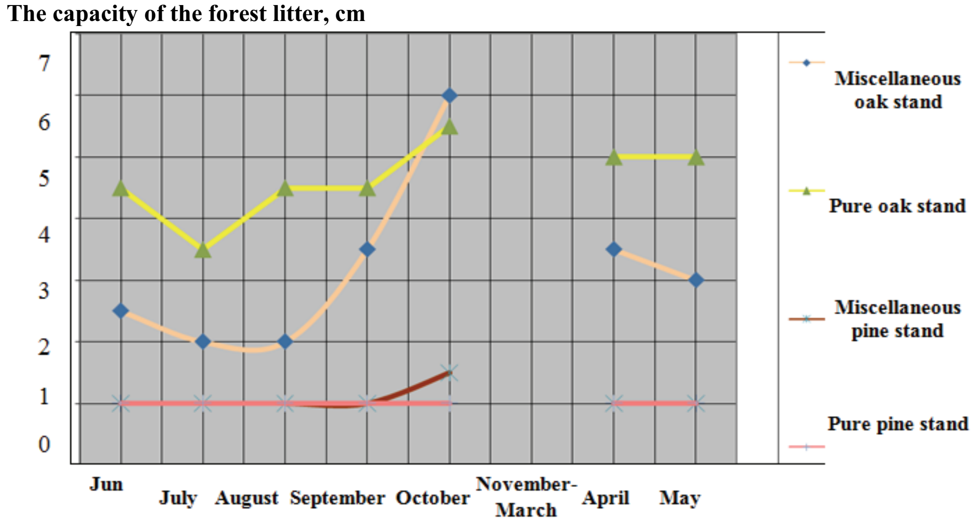

Figure 4. The capacity of the forest floor

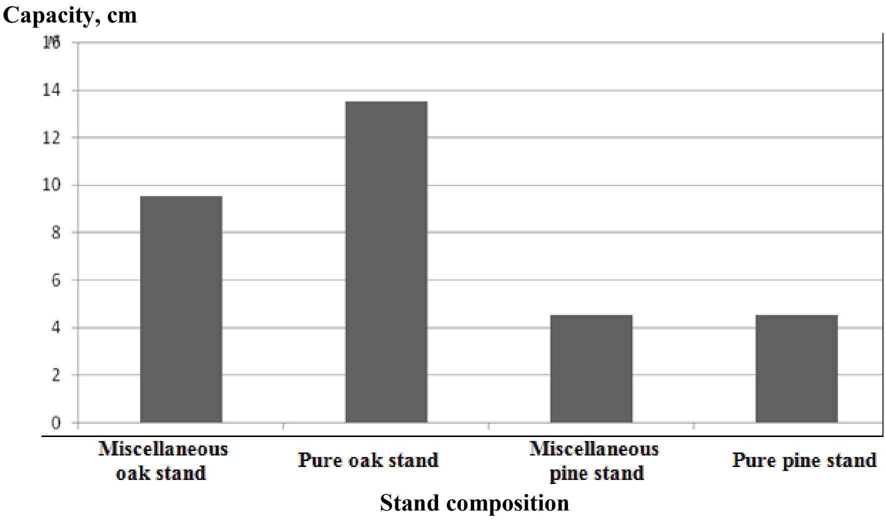

Figure 5. The capacity of humus horizon

The minimum capacity of the litter observed in the summer months (June—August), at this time, the conditions for microbial growth are optimal, manifested their active life, expressed increased rate of biological decomposition of the organic substrate (figure 4).

The humus-eluvial horizon in different experimental areas is presented in chart form in figure 5.

On the picture you can see that the humus-eluvial horizon depends on the composition of plants on sample plots. The greatest capacity of the A_1 horizon surface areas with a predominance of deciduous vegetation, which is faster transformered and contributes to the accumulation of soil organic matter. In Piazza VIII grow On pure oak stands, the humus-eluvial horizon there was the highest.

A little less power had the A1 horizon in Piazza VIII N, here the wood vegetation is presented by oak trees. The space occupied mixed oak plantations were even less sensitive to the power of the humus-eluvial horizon, but the lowest it was in the squares IV N I M engaged in mixed and pure pine plantations slightly more power horizon A_1 in the squares of the fourth quarter and L are also employed in mixed and pure pine plantations.

The dependence between the humus-alluviales the horizon and capacity of the forest floor. The highest values are observed under broad-leaved forest and lowest under conifers.

The research conducted in the soil on permanent sample plots Forest experiment station RGAU-MAA showed that between the capacity of the forest litter, humus-alluviales horizon, the value of humus content, its qualitative composition, as well as field moisture content revealed the General nature of the distribution, which indicates their close relationship. As can be seen from the graphs, between the considered indicators of the close relationship, which is determined by the composition of wood plantations. The capacity of the forest litter, field soil moisture depends primarily on the composition of the plantings and, as our research has shown, dynamically change according to months and seasons. It is the composition of the forest affects sod soil-forming process and, as a consequence, it is displayed in the capacity humus-alluviales horizon and humus content in sod-podzolic soils. The dependence between the parameters determined by the composition of woody plants, humus content and its qualitative composition.

Soil reflects both genetic and biogeocenosis properties, the resulting functioning of the forest ecosystem. Changes in the soil caused by the effects of various forest crops, ultimately lead to changes in forest properties, which in turn affects the nature of the plantations and their productivity.

Insights

1. Conducted inventory survey of pilot areas 11, 8, and 4 blocks. Studied composition and age of trees. Tree planting area M (4Д5Лп1Б units In a, CL, I) and E (9Д1Лп units. With, In) the 11th quarter are mixed, with a predominance of oaks; N (8Д2Лп units C) and (10Д4Лп) 8th quarter is represented by pure stands of oaks; ON(10S unit B, E, V) and N (10C per, PL, B) 4th quarter are mixed stands dominated by pine trees, and M (9C1Лп units B, C, D) and L (9C1Лп units D, B, C) is the pure pine plantations.

2. Morpho-genetic study of sod-podzolic soils showed that the sample area differ according to the capacity and composition of litter and the power of humus and eluvial

horizons. Most power horizons A_0 and A_1 was observed under the pure and mixed oak plantations. The capacity of the forest litter on the areas with mixed pine and pure pine plantations differed only slightly. The humus layer was higher in the soil under mixed pine, compared to pure pine plantations.

3. The Capacity of the forest litter and humus layer have similar patterns. With the increase in the share of broad-leaved trees in mixed plantings increases the humus layer.

4. The Capacity of the forest litter was changed only slightly under pure and mixed coniferous stands, the reverse situation was observed on the sample areas with deciduous vegetation. Least power A_0 is marked in summer, when the rate of decomposition of organic matter maximum, due to the high activity of microorganisms. Maximum amount of litter observed in October after leaf under deciduous trees, and the minimum in summer under coniferous vegetation. The capacity of the forest floor varies depending on the season of the year.

5. Found that a positive effect on the soil have a broad-leaved tree species, which contribute to the formation of a more powerful humus horizon in comparison with soils under pine plantations. Reducing the capacity of the humus horizon is noted in the series: pure oak plantations — mixed plantations of oak — pine mixed stands and pure pine stands.

6. The Amount of hygroscopic moisture varies slightly by month and not depend on the composition of wood plantations.

7. The value of the field humidity varies by month and depending on the composition of wood plantations. This preserves the General pattern: field moisture content is higher in soils of the sample plots in almost all months occupied by pine plantations and lower in soils of plots with oak plantings.

8. In the soils under deciduous vegetation, the humus content is higher than under the mixed and pure coniferous stands.

9. The dependences between indicators: the capacity of forest litter, field moisture content, humus content and qualitative composition of humus horizon.

REFERENCES

[1] Bogatyrev L.G., Sapozhnikova V.A., Voegele A.A. Transformation of organic matter in the pine ecosystem as one of the criteria of estimation of intensity of cycle. Bulletin of Moscow University, No. 3, 1999, pp. 13—24.
[2] Vargas de Bedemar A.R. Mensuration forest cottage Petrovskaya agricultural Academy. A handwritten report. M., 1863, p. 281.
[3] Gavrilov K.A. Impact of different forest plantations on the soil. Forestry, No. 3, 2000, pp. 30—37.
[4] Gerasimova M.I., Isachenkova L.B. “Short memory” of sod-podzolic soils in forest regeneration successions In the book “soil Memory”. M.: Publishing house LKI, 2008. P. 638—649.
[5] Demin G.V. Influence of different forest types on the content and qualitative composition of humus in soddy-podzolic soils. // Forest Bashkortostan'. Modern heritage and prospects. Ufa, 2004.
[6] Dobrovolsky G.V. Diversity of the Genesis and functions of forest soils // Soil science. 1993.

[7] Karpachevsky L.O., Stroganova M.N. General regularities of soil formation in the forest zone // Soil formation in forest biogeocenoses, Nauka, 2006.
[8] Lebedeva I.I., Tonkonogov V.D. Memory of the genetic horizons of the soil profile and the Memory of soils. M.: Izd. LCI, 2008. P. 162—180.
[9] Morozov, G.F. The doctrine of the forest. 3 edition, state publishing house, Leningrad, 1928.
[10] Naumov V.D., Polyakov A.N. 145 years of the Forest experimental garden, Russian state agrarian University-MTAA named after K.A. Timiryazev. M.: Publishing house of Russian state agrarian University-MAA, 2009. 511 p.
[11] Naumov V.D., Rodionov B.S., Gomonov A.V. Estimation of forest growing conditions of tree plantations on the territory of LOD RGAU-MAA // Mat. International scientific-practical Conf. “Science in information space”. Dnepropetrovsk, 2013. 77—83.
[12] Naumov V.D., Rodionov B.S., Gomonov A.V. Comparative assessment of soil and vegetation on sample plots of LOD under mixed and pure coniferous and deciduous trees // Izvestiya. 2014. No. 2.
[13] Naumov V.D., Smirnova M.A. Morphogenetic classification and evaluation of sod-podzolic soils of the Forest experimental garden, Russian state agrarian University-MAA named after K.A. Timiryazev // Izvestiya, 2009; № 2.
[14] Polyakov A.N., Khlyustov V.K. Foresters Peter's and the Timiryazev Academy. M.: Publishing house of Russian state agrarian University-MTAA, 2009. P. 149.

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ПОЧВЕННО-ТАКСАЦИОННАЯ ХАРАКТЕРИСТИКА ПОСТОЯННЫХ ПРОБНЫХ ПЛОЩАДЕЙ ЛЕСНОЙ ОПЫТНОЙ ДАЧИ РГАУ-МСХА ИМЕНИ ТИМИРЯЗЕВА В УСЛОВИЯХ ДЕРНОВО-ПОДЗОЛИСТЫХ ПОЧВ

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В статье рассмотрено влияние дерново-подзолистых почв с разным проявлением дернового и подзолистого процессов почвообразования на формирование чистых хвойных и лиственных, а также смешанных древостоев в условиях учебно-научного консультационного центра «Лесная опытная дача». Выявлены взаимосвязи физико-химических свойств почв с лесоводственно-таксационными показателями исследуемых древостоев. В связи с этим был проведен комплекс лесотаксационных и почвенных исследований, которые включают в себя закладку почвенных разрезов с детальным описанием почвенных горизонтов, проведение описания древесной растительности с установлением возрастной, вертикальной и горизонтальной структуры произрастающих древостоев.

Ключевые слова: лесоводственно-таксационная характеристика, лесные дерново-подзолистые почвы, гумус, физико-химические свойства почв, лесная подстилка, влажность почвы

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LANDSCAPE URBANISM IN THE CENTER OF MOSCOW: NEW HYBRID MODELS OF PARK AREAS

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It is necessary to reconsider the role of natural areas and landscape approaches to improve the quality of urban environment for a sustainable development of modern cities. The development of city's green infrastructure, what is integrated in "landscape urbanism" term, implies the restoration of environment natural components by expansion of urban boundaries or searching for reserved areas of "abandoned" landscape in a city structure [10]. Creating a new development strategy of natural environment territories, in terms of post-industrial reality and progressive urbanization is the part of city's spatial development that must be adapted and supplied carefully. It is necessary to search for new development models of urban space, where the landscape typology and nature features are the means of environment identity [13]. The rapid degradation of natural areas, as a result of "densification" of a city and building development in the largest cities of Russia, primary Moscow, was observed from the beggining of 90-ies of the 20th century. It has led to the disappearance of natural areas, what influenced an environmental stress strengthening in different parts of an urban space, especially in its center, and strong recreational pressure on park areas, that are the most popular within a city. For changing this situation and creating a new scenario for parks development in the center of Moscow, it is necessary to form new urban objects, both in the center and in the middle and peripheral parts of the city. Scenario of sustainable urban development at different urban levels includes innovative ideas for life harmonization, associated with the concept of "living" cities, sustainable urbanization, preservation of historical heritage and new building technologies [5].

Key words: sustainable urbanism, space hybridization, model properties, blue-green infrastructure, local plants, the idea of linear park

INTRODUCTION

The symbiosis of landscape and urban planning approaches of city development involves the creation of hybrid spaces based on transformation of existing urban areas of a city [11]. The urban development problem of many European cities' central parts reveals the scarcity of natural areas for recreation. The solution depends on a competent strategy of preservation and development of historical and natural areas in the context of urban fabric, especially in the circuit of water areas. Creating a system of interconnected park areas at the periphery of water bodies in "walking" distance from landscaped residential complexes and office buildings, designed on the principles of "green" architecture, should form ecological stability knots in the new city natural frame. Such hybrid spaces with "natural gravity" areas in different parts of a city can be created, by adding green vehicle-to-pedestrian communication areas, squares and embankments, a new landscape-urban system of a city is formed, with improved performance of environmental comfort and environment safety for all residents [6]. Modern examples of such approach are the projects of Madrid Rio in Madrid, Aranzadi Park in Spain, Toronto's Lower Don Lands in Toronto, Beregovaya Liniya in Belgrade, Tagus Linear Park in Lisbon and many others. They demonstrate not only the soft integration of new objects in urban city structure, but their strongest "landscape" impact on the surrounding area as well. The examples above became the basis for comprehensive study and, adapted to Russian realities of urban policy, but also revealed new development method in formation strategy of new types of multicultural public and recreational park areas. Over the past five years the largest parks in Moscow such as Gorky Park, Neskuchny garden and Muzeon undergone a serious analysis and assessment of natural potential. Reconstruction of these parks along with natural potential preservation and the emphasis on the socio-cultural aspect in the formation of urban environment allowed to adapt each of the parks to new city's needs and its residents. This urban facility has a certain set of properties and differs from usual methods of urban areas development, representing a hybrid model of a linear park by the water "with blurred boundaries" between city, river and park area [2].

GOAL AND OBJECTIVES

The goals of the research are the revealing and comprehensive study of the properties of the linear Park hybrid model in the light of the theory of landscape urbanism. Objectives of the research includes a comprehensive assessment of their impact on surrounding areas, an offer of the methods of hybrid space maximum adaptation in the context of historical city center and the development of this hybrid model on different urban levels.

MATERIALS AND METHODS

The river is the main city-forming structure of the central part of the city. It's right bank is bordered by unique areas, such as Vorobyovy Gory, Neskuchny garden and Muzeon park. At the periphery of the last one, in the result of landscape transformation of transport artery, socially oriented hiking and cycling communications appear in the natural environment. This is new Krymskaya embankment, formed on the principles of landscape urbanism. Such hybrid model of space affects regeneration of disturbed areas adjacent to the river and becomes a vector of the urban transformations of the city's central part. Without breaking the identity of Moscow historical center, it is blended harmoniously into the existing landscape and urban context. Today, the growth of attendance and new park area popularity, as a single natural and recreational space, occurs. Attendance of Gorky Park during the week is 20 000 people, and 100 000 — on weekends and holidays with a serious communication pressure on natural areas [18]. After refunctionalization of the entire natural area structure in 2011—2012 it became one of the most function filled parts of the linear park and, as any new hybrid urban model, it has new properties. Following the current trend of sustainable urbanism, admitted by Douglas Farr [4], for creating sustainable systems it is essential to integrate transportation system with land use and technologies with the development of biodiversity corridors in a specific ratio. Stable system bonds are reflected in properties of the hybrid model, and according to sustainable landscape urbanism, the model can be developed in time harmoniously only in case of "work" or action of each property. According to the urban planning theory and practice of landscape urbanism, hybrid models have the following properties: interconnection between landscape, architecture and urban context, formation scenario of area composition, historical contextuality, versatility, social specialization of area potential opportunities, visually-coloristic approach, seasonal and temporal variability, identity, horizontal, saturation, scale identity of architecture and landscape, permeability of spatial-planning structure, environmental comfort and safety, accessibility [10]. Observing the development of the linear park hybrid model, one can confidently say that some properties are perfectly manifested, and some properties are manifested partially, or require serious improvements and revision in engineering. Otherwise, such models may contain design and reconstruction errors in the future. It will inevitably reduce the level of psychological and environmental comfort in the center of Moscow, and also affect the future sustainable development of the regenerated areas. Let's consider the impact of hybrid model properties of urban park area and compare advantages and disadvantages of these properties. Interconnection between landscape, architecture and urban context, in my opinion, fully disclosed in presented area. It is manifested through the history of the place, functional connections of all territory parts with architecture and unique landscape. Its influence extends to all the surrounding areas and associated with regeneration of these areas in the city center. According to the plans of Moscow government Krymskaya embankment should become the only one pedestrian route from Vorobyovy Gory to “Krasniy Oktyabr” former factory [18].

Formation scenario of an area composition is closely connected with historical contextuality and versatility that will involve horizontal linkages in structure of an urban fabric. Central city part renaissance keeps creative and cultural reconstruction of the city as a space for meetings and presentations, space to “see and be seen, as the newly open living space” (Hoppula [3]). These properties are interrelated and have a great “read” in the space. Historical context is kept by the Moskva River as the main city-forming element with the unique landscape of three park areas. Preserved natural landscape of Neskuchny garden and Gorky Park is integrated with the urban landscape of the Krymskaya embankment (Fig. 1).

Figure 1. The urban landscape of Krymskaya embankment — historical context and the versatility of the pedestrian communication in the landscape with local plants (photo by the author)

Social specialization of the area potential opportunities involves an area social adjustment for people of all ages and interests. In this context, the present model of park area improves life quality in the city and is designed for every person of different age and social status [15]. Park functional zoning includes a playground, areas for recreation and cognitive rest, sports grounds, recreation near the water, beach area, dance floors, hiking and biking trails, equipment rental and many more. The territory as a whole and individually has different recreational areas of interest for all users of this space. Each of the parks associatively filled with a specific set of landscape tools and color images, maintaining the identity of the hybrid model. Along with historical memory of the place, the new aesthetic concept of parks development fits the idea of linear parks in Moscow center perfectly. However, visual coloristic range of Neskuchnyi garden could be more expressive, using, for example, means of landscape design as the forest canopy design of different types or color vegetation array of modern sculpture "to reinforce" a pleasant comfort and identity, named "cultural goodwill" by Pierre Bordeaux (Ilmonen [3]) (Fig. 2).

Figure 2. Contemporary Sculpture "The Power of dogs", made in a rack and pinion technology — by Hungarian sculptor Gabor Miklos Szoke (photo by the author)

One of the most important properties of a hybrid landscape of urban area is its seasonal (all-weather) and temporal variability. Year-round use of the natural area is a very important component of any architectural and landscaping concept. Then the landscape is perceived as aesthetic value especially in the colder seasons, using it for different kinds of leisure activities and socializing in a winter landscape. For Russia, with its climatic features, including the long winter period, late autumn and protracted spring colors, landscape support is required. Changes of all-weather and time-variability to enhance the identity of the hybrid model of park landscape is needed again in the structure of Neskuchnyi garden (Laine [3]) (Fig. 3).

By the horizontal saturation of hybrid urban landscape forms of vegetation design and work with the natural territory relief are proposed. In this case, the selection of landscape plant components are made by formation of multi-tiered perennial plants adapted to Russian climate conditions. It is necessary to integrate the soft nature components in the area of landscape structure with decorative effect creation of perennial ground cover plants, bushes and forest edges, by analogy with the natural forest.

Figure 3. The typological structure of Neskuchnyi garden — actively changing steep terrain with no evidence of area variability (photo by the author)

Figure 4. The “capture” of new territories in the circuit and on the periphery of the linear park — Krymskaya embankment (photo by the author)

Four final properties are the main problems of hybrid park area. The permeability of the space-planning structure of territory is violated due to intensive recreation and communication pressure. It is unevenly between Gorky Park, Krymskaya embankment and Muzeon. Scale identity of architecture and landscape manifests itself in the contradiction of urban development throughout the territory, at the end of the 20th century, urban development was improved on park areas. And today, the new hybrid model influences on the transport infrastructure in the center of the city actively, creating huge traffic jams at the external part of the Garden Ring in Moscow (Fig. 4).

There are two more properties of hybrid urban landscape which has not been met. Environmental comfort, safety and territory accessibility related to parks recreation popularity, which is manifested in the shortage of parking spaces. The presented hybrid model of park area is a new and very interesting landscape, urban facility at the natural and urbanized area in the center of Moscow. Historically in the context of the urban fabric, it actively influences the surrounding area. Buildings density in the central part of the city, and the popularity of the place determined the main problems of further sustainable development of the hybrid park model. In order to overcome the negative impact of the properties above there are appropriate methods for the qualitative improvement of urban planning situation and fix design errors of future projects.

Method of park area restructuring involves working with typology of each section of park area landscape and focusing on changing terrain and former transport routes. The method is also aimed at finding reserved territories in the circuit and on the periphery of linear park hybrid model for personal transport parking organization. In this connection, the example of the Krymskaya embankment reconstruction, performed by architectural "Wowhous" Office, is significant [9]. In the project a high level of modern design with social and environmental aspects compete with place popularity and, as a consequence, led to miscalculations in the organization of a sufficient number of places for vehicles parking.

Method of layer-by-layer modeling of renewing nature means the use of 3 tiers of plant components in the structure of the landscape to change its identity [12]. The main objective of the method is the change of visual image composition. In world practice, there is a tendency not only in the returning nature in a city but the creation of natural landscape, following the principles of humanist ecology and environmental design [8]. This approach involves accented work with natural biotope of selected urban area, deep knowledge and understanding of development dynamics of trees and shrubs, perennial grass and meadow crops [13]. In the course of this work, the typological structure of the territory in closed and open areas, meadow spaces and natural oases is determined. Territory restructuring on different types of sites with "spontaneous" nature possesses sufficient resources to recreate the natural undergrowth and forest edges by analogy with forests. In the middle of the XX-th century "imitation" of nature meant the union of natural habitat and plants of the climatic zone in a single landscape composition [8]. Selection of additional vegetation were performed by formation of tiered perennial plantings so, that the work of a landscape architect was almost imperceptible to landscape supervisor.

The method of integration of park area water-green infrastructure in city center urban fabric means "step by step" adaptation of the right bank of the Moscow-river to the new recreational needs of society in new natural environment. The method is designed for active research of functional connections methods between the main city-forming element, the river, and natural and urbanized landscapes of three park areas in order to regenerate the urban space. A vivid example of the use of this method is a general plan of Perm, where "key" moments of city regeneration is creation of stable water-in-green frame of open spaces [1].

RESULTS AND THEIR DISCUSSION

The analysis results of a new linear park hybrid model on different urban levels from territory elements to the landscape typology demonstrated that reconstruction stages of three park areas are aimed at preserving the natural heritage and the development of recreational infrastructure in the central part of the city. Most of the properties have a positive effect on the actively changing social, cultural, environmental and aesthetic performance of architectural and town-planning object in the center of Moscow. However, environmental comfort, safety and territory accessibility are not provided with competent restructuring of adjacent areas on the level of design for parking space search. For stepwise solution of these issues in the sustainable development of the linear park hybrid model offers new methods of its landscape renovation. The results of their implementation in the central part of the city will affect urban development of the entire area of the Moskva River. The development concept was elaborated in the project of "Project Meganom" architectural bureau, which became design competition winner for coastal areas development of the Moskva River [18]. The main focus is on the environmental strategy and the overall concept of coastal areas development of the main water artery of the city.

CONCLUSION AND RECOMMENDATIONS

In General, landscape-urban hybrid model of park area enhances life quality in the city and represents a great practical and scientific interest. Combining the properties of hybrid areas with regeneration methods and the process of de-industrialization, water-green infrastructure can obtain the status of environmentally sustainable and socially efficient spaces. The appearance of such hybrid landscape-urban objects that are city stable based on the principles of landscape urbanism and associated with the return of nature in Russian cities.

The main results of scientific work were presented in two reports on the international landscape conferences in Saint-Petersburg and Stockholm in 2015 and 2016. Theoretical bases are developed in the master thesis in 2015. The scientific research presented in article expands scientific knowledge of the ecological way of stabilizing park areas in the central part of Moscow. It is necessary to continue this work for useful integration of the theory and practice at all town-planning levels. The presented model of the organization of the inhabited environment shows new opportunities of regeneration of building of the Russian cities and formation of strategy of their sustainable development for the change of the quality of human life in the city. It gives a positive resource for the creation of "living" cities" with the steady natural and architectural environment.

REFERENCES

[1] Appenzeller, M. Gietama, R. City regeneration today. TOPOS: The International Review of Landscape Architercture and Urban Design — 2010, № 73: Sustainability, 2010, pp. 18—23.

[2] Meyer, E.K. River Park as a Place of Movement. TOPOS: The International Review of Landscape Architercture and Urban Design — 2014, № 89: Sustainability, 2014, pp. 76—82.

[3] Arabianranta. Rethinking Urban Living. (City of Helsinki Urban Facts. City of Helsinki Economic and Planning Center. Art and Design City Helsinki Oy). — WS Bookwell Oy, Porvoo, 2007. P. 288.

[4] Farr, D. Sustainable Urbanism: Urban design with nature (2008) John Wiley & Sons, Inc., 352 p.
[5] Nannan, D., Zhang, L., Ruff, S. From Expo City to Sustainable City. TOPOS: The International Review of Landscape Architercture and Urban Design — 2010, № 70: Sustainability, 2010, pp. 19—27.
[6] Gleeson, R. Toronto's Lower Don Lands. TOPOS: The International Review of Landscape Architercture and Urban Design — 2010, № 73: City Regeneration, 2010, pp. 62—67.
[7] Information on http://archsovet.msk.ru/competitions/moskva-reka/meganom-moskva-reka.
[8] The Contemporary Garden. Phaidon Press Limited. ISBN 978 0 71 48 4958 4-2009. 111 p.
[9] Information on http://wowhaus.ru/mobile.php?n=287&p=1 Архитектурное бюро Wowhous: Крымская набережная http://wowhaus.ru/architecture/crimea-quay.html.
[10] Krasilnikova, E. Landscape Urbanism. Teoriya-Praktika: scientific monograph / Krasilnikova E.E. Volgograd: LLC IAA Oblastnye vesti, 2015. P. 1: scientific and practical bases of landscape urbanism [Text]. 2015. P. 156 (in Russian).
[11] Information on http://green-city.su/landshaftnyj-urbanizm-novyj-vzglyad-na-staruyu-problemu.
[12] Nefedov, V. Urban landscape design. SPb, Luibavich. 2012. 317 p. (in Russian).
[13] Nefedov, V. How to return the city back to people. M.: Iskusstvo — XXI vек, 2015. 160 p.: ill. (in Russian).
[14] Information on: http://green-city.su/beregovaya-arxitektura-i-dizajn-sredy-u-vody/ (in Russian).
[15] Information on: http://www.scientific.net.
[16] Information on: www.mka.mos.ru.
[17] Information on: www.park-gorkogo.com.
[18] Information on: http://archsovet.msk.ru/article/konkursy/ekologiya-reki-strategiya-i-praktiki.

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ЛАНДШАФТНЫЙ УРБАНИЗМ В ЦЕНТРЕ МОСКВЫ: НОВЫЕ ГИБРИДНЫЕ МОДЕЛИ ПАРКОВЫХ ТЕРРИТОРИЙ

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Для устойчивого развития современных городов необходимо пересмотреть роль природных территорий и ландшафтного подхода в улучшении качества городской среды. Развитие зеленой инфраструктуры мегаполисов, объединенное термином «ландшафтный урбанизм», подразумевает восполнение природных компонентов среды при расширении городских границ или поиск резервных участков «заброшенного» ландшафта в структуре города [10]. При создании новых стратегий развития территорий природная среда в условиях постиндустриальной действительности и прогрессирующей урбанизации является той составляющей пространственного развития городов, которую необходимо бережно адаптировать и восполнять. Необходим поиск новой модели развития городского пространства, в которой типология ландшафта и компоненты природы являются средствами идентичности среды [13]. Стремительная деградация природных участков в результате «уплотнения» города и застройки в крупнейших российских городах, в том числе и Москве, наблюдалась с 90-х гг. XX в. Она привела к исчезновению внеархитектурных пространств, что, в свою очередь, повлияло на усиление экологической напряженности в разных частях городского пространства, особенно в его центре, и сильнейшей рекреационной нагрузке на парковые территории, наиболее востребованные городом. Для изменения этой ситуации и создания нового сценарного развития парков в центре Москвы необходимо формирование новых урбанизированных объектов, как в центре, так и в срединной и периферийной части города. Сценарий устойчивого развития города на разных градостроительных уровнях включает инновационные идеи по гармонизации жизни, связанные с понятием «живущие» города, устойчивой урбанизацией, сохранением исторического наследия и новыми строительными технологиями [5].

Ключевые слова: устойчивый урбанизм, гибридизация пространства, свойства модели, голубая и зеленая инфраструктура, местные растения, идея линеарного парка

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MONITORING, RESTORATION AND MAINTENANCE OF AGED TREES IN SUMMER AND MIKHAILOVSKY GARDENS OF ST. PETERSBURG

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The image of the Summer Garden is inseparable from the image of St. Petersburg. It was survived together with the city of the period of formation, rapid flourishing, change of rulers, change, economic systems, natural and military disasters. In June 2009, Russian Museum proceeded to largest restoration on the reconstruction of the memorial ensemble of the Summer garden. The article presents the results of inspection condition of old-growth trees in Summer and Mikhailovsky Gardens and analyze inventory data from 1962 to 2014, the dynamics of change in the number of trees.

Key words: Summer Garden, Mikhailovsky Garden, plantations of trees, inventory of tree plantations, old-growth trees

INTRODUCTION

Urban green zones make a substantial contribution to the environmental conditions and the quality of life in the modern cities. For example, trees and shrubs in the leafy state reduce dust in the air an average of 40% [7]. Old rural parks resemble high-conservation-value forests more than the best preserved contemporary forest remnants. Old parks do provide a refugium for temperate deciduous forest species [1].

Under specific circumstances the old trees in the park may provide valuable information for restoration decisions. The most important challenge in restoration is to identify trees and provide conditions to achieve an original design concept. Due the similar trends in development of manors and manor parks in the Baltic countries, the topic is equally interesting for all Baltic States.

Reconstruction and design of the original landscape requires the inventory data, including total amount, age, dominated species and the structure of plantations. Furthermore, the difference between the current structure and the original plan shall be considered by the landscape architectures and planners. One of the ways to deal with this issue is to identify the really old trees from the new or subsequent growth, and focus attention on those [2].

Since the old trees illustrate a long period of environmental conditions' dynamics, investigators are increasingly turning to dendrochronology to create context for current environmental change. While a suite of characteristics to identify old trees has been developed, most of these characteristics are for conifers or trees growing in low-density forests. The common indicators of old (> 250 year old) EDF angiosperms are presented to aid in the recovery and preservation of these living sources of information [3]. This study aimed to analyze the inventory and dendrochronological information for two historical parks in Saint Peterburg in order to develop the best management practice to restore and maintain the plantations.

MATERIAL AND METHODS

The research area included to historic gardens, located in the center part of Saint-Petersburg (59°57′N; 30°18′E). Both areas were passed the management of the Russian Museum to create a single palace-garden complex in the center of St. Petersburg. The Mikhailovsky Garden with Mikhailovsky Castle Garden and Engineers Square was included in the complex in 1998, whereas the Summer Garden with a summer palace of Peter I and the house of Peter I on Petrovsky Embankment was embraced in 2004.

Restoring the historical gardens was claimed as the principal goal for the established palace-garden complex. An new branch of the Russian Museum, focused on the green areas of the Summer and Mikhailovsky Gardens was established in 2012. An inventory of the green areas was performed and the research and restoration activities were organized to maintain and develop the garden ensemble. Although the inventories in the Mikhailovsky Garden were conducted previously (in 2011 before the restoration and in 2008 after the restoration), the inventory results were not complete. A new inventory of the gardens and green areas was carried out in 2012—2014 to fill existing data gaps. Since the age of the trees was not specified in the previous inventories, trees of each type (breed) with different diameters were sampled and the age category was identified. Selected aged (older than 150 years) trees were analyzed with the two-dimensional impulse tomography Arbotom (Rinntech, Germany) (in total 300 trees). The selected ancient trees in the Mikhailovsky Garden (for example, an oak dated back to the Peter I period and overmature lime-trees) were additionally examined by specialists of NCSA's and the core samples were taken. The obtained results on the age of the trees were verified using the historical documents (for example, the greening plan of Rastrelli). The inventory results were used to develop the best management strategies to maintain the plantations. A comprehensive monitoring of plantations' state was carried out to evaluate the efficiency of the implemented managements.

RESULTS AND DISCUSSIONS

In inventory results reveals the predominance of old trees in both Summer and Mikhailovsky Gardens (Table 1).

Table 1

Number of trees by age group, years

The name of the garden	up to 40		40—100		Over 100		Total	
	Pcs.	%	Pcs.	%	Pcs.	%	Pcs.	%
The Summer Garden	256	13,5	582	30,6	1063	55,9	1901	100
The Mikhailovsky Garden	200	17,0	392	33,0	595	50,0	1187	100

The obtained results were compared with the historical data, obtained for the green plantations of the Summer Garden in 1930—1940-s. The oaks of the age up to 500 years were the oldest trees in the garden in 1940-s, whereas the oldest lime-trees were 250 years old, and larch trees aged 200—300 years [8]. The comparative analysis of the inventory data collected at the Summer Garden for the period 1962—2012 years reveals that the oldest trees (200 years or older) are represented by lime trees and single oak trees. Similar results were obtained for the Mikhailovsky Gaden, where lime trees and single oaks were the oldest trees. The aged of the trees was not always positively correlated with the diameter, indicating that a larger diameter not always corresponds to an older age.

The aged trees are vulnerable to climatic conditions (e.g. windfalls and droughts) and anthropogenic pressures and therefore require for the special maintenance treatments. Prior restoration of the Summer garden comprehensive measures to adapt the trees to stressful situation was carried out. According to our information, it was for the first time in Russia. Several treatments were implemented. Sanitary, forming, decimation and compensating pruning of trees was carried out. The 44 problematic trees (curved and branched specimens) have been lowered to one-third or half of the initial height to preserve the trees and improve the light conditions. Root and leaf nutrition and treatments with biostimulators were implemented several times. The revealed 518 hollows (including 230 high from the surface) and frost cracks were treated. More than 100 young trees were planted and 21 trees were relocated during the restoration of the Summer Garden [5]. The implemented measures substantially increased the sustainability of the plantations. As seen from Figure 1 plants' health condition (in score) after reconstruction in the Summer Garden in 2012 was better when compared with before reconstruction in 2006—2007 years. During the four-year period after the restoration windfalls in the Summer Garden did not occur [6].

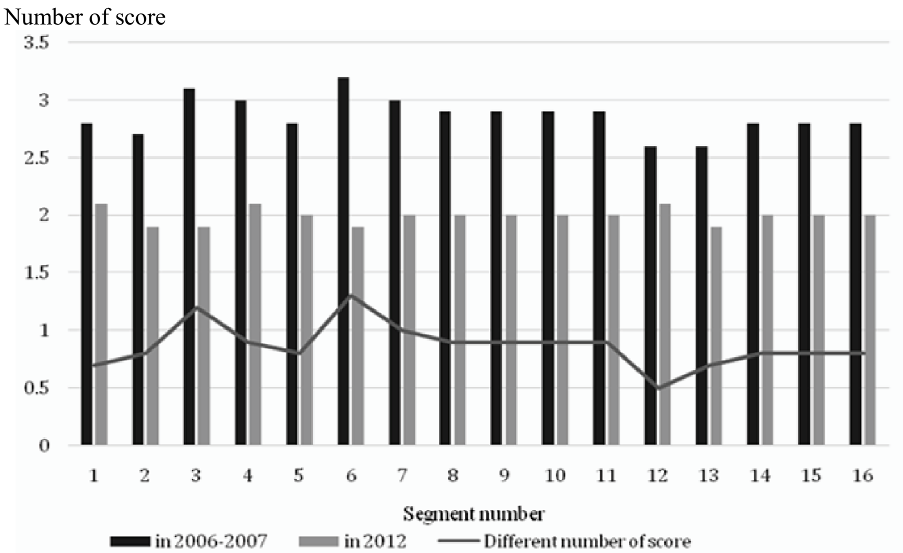

Figure 1 Comparison of plants' health condition before and after reconstruction in the Summer Garden

The treatment of the aged trees was carried out in the Mikhailovsky Garden during the restoration in 2000—2003. The following measures were taken: pruning, treatment of hollows and frost cracks, installation of protective and supportive structures.

The drainage pipes were installed in the Mikhailovsky Garden, however their effectiveness was not proved. For example, the examination of the tubes carried out during the plantations' monitoring showed that the tubes did not functions partly because they were clogged with rotting wood and rot, partly because the lowering of the hollow's boundaries. Since the effectiveness of the drain tubes was not confirmed for the Mikhailovsky Garden, they were not implemented for the Summer garden afterwards.

Currently, the following managements are implemented to all aged trees in the garden: sanitary pruning, moulding pruning and thinning of the crown (once a year), treatment with pesticides (twice a year). The aged trees in printed coverage in the Summer garden also received foliar fertilization until 2016 was. The following measures are implemented to treat the trunks: stem growth is removed, hollows are treated with further examining and treating sprout and truck damages.

Comparative monitoring of the aged trees' state was carried out in both gardens in 2016. In result 274 hollows were fixed in the Summer Garden, whereas 76 hollows were found in the Mikhailovsky Garden. The 92 crowns and trunks are fixed with ties in the Summer Garden, which is almost three time more than in the Mikhailovsky. Besides, 3 clamps and 1 holder were mounted on trunks during the restoration period. The positive experience of lowering tree in Summer garden were implemented in the Mikhailovsky Garden to restore the plantations.

To effectiveness of the implemented maintenance measures was evaluated based on monitored of the plantations' conditions. It was found, that the sanitary score of the plantations' conditions didn't changes since 2012 and gave similar 2.0 in average for the Summer garden [5]. The same score was obtained for the Mikhailovsky Garden. A major part of the trees in the gardens of the Russian Museum belongs to the second category (Table 2). The elm trees usually belong to the fourth category, whereas the first category is mainly reported for the young plantations. However, some of the young trees don't correspond to the first category to strong shadowing under crones.

Table 2

Distribution of trees between the state categories (August 2016), Pcs.

Garden	The Summer Garden					The Mikhailosky Garden				
Category condition	1	2	3	4	Total	1	2	3	4	Total
Number of trees	105	1 663	88	0	1 861	101	1 020	62	1	1 184
%	5,66	89,61	4,73	0	100	8,53	86,15	5,24	0,08	100

The applications for the two historical trees in the gardens were submitted in summer 2013 to the Russian program "Tree — is a monument of nature". Those trees were the oak of time of Peter the Great and the maple, located near the Palace of Peter I and frequently encountered in the paintings and engravings of the late XIX — early XX centuries of the Summer garden and the. In result both trees were included in the Register of Russian old-growth trees the end of 2013. The trees were officially recognized as "tree-monuments of nature" in winter 2014 by the decision of the Commission.

The analysis of the overmature lime-tees' showed an absence of rot for one of them. Based on the three sampled cores 265 and 267 annual rings were detected at [4]. The age of the tree-monument of nature — an old oak tree, located on an Oil meadow of the Mikhailovsky Garden, was estimated to 278 years. This outcome incorporated with the analysis of iconographic materials alowed Cherdantseva to draw conclusions that the oak was planted during the reconstruction of the garden following the project Rasstrelli's plan of 1741, organized for the Empress Elizabeth Petrovna. Therefore there are evidences to call this oak "The tree of Elizabethan time". The core analysis of the other lime-trees allowed interpolating its age to 286 years. There are 90 lime-trees of the similar age in the Summer Garden and 70 — in the Mikhailovsky Garden. Up to 27 aged trees (including 20 elm trees) were cut and 4 young tree were planted in the Summer garden since 2012. In total 24 aged trees were cut in the Mikhailovsky Garden, including 10 trees, affected by the 'ulm' disease.

The Mikhailovsky Garden hosted charity event "Tree of life" for the first time in 2014. Celebrities in the cultural, scientific and business spheres planted new trees within this action. The memorial name plates were with personal names or the names of the company were attached to the trunks of the trees. Each participant received a medal and a certificate. In total 28 new trees were planted to replace the dead aged trees during last two years. Planting trees in the historic garden is the best way to preserve the memory of yourself for future generations, because the trees live for centuries. Every planted tree males an invaluable contribution to the restoration of the architectural-spatial composition of the historical gardens. Although, the total extent of the Central Imperial gardens of Peter the Great in St. Petersburg reduced substantially over last 300, their significance and impact on the environment as the 'green lung of the city center' it is difficult to overestimate [6]. Therefore, it is important to keep them in appropriate condition and to preserve old-growth stands of past eras!

REFERENCES

[1] Lõhmus K., Liira J. Old rural parks support higher biodiversity than forest remnants, Basic and Applied Ecology, Germany, Volume 14, Issue 2, March 2013, P. 165—173.

[2] Nutt, N., Nurme, S., Hiob, M., et al. Restoring manor parks: Exploring and specifying original design and character through the study of dendrologous plants in estonianhistorica manor parks, Baltic Forestry, Volume 19, Issue 2, 2013, P. 280—288.

[3] Pederson, N. External characteristics of oldtrees in the eastern deciduous forest, Natural Areas Journal, Volume 30, Issue 4, October 2010, P. 396—407.

[4] Lovelius N.V., Lukmazova E.A., Palchikov S.B. et al. Linden overmature generation in the Summer garden of St. Petersburg // Geography: the development of science and education. A collective monograph on the International scientific-practical conference LXVIII Gertsenovskie reading 22—25 April 2015, devoted to the 70th anniversary of UNESCO. SPb. Publishing house of the Herzen State Pedagogical University of Russia. P. 91—95.

[5] Lukmazova E.A., Cerdanceva O.A. Changing the condition of green plantings in the Summer Garden in St. Petersburg after reconstruction // RUDN Journal of Agronomy and Animal Industries, № 5. M., 2012. P. 33—42.

[6] Mosina L.V., Dovletyarova E.A. Forest experimental cottage RSAU — MAA named after K.A. Timiryazev as an object of ecological monitoring of forest and forest park landscapes Moscow metropolis. PFUR, 2014, P. 1—221.
[7] Petrovskaya P.A., Stolyarova A.G. The basic principles of urban environment landscaping // RUDN Journal of Agronomy and Animal Industries,, № 5, M., 2013. P. 93—100.
[8] Dubyago T.B. The Summer garden. M.-L., 1951.

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СОХРАНЕНИЕ СТАРОВОЗРАСТНЫХ ДЕРЕВЬЕВ И МОНИТОРИНГ ИХ СОСТОЯНИЯ В ЛЕТНЕМ И МИХАЙЛОВСКОМ САДАХ САНКТ-ПЕТЕРБУРГА

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Образ Летнего сада неотделим от образа Санкт-Петербурга. Он пережил вместе с городом период становления, бурного расцвета, смену правителей, экономических формаций, стихийных и военных бедствий. В июне 2009 г. Русский музей приступил к крупнейшей реставрации по воссозданию ансамбля-памятника Летний сад. В статье приводятся результаты обследования состояния старовозрастных деревьев Летнего и Михайловского садов и анализ инвентаризационных данных с 1962 по 2014 г. динамики изменения количества деревьев.

Ключевые слова: Летний сад, Михайловский сад, зеленые насаждения, инвентаризация древесных насаждений, старовозрастные деревья

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GREENING AS AN ELEMENT OF SUSTAINABLE URBAN DEVELOPMENT: VALUATION OF ECONOMIC FEASIBILITY, POLICYASSESSMENT AND PRACTICAL EXAMPLES

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The article reveals the importance of urban greening as a part of sustainable urban development concept. We examinethe ecological, social, cultural, spatial benefits of urban greening promotionas well as the possible constrains to urban space vegetating. It is shown that the assessment of tree benefits can be important for implementation of sustainable urban development. In turn,appropriate urban greening assessment is also important. The article provides existing urban greening assessment methods and their implementation in real-life practices.

Key words: sustainable urban development, urban greening, green space change, urban challenges and problems

INTRODUCTION

Sustainable development has been a subject of active scientific research in recent years [5; 11; 22]. The sustainable development is the interdependence of environmental, economic and social issues in the process of human development, initially its basic principles were discussed at the United Nations Conference on the Human Environment [42]. The conference's declaration pointed out that while economic and social development is essential for the improvement of the quality of life, "the protection of the human environment is amajor issue which affects the well-being of people and economic development throughout the world" [42].

The issue of sustainable development becomes extremely acute when it is linked to the global trend in urbanization. Sustainability in the context of urban development means a necessity to solve a variety of problems: social, economicenvironmental and management system [43]. Environmental aspect is an important element of sustainable urban development, which includes the issues of air quality conservation, waste management, efficient energy use, water management andgreenery planting.

The main hypothesis of the paper is that promotion of urban greening, in particular in Russia, will lead to significant improvements in economic and social spheres. Greening benefits considerably exceedthe costs for its implementation and maintenance. However, it is necessary to findan economic approach for adequate assessment of the greening benefits. The goal of this article is to determine efficient economic approaches for the assessment of greening benefitsand, additionally, for measurement of government policy in this field. Such approaches might be useful for greening system optimization in urban environment, especially in megacities.

The paper is organized as follows. First, it presents the concept of sustainable urban development. The specific features of urban systems' functioning are mentioned and the threats to sustainable development in condition of intense urbanization are presented. The following section discloses the concept and functions of urban greening and provides the evidence of its contribution to all three aspects of sustainable urban development. The main problem of green urban spaces development such as the difficulties in determining its economic feasibility is stated and then a way of valuation the economic value of urban forests is proposed. The paper also provides some illustrative real practice examples of urban greening measurement practices implementation.

SUSTAINABLE URBAN DEVELOPMENT

The definition of "sustainable development" was introducedby the World Commission on Environment and Developmentwhich determined it as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. The main goal of sustainable development was the long-term stability of the economy and environment [11].

Nowadays the urbanization is the modern tendency globally, so theissues of sustainable urban development become extremely important. According to the United Nations Department of Economic and Social Affairs, in 2050 the world population is projected to be 66% urban as urban dwellers number is projected to grow by 2.5 billion between 2014 and 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa [44].

On the one hand, cities are the engines of economic growth and innovation [21]. On the other hand, the process of urbanization poses lots of challenges, affecting all the three pillars of sustainable development. Urbanization sharpens the problems of climate change, poverty, unemployment, aging population and the youth bulge, commoditization of land and housing, amplification of different types of crises etc. [41]. Policymakers throughout the world are coming to the conclusion that rapid and unplanned urban growth threatens sustainable development. In turn sustainable urban development will lead to economic and social improvements. The 2030 Agenda for Sustainable Development tackles this challenge through its Sustainable Development Goal 11, which aims to "make cities and human settlements inclusive, safe, resilient and sustainable" [45].

It is also critical to point out that sustainability at the context of urban development means necessity to solve the problems of energy conservation, effective use of resources, public transport system planning, re-use of materials, organic waste composting, the issues of densification and compact building. There are different approaches to solve these problems, that may contribute to sustainable urban development. Among them the promotion of Transition Towns, Fairtrade Towns, Sustainable Cities, Green cities, Eco cities, Livable cities, UN-Compact Cities, the Innovation City, Social Enterprise Cities [28; 10]. In order to summarize the existing approaches to sustainable urban development United Nations Department of Economic and Social Affairs suggests four pillars that would enhance the sustainability of cities: 1) Social development, 2) Environmental protection, 3) Economic development, and 4) Effective urban governance (Table 1) [43].

Table 1

Elements of urban sustainability
(Sources: estimated by authors, based on UNDESA, 2013 [43])

Sustainable cities			
Social development	Environmental protection	Economic development	Effective urban governance
Social equity and poverty reduction	Forest and soil management	Green productive growth	Decentralization and planning
Education and health	Urban greening	Creation of decent employment	Increasing civil engagement in governance
Food and nutrition	Waste and recycling management	Production and distribution of renewable energy	Strengthening civil and political rights
Green housing and buildings	Sustainable transport system and energy use	Technology and innovation (R&D)	Support of local, national, regional and global links
Infrastructure development	Water management (including fresh water)	Creation of decent employment	Increasing civil engagement in governance
Recreation areas and community support	Air quality conservation		
	Adaptation to and mitigation of climate change		

Thus, the sustainable urban development is a balanced progression in three main dimensions: economic, social and environmental with paying special attention to management system development. It includes a variety of issues such as, for example, green housing, air quality conservation, public transport system, water management, greenery planting and others. The importance of these issues cannot be underestimated as the solution of these problems may lead to social and economic improvements.

Now we would like to separately consider such particular element of sustainable environmental urban development as urban greening and discuss its importance and challenges.

GREENING AS A PART OF SUSTAINABLE URBAN DEVELOPMENT

Urban green spaces development or urban vegetation(greening) is an important part of sustainable urban development. The value of green spaces can be systematized in different ways. We can define the value of green spaces according to spacial, technological, social and cultural dimensions [39].

Urban green spaces play an important role in the ecological aspect of city development. Firstly, it contributes to the sustainable biodiversity conservation by providing a livable area for plant and animal life [15]. Furthermore, plants reduce air pollution and lower noise [6], which influence both ecological situation and living conditions in the area. One of the major functions of vegetation is the thermal performance adjusting, which is reached by reflecting the solar radiation [16] and balancing the temperature, especially in hot, dry areas. The other ecosystem service provided by plants and forests is water retention [19].

The amount of urban green spaces in the nearby environment also contributes to the personal citizens' well-being in several ways. For instance, the green spaces availability favorably influenceson the level of physical health of the inhabitants [20], even reducing mortality [13]. Lovasi et al., 2013 [26] has proved that high obesity rate of preschool children in low-income families in NYC is partly caused by lack of green spaces around for leisure and active lifestyle. It was found that trees can contribute to the reduction of workers' stress [25]. It has been also shown that the amount of green space in the living environment and the frequency and length of visits to the forestry and parks are positively associated with the individual mental health and vitality and decrease the level of perceived stress [17].

An important feature of urban green spaces is the provision of a site for communication and recreation. People tend to use green spaces for physical exercises [24] and outdoor communication and activities [8]. Moreover, green spaces not only stimulate social interaction, but also act as a cultural heritage site,contribute to the city identity and enrich aesthetic values [34; 27]. Hence, green spaces satisfy various physical, psychological and social needs of the residents. It can be then concluded that green spaces indirectly low the social tension and stabilize the social situation by increasing the life satisfaction of citizens in general.

The development of urban green spaces faces various challenges. For example, urban vegetation is often of a low priority in both governmental strategies and programs and private sector activities. The reason is that the potential greening benefits are underestimated by authorities and business as there is not enough evidence of the necessity of such practices and, what is more important, its economic value. Because of potential contributors' inability to assess the return on the investment there is often lack of financial sources in the area.

As urban sprawl as a form of urban development has several disadvantages such as low efficiency of energy and resources use, social inequalities and environmental problems [33], more ecological and sustainable cities tend to have more compact or dense forms [30]. However, such forms cause new challenges to urban greening. For example, soil quality is one of the important urban problems (soil is exhausted and less fertile, abounds cables, tubing etc.), which becomes even more severe in dense city environments [36]. Moreover, there are the challenges of both planning new green spaces in compact cities and conserving the existing ones while the infill development [18]. One of the ways to solve the problem of space shortage is roof planting. For instance, the Swedish government and The Delegation for Sustainable cities launched an initiative, promoting urban greening and efficient use of urban space. One of the accomplished projects was the construction of green walls and green roofs in the city Malmö and even creating a Scandinavian Green Roof Association [37].

The other challenge in urbangreening is the difficulties in coordination the needs, requirements and abilities of different parties. Conservation and development of urban green spaces requires a comprehensive approach including the collaborationwith local authorities, inhabitants, who are also divided in several groups by their preferences, civic activists, developers and entrepreneurs. Decision makers need to take into consideration and adequately reflect all the needs, often contradicting [12]. To this point administrative and bureaucratic problems of making and implementing decisions are added, which makes urbangreening a complicated process.

Thus, urban greening plays an important role in sustainable urban development. Besides mentioned ecological benefits and positive influence on citizens' health and overall quality of life, urban green spaces also contribute to urban design, connecting different parts and scales of the urban landscape [39]. However, there are several challenges for the successful urban green spaces development, such as lack of investment, tendency to dense city forms and coordination of needs of different parties.

ECONOMIC EVALUATION OF URBAN GREENING BENEFITS

As mentioned above, one of the challenges of urban green spaces development is the lack of financing due to non-obviousness of the returns on such investments. Although the aim of sustainable development is set in almost every modern city's strategical plan, the real implementation of this principle and, in particular, greening, is typically postponed. The reason for it is that the ecological situation is not critical yet and ecological threats are not perceived as urgent, while the benefits from plantings are questionable. Governments prefer to invest in more measurable areas such as transport or education where the direct social benefit of the policies can be easily assessed and presented.

As green areas belong to the category of social goods, they are non-rivalrous and non-excludable. First means that the consumption of the good by one consumer cannot influence the possibility of the other consumer to use the good simultaneously. Second means that non-paying consumer cannot be prevented from using the good. These characteristics make plantings a non-appealing investment for private businesses as at the first glance they do not generate income.

The possible solution for this problem lays in the possibility of evaluating the economic benefits of the plants in the particular area. In reality, each tree carries particular value that can be expressed in the value indicator. Appropriate valuation of the services that green areas provide to the society leads to the amount of green spaces and level of their maintaining which is maximizing the social utility.

As mentioned in the second chapter, there are direct benefits from a green landscape to each resident living in the area, such as health, recreational, social, aesthetic benefits. This fact is reflected in the direct correlation between the quantity and quality of greening in the area and the realty prices, as there is obviously a higher demand for the houses situated in better environmental conditions. Health benefits can be also potentially evaluated through the annual medical costs savings, although the procedure requires certain nontrivial research.

Assessing the profit for a local economy two things should be taken into account. First, the revenue growth of local enterprises and shops, both from the increase in the number of the area visitors coming for leisureand recreation, and from the changes in willingness-to-pay of the residents and visitors. It has been proved that the quality of public environment has a significant impact on the consumer behavior. For instance, Kathleen L. Wolf, 2004 [40] has shown that consumers associate the presence of urban forests in the central retail district with higher visual quality rating of the district. The other study has shown that greenery among other atmospheric characteristics of shopping center influences the consumer behavior and the willingness-to-pay [32]. Second, it can be said that green areas contribute to the budget replenishments, as additional consumption generates tax flows to the local budgets.

Ecological value of parks and green spaces can be alsoeconomically evaluated. For instance, one of the valuation objects can be storm water management, slowing the run-off of the water and reducing the load of storm water system, consequently lowing the expenses for its maintaining. Savings due to the reduction in air pollution can be measured by assessing the costs of the air cleaning facilities that would result in the same level of air purification as a certain planting. When calculating the expenses for the cleaner costs of maintenance, service and depreciation should be considered. Total urban greening benefits (B) can be calculated according to the following formula (based on the concept suggested by Kudryavceva et al., 2015 [22]):

$$B = \sum_i \sum_j (a + h + p + x)$$

Where a is the average annual added value of the air enhancement which includes solid particles retention, and pollutant gasesabsorption;h refers to reduction in the average annual water outflow;p reflects the aesthetical value and total convenience of close green area location which is expressed in the realty prices rise;x reflects the local economy profit including additional earnings of shops and elements of infrastructure and additional budget tax revenue;i refers to the tree;j refers to the segment of the woodland.

For conducting the research and data representation, the remote sensing systems are used. For instance, geographical information systems (GIS) are widely used for ecological and economic benefits assessment of urban vegetation. A number of systems is designed to analyze the potential value of urban green space and urban forests based on such technologies or other approaches. Existing approaches of trees valuation would be presented in one of the following chapters.

Thus, the necessity of economic valuation of urban vegetating has been proven. We have suggested a method for valuation of urban greening benefits that would take into account most of the measurable gains, such as ecological, social, aesthetic.

MEASUREMENT OF URBAN GREENING POLICIES

There are several reasons why timely and credible assessment of urban vegetation practices is necessary. The relevant data about the condition of green areas is required primarily for its conservation, maintaining and improvement [23]. Time series observation taken for one area makes it possible to evaluate the effectiveness of the policies and activities in the field of urban greenery, understand its week points and improve the strategy. Assessment of policies with numerical indicators is useful for informing the population about the results due to its visibility. As indicators demonstrably illustrate the results of local authorities' activities in the area of sustainable development, they can increase public confidence in the government and positively affect the level of civic engagement in urban development practices [2].

There are several approaches for assessment of greening practices, which are commonly used.The first one is inventory method, which comprises two stages: a field stage, including observation of plants and collection the data concerning their overall condition and characteristics.On the second stage, the received information is integrated into the database with its further introduction to the registry forprocessing. There is special system of indicators and criteria for assessment of plants status. For instance, inventory method for trees can include individual assessment of the following characteristics: the type of planting, species, age (divided by classes), diameter, height, damages, quality (divided by classes) [23].

Another approach that can be applied is the calculation and analysis of various indexes and indicators reflecting the quality and extent of urban greening. The scheme 1 showsa variety of existing indicators used for assessment the urban greenery status, these include thesize and structure of urban green space, its ecological and social qualities, the accessibility of urban greening and expenditure on its maintenance [4].

Indicators of urban greening

Size and Structure	Qualitative properties (ecological)	Social Functionality	Accessibility	Maintenance
♦ Green space indicator ♦ Surface area of green structures in the city (%) ♦ Extent and number of forests, parks, private gardens, water areas, green edges, etc.	♦ Environmental functionality (e.g. adsorption of emissions (e.g. storm water) and microclimate) ♦ Biodiversity indicators — occurrence of red-listed species in green structures (number of species); City Biodiversity index ♦ Protection indicator — number of and surface are (ha) of Protected areas	♦ Number of urban green spaces with rest and relaxation opportunities, walking and biking opportunities, with playgrounds for children; with sport grounds; with cultural events, etc.	♦ Number and percentage of inhabitants living no less than 300 meters (walking distance) from a green structure above a certain size ♦ Number and percentage of inhabitants with a green structure in sight	♦ Maintenance budget per inhabitant ♦ Percentage of extensively managed areas ♦ Percentage of intensively managed areas

Scheme 1. Indicators of urban greening

(*Sources:* estimated by authors, based on BUUF City Status Reports [4]

For assessing the efficacy of territory use,another indicator such as the coefficient of ecological stability can be used [7]. It is calculated according to the following formula:

$$K = \frac{\sum(P_i K_i)}{\sum P_i} K_p,$$

where P is the area of the site with the corresponding index of ecological stability; K is the coefficient of ecological stability of the site I; K_p is the coefficient of the morphological stability of the relief (based on the possibility of landslides and mudflows).

Computing of the green space can be executed through special instruments that calculate area using maps.

It should be also mentioned that trees and other plants can be divided in several groups by their impact to the environment, meaning that some breeds can be more useful in solving particular problems than the others due to the specific features of each type of plant or breed. It is clear then that the individual coefficients for each group of plants can be calculated.

Thus, the assessment of urban greening is necessary not only to conserve, maintain and improve green areas, but also to raise public awareness of urban greening importance and to provide evaluation of the policies and activities in the field of urban greening for their further improvement.As we have shown, there are different approaches for assessment of greening practices, such as inventory method and indicator-based method, which are now actively used by policymakers and communities throughout the world to promote urban greening.

EXAMPLES OF REAL-LIFE PRACTICES OF URBAN GREENING PROMOTION

One of the main problems of moving towards sustainable urban development is monitoring the process of transformation to the desired state or objective [29]. Communities introduce different sustainability projects and plans concerning urban greening, and use different measurement approaches to monitor the progress. For instance, the trees' inventory was held in the city of Renton in 2009 [9]. This inventory included the calculation of all tree species, their diameters and age groups, their condition and maintenance recommendations. As the result of the assessments, the economic benefits were valuated using the Guide for Plant Appraisal and presented to the public [9]. There are several systems already implemented in the world that measure the economic value of the plantings. One of them is Helliwell System, the method developed and adopted by the Arboricultural Association and the Tree Council in Great Britain that has been widely used since then for various public and private inquiries. The method concentrates on one benefit provided by trees — visual contribution to the landscape. According to the methodology, each plant receives number of points for specific criteria which are then combined to form a final score. The latest can be transformed into money value by multiplying on a conversion factor, which is periodically updated by the Tree Council. Basic factors for assessment are size, expected duration of visual amenity, importance of position, presence of other trees, relation to the setting and form [35]. The next method developed for tree valuation is Capital Asset Value for Amenity Trees (CAVAT) developed by the London Tree Officers' Association (LTOA). There are two versions of the method: Full and Quick, varying in precision and optimal amount of assessed woodland. The approach is based on the idea of a unit value factor, which is determined by the replacement cost of the tree. The basic value, which is derived from a unit value factor and the size of truck, is then adjusted with such factors as location, functionality, social value and some more [35]. The unit value factor is calculated corrected to inflation. The method has been used to assess the required compensation for the trees damaged by the firms, the example of which took place in 2007 in London. The other method is I-Tree, the software that was introduced in 2006 and simplified the process of urban forest costs and benefits determination. London's I-Tree eco Project was set up to demonstrate the economic benefits of urban greening in London using I-Tree software. According to the project's report, "London's trees provide at least 133 million pounds of benefits every year in terms of air pollution removal, carbon sequestration and reducing the amount of water going into drains.The project revealed some extra-benefits of urban vegetation such as increase in property value, shade and cooling provision, aesthetic benefits, illnesses' recovery assistance, crime reduction, social cohesion improvement and even provision of fruits and nuts for people,animals and nectar for insects [38]. To illustrate some ways of measurement the GetGreen Columbus project, launched in 2005 in Columbus OH, can be considered. Its goal was to coordinate sustainability efforts in order to reduce waste of resources and improve air and water quality using a variety of means. The results of the different initiatives were presented in the GetGreen Annual Report in 2014 demonstrating remarkable achievements in the field of urban greening [14]. The results were measuredin percentage points: 2014 greenhouse gas emissions have been reduced by 25%, and they were also measured in days: in 2014, there were no days when air quality reached unhealthy levels compared to 2 days in 2013 and 13 days in 2012.

Although the world community is actively taking steps towards the real-life implementation of sustainable urban development principles, including urban greening promotion, in Russia only a few cities have the resources and perspectives for the realization of sustainable urban development projects [3]. One of the reasons may be the lack of urban planners and landscape architects within the municipal organization [31]. The other reason is the lack of society's interest in the problem of sustainable urban development, especially in its environmental aspect [3]. For instance, in 2000 the Danish Ministry of the Environment started a bilateral environmental aid project in St. Petersburg [31]. The aim of the project was "to 'sow the seeds' for a more strategic approach to planning and management of green spaces in St. Petersburg" by developing a GIS-based information system and rising public involvement in the improvement of green areas. However, the project failed to raise public awareness of the importance of urban greening promotion and came to a conclusion, that without the appropriate development of human capital in Russia, urban development projects will simply remain without an audience.

CONCLUSION

Urban greening is an essential part of sustainable urban development. Smart planning of urban green space may contribute to the improvements in ecological, social and economic spheres of citizens' life, providing good conditions for biodiversity conservation, reducing air pollution, managing temperature balance, increasing citizens' overall satisfaction etc. These benefits, thoroughly evaluated, may pursue the governments, if they tend to postpone the implementation of urban greening principles, to change their stance towards potential returns of their investments.

Although, as it was mentioned, urban greening may meet some challenges such as the lack of policymakers' attention to the problem of judicious urban planning, communities all over the world increase their engagement in urban vegetation development, setting up a variety of projects aiming to move towards urban sustainability.

One of the ways of encouraging local authorities and business to invest in urban green spaces development is the proper measurement of economic values of the plantings. The paper has offered an approach to such valuation, which is based on the main factors of trees contribution to the city environment, such as ecological, social and economic benefits. The applicability of the theoretical proposal was illustrated by showing the existing systems of trees valuation used worldwide.The measurement of the green spaces policies is necessary which was supported by several arguments. The methods for it were proposed, followed by the corresponding examples.

Provided evidence has shown that there are useful methods and ways of optimizing the system of urban vegetation in big urban agglomerates, in particular in Russia. Further investigation should include more detailed study for the methods most appropriate for a concrete city in each specific case.

REFERENCES

[1] Brundtland Commission, 1987. Our common future: Report of the world commission on environment and development. Stockholm, Sweden: United Nations World Commission on Environment and Development.

[2] Bobylev S. Insicators of sustainable development for Russia. Social-ecological technologies. 2012. № 1.

[3] Bobylev, S., Perelet, R. 2013. Sustainable Development in Russia. Saint Petersburg, Russian Federation: Russian-German Environmental Information Bureau.

[4] BUUF City Status Reports (2003) Baltic University Urban Forum City Status Report V. Project part-financed by the European Union (European Regional Development Fund) within the BSR INTERREG III B Neighbourhood Programme 2003.

[5] Chapple, K., 2015. Planning sustainable cities and regions: Towards more equitable development. Abingdon, Oxon; NewYork: Routledge.

[6] Chaturvedi, A., Kamble, R., Patil, N.G., et al., 2013. City-forest relationship in Nagpur: One of the greenest cities of India. Urban Forest. Urban Green. 12, 79—87.

[7] Chernikov V., Aleksanin R., Golubev A. Agroecology. Kolos, 2000. 536 p.

[8] Chiesura, A., 2004. The role of urban parks for the sustainable city. Landscape Urban Plan. 68, 129—138.

[9] Davey Resource Group, A Division of the Davey Tree Expert Company, 2009. Benson Hill Public Property Tree Inventory and Assessment Report.

[10] El Ghorab H.K., Shalaby H.A., 2015. Eco and Green cities as new approaches for planning and developing cities in Egypt. Alexandria Engineering Journal 55, 495—503.

[11] Emas, R., 2015. The Concept of Sustainable Development: Definitions and Defining Principles.

[12] Ernstson, H., 2013. The social production of ecosystem services: a framework forstudying environmental justice and ecological complexity in urbanized land-scapes. Landsc. Urban Plan. 109, 7—17.

[13] Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., 2016. Residential green spaces and mortality: a systematic review. Environ. Int. 86, 60—67.

[14] GetGreen Columbus. Planning Tool Exchange, 2016. Retrieved from http://www.planningtoolexchange.org/project/getgreen-columbus.
[15] Goddard, M.A., Dougill, A.J., Benton, T.G., 2010. Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol. Evol. 25, 90—98.
[16] Gomez, F., Gil, L., Jabaloyes, J., 2004. Experimental investigation on the thermal comfort in the city: relationship with the green areas, interaction with the urban microclimate. Build. Environ. 39, 1077—1086.
[17] Grahn, P., Stigsdotter, U.A., 2003. Landscape planning and stress. Urban For Urban Greening 2 (1), 1—18.
[18] Haaland C., Konijnendijk van den Bosch C., Challenges and strategies for urban green-space planning in cities undergoing densification: A review, Urban Forestry & Urban Greening 14 (2015) 760—771.
[19] Hall, T., 2010. Goodbye to the backyard? The minimization of private open space in the Australian outer-suburban estate. Urban Policy Res. 28, 411—433.
[20] Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health 35, 207—228.
[21] Keivani R., 2010. A review of the main challenges to urban sustainability, International Journal of Urban Sustainable Development 1:1—2, pp. 5—16.
[22] Kudryavtseva O., Bobylev S., Solovyeva S., Indicators of sustainable development for Russia: urban dimension. On the way tosustainable development of Russia. 2015. 74. P. 16—23.
[23] Kulakova S. Assesment of urban plantings condition. Geographical vestnik. 2012. № 4 (23).
[24] Lee, A.C.K., Maheswaran, R., 2011. The health benefits of urban green spaces: a review of the evidence. J. Public Health (Oxf.) (33), 212—222.
[25] Lottrup, L., P. Grahn, and U.K. Stigsdotter. 2013. Workplace Greenery and Perceived Level of Stress: Benefits of Access to a Green Outdoor Environment at the Workplace. Landscape and Urban Planning 110:5—11.
[26] Lovasi, G.S., Schwartz-Soicher, O., Quinn, J.W., et al., 2013. Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City. Prev. Med. 57, 189—193.
[27] Mell, C., 2009. Can green infrastructure promote urban sustainability? Eng. Sustainability 162, 23—34.
[28] Mössner, S. 2016. Sustainable Urban Development as Consensual Practice: Post-Politics in Freiburg, Germany, Reg. Stud. 50, 971—982.
[29] Musakwa, W. & Van Niekerk, A. Environ Dev Sustain (2015) 17: 547. doi: 10.1007/s10668-014-9560-7.
[30] OECD, 2012. Compact City Policies: A Comparative Assessment, OECD Green Growth Studies. OECD Publishing, Paris.
[31] Nilsson K., Akerlund U., Konijnendijk C., Alekseev A., Caspersen O., Guldager S., Kuznetsov E., Mezenko A., Selikhovkin A., 2007. Implementing urban greening aid projects — The case of St. Petersburg, Russia // Urban Forestry & Urban Greening № 6.
[32] Op Heij T.J.P. (Tim), 2012. Environmental influences on consumer behaviour, October 2012, Eindhoven.
[33] Power, A., 2001. Social exclusion and urban sprawl: is the rescue of cities possible? Reg. Stud. 35, 731—742.
[34] Priemus, H., Rodenburg, C.A., Nijkamp, P., 2004. Multifunctional urban land use: a new phenomenon? A new planning challenge? Built Environ. 30, 269—273.
[35] Sarajevs V., Street tree valuation systems, Research note, Forestry Commission England, 2011.
[36] Tian, Y., Jim, C.Y., Tao, Y., 2012. Challenges and strategies for greening the compact city of Hong Kong. J. Urban Plann. Dev. 138, 101—109.
[37] The Delegation for Sustainable Cities, 2012. Sustainable urban development projects: Projects that have received financial support from the Delegation for Sustainable Cities.

[38] Valuing London's Urban Forest: Results of the London i-Tree Eco Project, Treeconomics London, 2015.
[39] Wlodarczyk. D. (ed.), 2007. Green Structure in Development of the Sustainable City. Baltic University Urban Forum. Urban Management Guidebook V. Baltic University Press, Uppsala.
[40] Wolf Kathleen L. Trees and business district preferences: a case study of Athens, Georgia, U.S. / International Journal of Arboriculture 30(6). November 2004. P. 336—346.
[41] UN Habitat (United Nations Human Settlements Programme), 2015. Global Country Activities Report: 2015 — Increasing Synergy for Greater National Ownership.
[5] UN General Assembly, 1972. United Nations Conference on the Human Environment.
[6] UNDESA (United Nations, Department of Economic and Social Affairs), 2013. An Integrated Strategy for Sustainable Cities. UN-DESA Policy Brief No. 40.
[7] UNDESA (United Nations Department of Economic and Social Affairs), 2014. World Urbanization Prospects: The 2014 Revision. (New York: 2014).
[8] UNDESA (United Nations Department of Economic and Social Affairs), 2016. Global Sustainable Development Report 2016, NewYork, July.

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ОЗЕЛЕНЕНИЕ КАК ЭЛЕМЕНТ УСТОЙЧИВОГО ГОРОДСКОГО РАЗВИТИЯ: ОЦЕНКА ЭКОНОМИЧЕСКИХ ВЫГОД, ИЗМЕРЕНИЕ РЕЗУЛЬТАТОВ ПОЛИТИКИ И ПРИМЕРЫ ИЗ ПРАКТИКИ

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Статья показывает важность городского озеленения как одного из средств достижения целей устойчивого городского развития. Авторами представлены экологические, социальные, культурные, пространственные выгоды от развития городского озеленения, а также выделены основные ограничения к развитию озеленения в условиях крупного города. Показано, что оценка экономической выгоды лесов, а также адекватное измерение результатов политики в области озеленения играют важную роль в процессе реализации принципов устойчивого городского развития. Статья представляет существующие методы оценки озеленения и иллюстрирует их внедрение на примерах из российской и зарубежной практики.

Ключевые слова: устойчивое городское развитие, городское озеленение, изменение зеленых зон, проблемы и задачи городов

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THE MAIN DESIGN PRINCIPLES OF HYBRID SPACES IN TERMS OF THE URBAN PLANNING REGENERATION

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Urban planning regeneration is a viable mechanism contributing to the urban development during complex reconstruction of the existing city space-planning structure. The dynamics of changing of urban planning theories and practices are characterized by an integral approach to city development through contradictory processes: intensification of globalization processes on the one hand; searching for identity on the other hand. Formation of hybrid spaces in urban fabric of modern cities is relevant and has significant socio-economic importance to the process of urban planning regeneration. In the context of permeability theory hybridity is determined as multi-layer, multi-functional feature of urban space, where there is no clear separation between public and private; buildings and facilities forming the structure are combined by multilevel public space where its virtual perception is also vey the important as well as its information capacity and its transformation ability. Hybrid spaces are multifunctional architectural and landscape entities, designed by applying the landscape urbanism approach and having the spatial connectivity with adjacent areas. The hybrid spaces are very importantt for the city economy, as they are development drivers to spatial, social and public changes. This research is aimed at defining modern design principles of hybrid spaces in terms of urban planning regeneration. The paper focuses on the principles of hybrid urban spaces design in the context of landscape urbanism such as the integration of dwelling areas and public spaces through the green infrastructure.

Key words: urban hybridization, integral urbanism, landscape urbanism, hybrid spaces

INTRODUCTION

The establishment of hybrid spaces in the modern city structure is directly connected with the social and economic processes of the city development and also with the current intensification of globalization processes (Figure 1). The territorial competitiveness is growing due to information permeability, infrastructure development and technological development. People tend to choose the most comfortable area for their residence, recreation and shopping.

The environmental quality of hybrid spaces is defined by its comfortability, multifunctionality and services interesting for: residents and business, tourists and investors, authorities and society [1; 2].

In the city life and development, the hybrid spaces are rapidly growing city areas with self-organizing qualities, comprising the social and economic, functional and planning, recreation, landscape and composition, as well as environmental aspects. Space hybridization is based on the multifunctional connection with the internal city structure and the suburban areas.

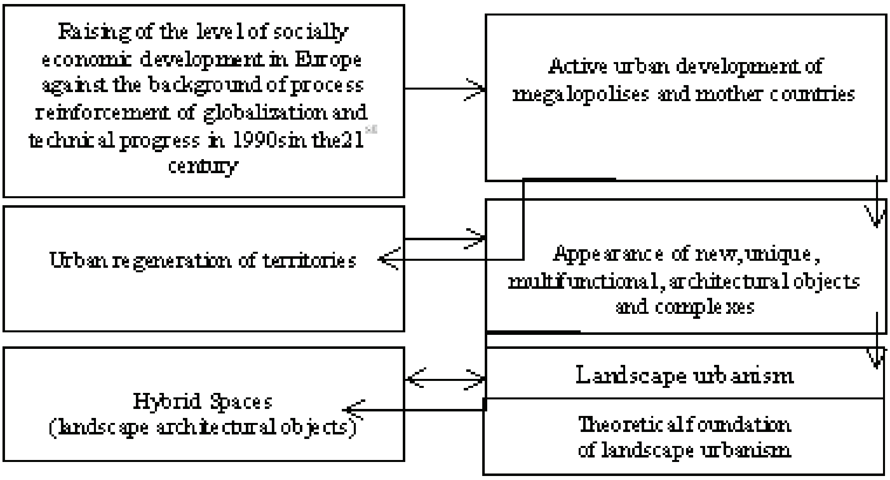

Figure 1. Background of hybrid spaces [8]

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Today the tendency of hybrid spaces transformation into dominant nodal spaces in the city structure is observed. The functional saturation of hybrid spaces depends on the urban planning context and their location. Today the most popular are the hybrid spaces with the mixed structure of the spatial interaction between the residential, social and recreational functions.

Hybrid spaces allow to make city successful. There is four city development stages: 1) services offered within the regenerated area and the infrastructure begin to satisfy the citizens, companies and visitors; 2) new places of interest are developed to maintain the current business and provide public support to estimated business; 3) hybrid spaces highlight their peculiarities and advantages through an active and bright image or communication programme; 4) hybrid spaces are supported by citizens, public leaders and governmental agencies and thus attract new companies, investments and tourists.

It should be noted that the modern urban planning practice outruns the theoretical basis and concepts of hybrid spaces development and design.

THE ROLE AND SIGNIFICANCE OF HYBRID SPACES FOR THE CITY DEVELOPMENT DURING THE POSTMODERNISM PERIOD. BACKGROUND OF HYBRID SPACES

The period of postmodern urbanism (Ellin [3]) is characterized by predominance of the Anglo-American branch in theoretical concepts of the urban planning development. One of these branches is the landscape urbanism [4—7]. Landscape urbanism theory is connected with flexible, humane, creative, environmental and socially oriented regeneration approach. The approach aims at the active inclusion of nature into the city structure by maintaining its natural biodiversity to develop an identical and aesthetically attractive urban space. The landscape and urban approaches symbiosis defines a multidisciplinary trend in the landscape urbanism and the focus on hybrid spaces development (Figure 1). The application of the landscape urbanism principles in terms of the city space-planning structure transformation allows to form an urban socio-natural system. The complex approach allows to tackle difficult tasks concerning the urban spaces development at every urban planning level to create a comfortable urban environment.

By applying the main principle of the co-evolutionary approach [15] within the hybrid spaces development, especially the principle of nature and society cooperative development to define the main transformation directions of the existing urban planning structure, we can mitigate any negative effect of urban processes to create a sustainable and comfortable urban environment [8]. It is confirmed by the ideas of Frampton [18]. In his article "Architecture in the Age of Globalization", Frampton [18] concludes that the landscape cultural status has been changed in the age of postmodernism. Jencks [9] supposes that the postmodernist science of complexity, such as nonlinear dynamics, synergy, self-organization theory, chaos theory, dissipative structures theory, fractal geometry etc., have influenced and still are influencing the development of modern architectural thinking. It can be explained by the appearance of new types of multifunctional spaces — the hybrid urban spaces. Zanni [1] highlights that urban hybridization is determined by the multi-layered and multi-scaled urban tissue. In his view, it allows to create spaces in the city structure that connect its different parts according to cultural, historical and social context.

An analysis of functional and social interactions in the structure of hybrid buildings was carried out by Holl, Fernández Per, Mozas, Arpa [11], but they do not research the development of hybrid buildings in the context of landscape urbanism — from the point of the green infrastructure integration and the building structural arrangement.

Development of hybrid spaces in city structures began in the late 1980s. Parc de la Villette is a multifunctional architectural and landscape complex based on the urban planning regeneration of post-industrial abandoned areas and its surrounding working class areas in the 19th Paris district. The hybrid space development of the Parc de la Villette in the Parisian structure has influenced urban planning thinking and led to social and economic changes of its surroundings. It has also become a driver in urban transformations and changes carried out in this district of Paris (Figure 2). In the 1990s Paris, Barcelona and Canberra provided the first hybrid public recreational spaces, such as Promenade Plantée in Paris (by architect P. Mathieux and landscape architect J. Vergely, in 1993), Nus de la Trinitat Cloverleaf park, architects E. Batlle, J. Roig during 1992—1993), the National Museum of Australia, Canberra, architect R. Weller, during 1997—2001). Hybridization of the space-planning structure in these areas was the result of the design and creation of new public recreational space types, based on the integration of the landscape and the urban planning approaches towards the recreational objects planning in the city structure that differed from the common methods and techniques of the urban and landscape planning.

Hybrid spaces are multifunctional architectural and landscape entities or landscape and urban planning entities, designed by applying the landscape urbanism approach and having the spatial connectivity with adjacent areas. The spatial connectivity of hybrid spaces with the urban tissue through the greenway public pedestrian space system allows to influence on the urban development of adjacent areas and the future city structure by becoming accessible urban space markers for all city residents.

Thus, we can conclude that hybrid spaces formation carried out by synergistic interactions between the formed architectural and planning structure, existing historical and urban context, the specifics of the socio-economic conditions, green infrastructure, etc.

In 1992, the Spanish architect Manuel de Solà-Morales revealed the trend of social and functional interaction of modern cities, involving the understanding of modern use of private and public spaces. Public spaces can be used for both private events and collective use, because they include the maximum number of functions. So, hybrid spaces appear in the urban tissue structure with typological and morphological variety [20].

The philosophy and practice of the hybrid space development in Western Europe and the USA is institutionally reflected in the economic development departments. For example, Ohio has established seven regional economic development agencies; each of them covers a group of districts. The agencies work with the districts and local authorities on establishment of hybrid spaces to improve the local business climate and meet certain needs of their territorial enterprises. Such scheme is applied in different countries such as Ireland, Bulgaria, and New Zealand, etc. It can be concluded that the hybrid space development is controlled by specific institutions to support and develop the city infrastructure.

HYBRIDIZATION OF SPACE-PLANNING STRUCTURE AS AN URBAN PLANNING REGENERATION BRANCH

The evolution of hybrid spaces in the 21st century is based on the expansion of their functional saturation and the variation of their functional interaction. So, new types of hybrid spaces appeared in the early 21st century with both the public recreational and the residential functions.

Generally such hybrid spaces appear in the structure of coastal areas; the best known examples of the hybrid space establishment with developed residential function are the Hamburg centre development project, based on the Hafen City district; regeneration of harbour areas by the River Liffey in Dublin (Dublin Docklands); the Embankment in the district Diagonal Mar i el Front Marítim del Poblenou in Barcelona; the surroundings of the Park of the Nations in Lissabon; the Western Harbour district in Malmö; the Havneholmen district in Copenhagen. These examples are characterized by the context approach towards the hybrid space formation, based on the maintaining and recovery of the natural environment that contributed to their image and identity and influenced the development of their surroundings and of the city as a whole [12].

Today the hybridization of the space-planning structure of post-industrial, damaged, ravaged or ineffectively used urban areas is a relevant branch of the urban regeneration (Figure 2).

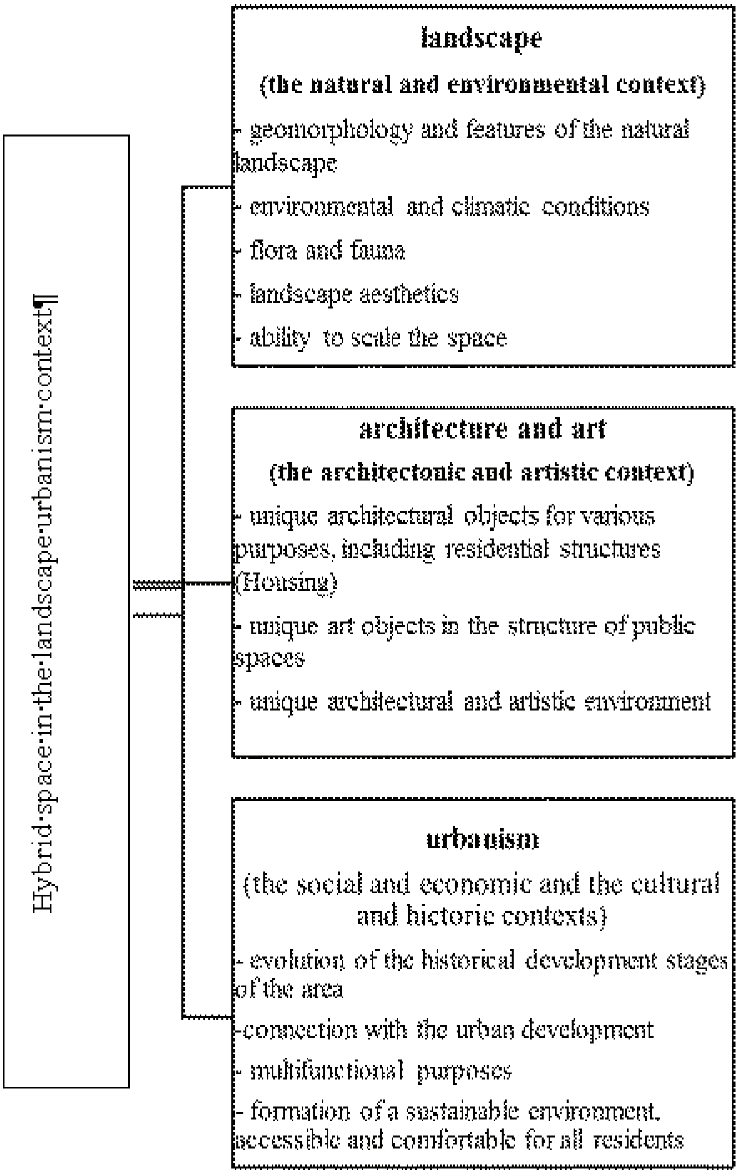


Figure 2. Hybrid spaces in the landscape urbanism context.
The symbiosis of landscape, architecture, art and urbanism [8]

The functional heterogeneity of these areas allows to forecast their future development according to changes in the social and economic conditions and cultural preferences. The structural multifunctionality of hybrid spaces produces synergistic effect that contributes afterwards to the creation of new functional interactions within the hybrid space structure. For example, mixing of both residential and social and business functions in the space structure generates the need for the shopping and recreational functions, this shows how the functional saturation of hybrid space is formed. It is worth noting that the synergistic effect, resulting from the functional integration, can appear only after the hybrid spaces in the central or rapidly developing city quarters.

Territories adjacent to hybrid spaces become actively developed because of influence of close hybrid spaces. Impulse to the development of adjacent territories, particularly of residential quarters (Barcelona is the typical example) is given by public pedestrian spaces system and green infrastructure based on the permeability principle. Example of such urban planning interaction is urban planning regeneration of residential quarters adjacent to the embankment in the Diagonal Mar i el Front Marítim del Poblenou district, Barcelona and the project of new hybrid quarter La Sagrera, Barcelona were formed on the basis of inter-modal transport hub.

Hybrid spaces give impetus to the infrastructure development. Thus, the more the territory infrastructure is developed, the more opportunities for attracting various resources there can be.

PRIORITY DESIGN PRINCIPLES OF HYBRID SPACES IN TERMS OF THE URBAN PLANNING REGENERATION

Modern hybrid spaces in big cities structure have expressed a social recreational purpose with a developed residential or social function. Functional saturation of hybrid spaces with residential function is vertical: space is cleared to the fullest degree; the space is organized based on the multi-functional principle, multi-layered inter-cultural public promenade, such as hybrid spaces structure of the Sofia Embankment in Moscow is organized this way [16; 21]. This project is an example of an active interaction between the residential complex of public spaces and green infrastructure elements. Therefore, we can conclude that the formation of embankment hybrid spaces is based on the principles of the landscape urbanism theory [4], that allow to move flexibly from the urban environment to natural. Thus, we see the introduction of green infrastructure elements in the building and construction of residential and multifunctional complex planning through all design levels. This allows to create memorable image not only for each structures that form hybrid space, but also of the whole hybrid space. This is why the modern understanding of hybrid spaces context should be reasonably considered as a symbiosis of urbanized space and natural environment.

The urban planning regeneration methods and techniques are widely variable depending on specific features of urban planning potential of the territory in terms of city development. For example, hybrid spaces formation of ex-post-industrial territories within the city structure is connected to their new functional saturation. Hybrid spaces formation principles also depend on urban planning context of the territory and specifics of the social-economic and investment conditions of the urban planning regeneration [16].

Hybrid spaces formation enables the creation of economic environment which is an economy growth point for the external environment. This capacity is determined by the emerging "concentration" effect in trade. The "concentration" effect is emerging with the "hybridization" of social, business, residential, retail functions in the regenerated city territory.

The hybrid space with vast variety of intermediate functions enables the creation of conditions for new sectors: the incubation process development facilitates information exchange and innovations distribution process, transfer of knowledge, and improves business communication process.

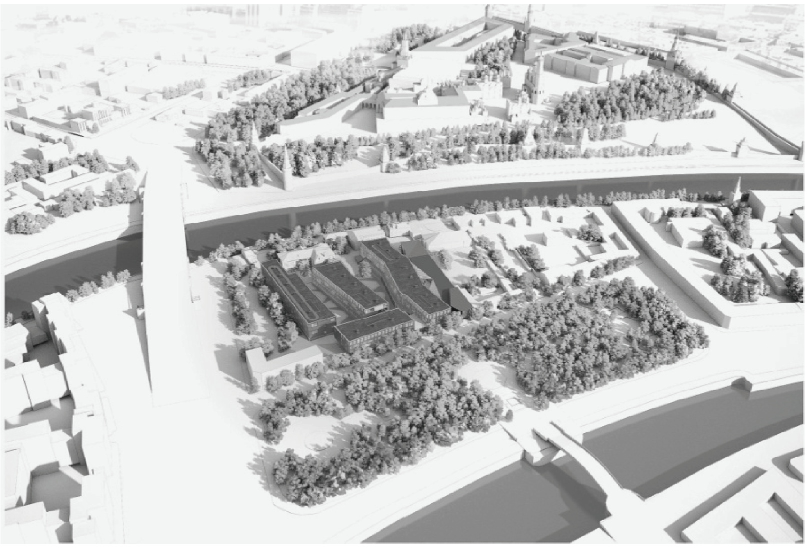
Hybrid spaces formation within the regenerated territory is one of the urban planning mechanisms driving social-economical, investment, cultural, business city development.

From our point of view, it is worth identifying the priority design principles of hybrid spaces in terms of urban planning regeneration.

It is of vital importance to describe these main principles. They are contextual innovation principle, urban planning variability principle, functional planning flexibility principle, cross programming principle, scaling principle and landscape innovation principle.

CONTEXTUAL INNOVATION PRINCIPLE

The contextual innovation principle is based on human-scale and natural environmental leading to hybrid space characterized with friendliness, communicability and contextuality. Such hybrid space should reflect regional and landscape peculiarities of the territory. Historical continuance (genius loci) — namely, conservation and reconsideration of heritage — keeps the past in memory, preserves the identity of the area during formation of the new space-planning territory structure. The concept of the Sofia Embankment in Moscow [21] is based on the contextual innovation principle (Figures 3).



Figures 3. Example of hybrid space (Competition project — Concept of multifunctional complex on the Sofia Embankment, Moscow, 2015. The territory of the Sofia Embankment in Moscow, 3D-model [21]

Adaptation of the project to its monumental environment is formed through upgrading of pedestrian arteries and historical routes that cross the adjacent city quarters, as well as through the adaptation of new housing developments to the neighbouring buildings and green spaces.

Urban planning variability principle. The urban planning variability principle defines the urban planning capacities of the hybrid space under creation. This principle is based on the social-economic approach that enables the forecast of possible functional interaction options which in perspective should define the significance of the hybrid space for the development of its adjacent territories (quarters) and city planning structure. Prevailing dominant functions (residential, commercial, entertaining, recreational, etc.) within the hybrid space structure define its significance for the urban planning development. Based on the fact that social-economic conditions change affects the functional saturation and functional use of architectural planning and landscaping elements forming the hybrid space structure, it is necessary to forecast several options of urban planning scenario of hybrid spaces development depending on architectural planning and landscaping elements functional interactions.

The urban planning variability principle enables singling out of three types of communication with hybrid space that form the territory impression. The type of communication consists of landscape, infrastructure, spatial orientation, territory organization, leisure area. It means that first of all the architecture and city landscape are assessed but then the attention shifts to the city's conveniences: how the transport, communication, commercial services systems are developed. Further, the administration work is assessed: how influential the local authorities are and what kind of their efforts for maintaining and developing the territory are provided. The next factor is associated with the leisure services rendering: how comfortable the place for tourist is, what benefits and rewards for visitors are available, what events and entertainment are available for visiting. This criterion includes the estimate of the local authorities' efforts for investments attraction.

The hybrid space allows people to form an opinion on this territory, how competitive it is compared to other territories, what impressions people have from this area.

Thus, it seems that the hybrid space takes into consideration a wide range of factors affecting the image of the territory and enables an active interference in the territory development process creating favourable conditions for attracting investments.

Functional planning flexibility principle. The functional planning flexibility principle in hybrid spaces formation is based on the extension of their functional saturation "palette", which not only affects but also defines the capacities of the variability extension as to the architectural typology of buildings and constructions that form the hybrid space. This principle enables flexible introduction of hybrid spaces into the existing urban planning tissue for the creation of comfortable, environmentally friendly, socially oriented and identical urban environments. The urban planning regeneration of residential quarters of the North Fringe district, Dublin [8] and development of quarters Bo01, Bo02, Bo03, and Bo04 in the Western Harbour district, Malmö are the examples. This is a symbiosis of flexible housing planning structure with vast variability of typological solutions, provision of the quarters with the sites of various functional purposes, application of effective engineering infrastructure and modern environmentally sustainable technologies in the landscape organization of adjacent territories on the basis of preservation of their environmental potential. Flexibility of the planning solution increases capacities of the identical architectural space creation through the formation of individual architectural environment of residential and public architectural and landscaping complexes that form a hybrid space and are characterized by the functional diversity of the space use that affects the identity and aesthetics of style solutions.

Cross programming principle. The cross programming principle involves the functional provision of local elements of hybrid spaces infrastructure with certain functions based on the interaction and interrelation effect of intertwining functions. For instance, hybridization in formation of contact areas of hub dominant public spaces consists of functional interrelation of the linear public pedestrian promenade, local public spaces and residential complexes. Hybrid spaces formed within the embankments structure on the basis of urban planning regeneration and non-functioning railway tracks and trestles and deserted post-industrial territories can serve as an example [8; 12; 16; 19].

Scaling principle. The scaling principle in hybrid spaces formation consists of urban planning typology extension in case of public and residential spaces depending on the specific urban planning context and size of territory. Territorial resource of certain city area defines the possibility of the hybrid space structure of public and residential space creation. This happens because of its urban context and functional purpose. As a result the areas become the image labels of the territory as well as accelerators for development of adjacent territories and city in general. (Example of Barcelona and Kaliningrad).

Landscaping environment adaptation principle. The landscaping environment adaptation principle is the return of the nature priority to the city spaces. This principle is based on the application of theoretical concept of landscape urbanism [4; 6; 8]. Through the scenario approach principle [4; 8] local "green" and "blue-green" framework of public recreational spaces within hybrid spaces structure is formed [13]. Maximal inclusion of natural landscape components into the "green framework" structure is formed on the basis of biophilic approach application [10]. Structuring of the public recreational spaces is performed through the application of not only one main principle of theoretical landscape urbanism — use of horizontal surfaces [4; 6; 8], but also in the "green infrastructure" formation [13] all the buildings and constructions forming hybrid spaces are involved regardless of their functional purpose. The formation of local green infrastructure of hybrid space is based on the scenario approach [4; 8] should be integrated with transport framework of the territory and pedestrian links system, — this is how the connection with the adjacent territories is created (Porta Nuova, Varesine, Milan) [17].

General Conclusions and Reflection. The urban planning identity of hybrid spaces and social economic efficacy are the main and essential approaches to hybrid spaces formation through the different territorial levels. Described above, the priority principles of hybrid spaces formation provide the means for the creation of hybrid spaces as economically effective, investment attractive, unique and memorable city territories.

In order to create the scenarios of hybrid spaces development it is necessary to stray away from formal models in favour of more open strategic models where the landscape takes important part. Currently, the essential aspect of urban planning regeneration is the use of landscape as the tool creating new aesthetic effects, new social programmes. Analysis of European and Russian experience presented in this research showed us that this approach is especially actively used in creation of hybrid spaces within developed residential function. Another important aspect is provision of hybrid spaces with various functions which enables more effective use of territorial resources, especially in central city parts with formed historical cultural environment. Thus, the analysed priority principles of hybrid spaces formation within the context of urban planning regeneration can be supplemented depending on the specific urban planning context and social economic development factors. Therefore, the integration of hybrid spaces into the city's tissue through the measures for activities efficacy increase is based on: prompt estimate of the territory potential: i.e. defining its main resources: historical, architectural, landscape, natural, social or industrial ones: it will help during the development of territory promotion strategy and the definition of the differentiating feature from other cities; consideration of hybrid space from the point of view of territorial location, i.e. defining the potential perspective development of the city's territory.

Mentioned examples of urban planning practices show that hybrid spaces are generally the markers for different functional parts of the city. Creating of unified architectural image of the hybrid space located in the central part of the city is connected with the fact that residential structures forming the hybrid space, usually “dissolve” — they are integrated into the architectural and planning context of hybrid space. This occurs on the due to the public spaces serve as the main communicator between them. Integration of residential complexes in the hybrid space structure occurs through active interaction with public, green spaces and transportation infrastructure.

REFERENCES

[1] Zanni, F., Urban hybridization, Politecnica: Milano, 2012.
[2] Ellin, N., Integral Urbanism, Routledge: New York, 2006. P. 18—59.
[3] Ellin, N., Postmodern Urbanism, Princeton Architectural Press: New York, 1999. P. 60—153.
[4] Waldheim, C., Landscape as Urbanism A General Theory, Princeton University Press Princeton and Oxford: New Jersey, 2016.
[5] Waldheim, C., The Landscape Urbanism Reader, Waldheim Charles (eds), Princeton Architectural Press: New York, 2006.
[6] Corner, J. & Hirsch, A. B., The landscape imagination. Collected Essays of James Corner 1990—2010, Princeton Architectural Press: New York, 2014.
[7] Mostafavi, M. & Najle C., Landscape Urbanism: A Manual for the Mechanic Landscape, Architectural Association: London, 2003.
[8] Krasilnikova, E., Landscape Urbanism. Theory-Practice: Part.1. Scientific and practical foundations of landscape urbanism, scientific monograph: LTD «IAA «District news», Volgograd, 2015.
[9] Jencks, C., Architecture of the Jumping Universe: A Polemic. How Complexity Science is Changing Architecture and Culture. Academic Press: London, New York, 1995.
[10] Beatley, T., Biophilic Cities: Integrating Nature into Urban Design and Planning, Island Press: Washington, Kindle Edition, 2010. P. 1630—2415.

[11] This is Hybrid. An analysis of mixed-use buildings. Fernández Per, A., Mozas, J., Arpa, J., A+t Architecture Publishers, 2014.
[12] Krasilnikova, E. & Antjufeev A., Creation of costal and recreation spaces on coastal territories, Strategic decision making in spatial development., peer-reviewed collection of contributions, ROAD and SPECTRA Centre of Exellence EU: STU, Bratislava, 2014. P. 59—87.
[13] Rouse, D. & Bunster-Ossa, I., Green Infrastructure: A Landscape Approach, APA Planning Advisory Service: Chicago, 2013.
[14] A New Future for Planning, by Valeur H. (eds) // The Architectural Magazine B, 2005.
[15] Valeur, H., Co-Evolution: Danish/Chinese Collaboration on Sustainable Urban Development in China: Danish Architecture Centre, 2006. Online. http://www.aguilar-and-associates.com/la-sagrera-new-intermodal-railway-station.
[16] Krasilnikova, E. & Klimov, D., Role and value of landscape urbanism in the modern process of city development and reconstruction, Balkan Architectural Bienale // Conference proceedings „capital a“, BAB, Belgrade, Serbia, 2015. P. 21—40.
[7] Troshina, M., Milan waiting // Project International 38: Joint projects, 2014. P. 50—61.
[8] Frampton, K., Architecture in the Age of Globalization // Project International 18: Joint projects, 2007. P. 140—141.
[9] Krasilnikova, E., Landscape and urban planning transformation of space-planning structure // The Hybrid Link 03, Hybridization between Form and Energy, 2014. P. 1—26. Online. http://www. http://www.urbanhybridization.net.
[10] Avermaete, T., Hooimeijer, F., Schrijver, L., Urban Formation and Collective Spaces // OASE 71, NAi Publishers, 2006. Online. http://www.oasejournal.nl/en/Issues/71.
[11] Concept of multifunctional complex on the Sofia Embankment, Moscow, 2015. The finalist of competition — Miralles Tagliabue EMBT, Burgos & Garrido arquitectos, TSNIIP, 2015. Online. http://archsovet.msk.ru/competitions/sofiyskaya-naberezhnaya/miralles-tagliabue-embt-sofnab.

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ОСНОВНЫЕ ПРИНЦИПЫ ФОРМИРОВАНИЯ ГИБРИДНЫХ ПРОСТРАНСТВ В УСЛОВИЯХ ГРАДОСТРОИТЕЛЬНОЙ РЕГЕНЕРАЦИИ

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Для жизнедеятельности и развития городов гибридные пространства представляют собой быстро развивающиеся территории города, обладающие свойствами самоорганизации в широком градостроительном аспекте — социально-экономическом, функционально-планировочном, рекреационном, ландшафтно-композиционном и экологическом. Динамика изменения градостроительной теории и практики характеризуется интегральным подходом к развитию городов в условиях протекания противоречивых процессов: усиления процессов глобализации, с одной стороны; поиска идентичности, с другой стороны. Формирование гибридных пространств в городской ткани современных городов является актуальным процессом и имеет важное социально-экономическое значение для градостроительной регенерации. В контексте теории проницаемости гибридность определяется как многослойная, многофункциональная особенность городского пространства, в котором нет четкого разделения между государственным и частным; здания и сооружения, образующие гибридную структуру, объединены многоуровневым общественным пространством, и его виртуальное восприятие играет также важную роль, определяя его информационную емкость и способность трансформации. Гибридные пространства представляют собой мультифункциональные архитектурно-ландшафтные или ландшафтно-градостроительные комплексы, которые формируются на основе приемов ландшафтного урбанизма и имеют пространственную связность с прилегающими территориями. Особое значение гибридные пространства имеют для экономики города, так как являются драйверами его развития, находящиеся на острие пространственных, социально-общественных преобразований. Целью данного исследования является поиск и определение современных научно-практических принципов формирования гибридных пространств в условиях градостроительной регенерации. В статье рассматриваются принципы формирования гибридных пространств в контексте ландшафтного урбанизма, а именно интеграция жилья и общественных пространств через зеленую инфраструктуру.

Ключевые слова: градостроительная гибридизация, интегральный урбанизм, ландшафтный урбанизм, гибридные пространства

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ANALYZING THE INFLUENCE OF DIATOMITE AND MINERAL FERTILIZERS ON THE FEATURES OF CADMIUM-CONTAMINATED URBAN LAWNS

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Contamination with heavy metals is among key anthropogenic pressures, experienced by urban lawns. It results in depletion of their environmental quality and functions. Implementation of fertilizers, containing silicon, is a promising approach to increase urban lawns' sustainability to heavy metals' pollution. Based on the field experiment, an influence of cadmium contamination on the chemical features and biomass quality of modeled urban green lawn ecosystems was studied. We demonstrated an increase of cadmium consumption by biomass on the second year of observations as the result of diatomite implementation together with mineral fertilizers. Both total sugar and disaccharides' content in biomass was 15—20% higher for the contaminated plots where diatomite was implemented together with mineral fertilizers, compared to the uncontaminated control. This evidences a positive effect of the implemented reclaiming on stress tolerance of the green lawns.

Key words: heavy metals, pollution, urban lawn ecosystems, environmental functions, silicon, field experiment, sugar, stress tolerance

INTRODICTION

Urbanization is a global trend of the 21st century [22]. Land conversion into urban results in semi-natural and artificial ecosystems, characterized by specific vegetation and soils [5; 9; 34]. Urban lawns play a key role in the structure of urban ecosystems. Many studies report on the substantial areas, covered by urban lawns in settlements (up to 40% unsealed areas) [33; 29] and the diversity of their functions. Along with the obvious ornamental function, lawns increases the deposition of fine dust, participate in filtration of surface waters, contribute to carbon sequestration and together with plantations increase the effect of noise absorption [31]. The specific features of urban soils and soil constructions under lawn ecosystems were also investigated [1; 16], in particular the high content of organic carbon and nutrients, lightweight, particle size distribution, increased average temperatures (especially in summer), intense emission of greenhouse gases such as CO_2, and in some cases N_2O and CH_4 [24; 27; 2]. The implementation of environmental and aesthetic functions of urban lawns largely depends on their resilience to ongoing anthropogenic pressures in the urban environment.

The main types of anthropogenic impact on urban lawns are compaction, salinization and pollution [9; 10]. Among them, the cadmium contamination is one of the most negative impacts, as this metal has a high toxicity to living organisms even at low concentrations [12; 7; 15]. So far, there is no consensus on the effects of cadmium on the properties and functions of soils and vegetation. For example, depending on the concentration, salts of cadmium had an inhibitory and a stimulating effect on the microbiological activity of soils and growth of plant biomass [35; 17]. At the same time, cadmium along with lead, arsenic, and mercury is among the pollutants of the first class of danger. Environmental and health risks associated with cadmium pollution, raises the importance of selecting the optimal fertilizers and reclaiming substances (meliorates), reducing the negative impact on soil, plants and the environment [11].

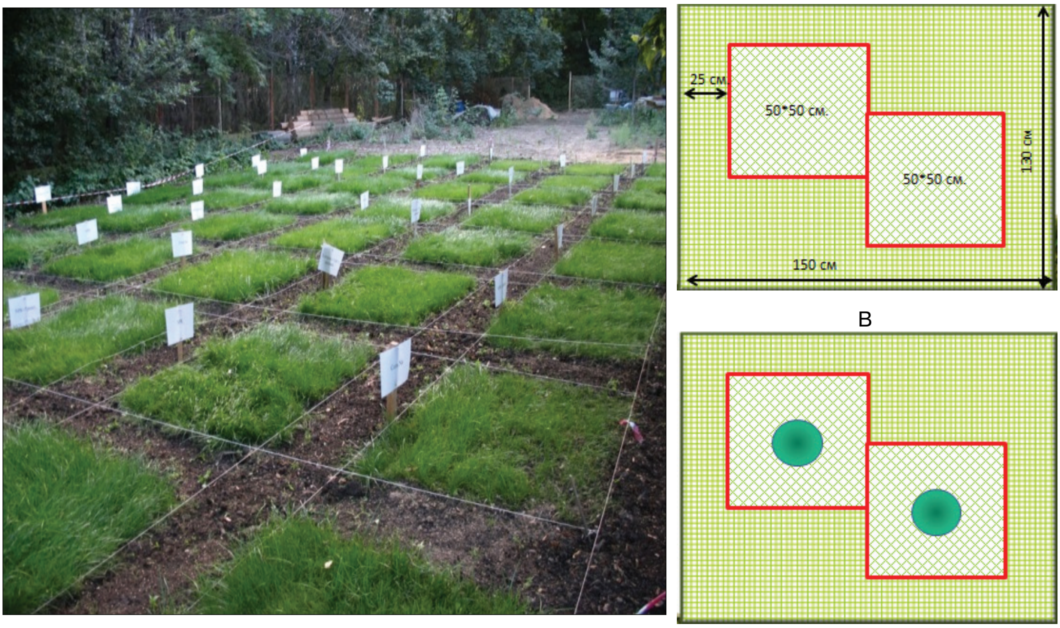
Agrochemical methods of reclamation of polluted soils are mainly based on i) the transfer of heavy metal cations to the inaccessible for plants forms by increasing the physico-chemical adsorption capacity of soils; ii) the creation of conditions for the deposition of metals in the soluble for the antagonism of ions manifestation. The application of fertilizers and meliorates containing silicon, is a promising method of increasing the stability of plants in conditions of contamination [21]. An ability of siliceous materials (diatomite, zeolites) to provide a beneficial effect on the resistance of plants to abiotic stresses (drought, salinity) is widely accepted [20; 28]. Many studies claim the impact of silicon on the toxicity of heavy metal compounds in higher plants, for example barley [23; 26; 6], maize [25] and vegetables [32]. At the same time, the effectiveness of silicon-containing meliorates on urban lawns contaminated with cadmium, remains poorly studied [4].

The aim of this study was to examine an influence of silicon-containing meliorates of diatomite in combination and without mineral fertilizers on the uptake and redistribution of cadmium in urban lawns, as well as on the quality of model biomass in urban lawns.

MATERIALS AND METHODS

Taking into account the high spatial diversity of lawn ecosystems and the abundance of different factors of possible influence, a multi-factor field experiment was carried out. The experiment was conducted in the period from 15 July 2012 to 15 September 2013 at the soil experimental station of Lomonosov Moscow State University (LMSU) (55°42′ N; 37°31). The experiment included model turf ecosystem, representing ‘constructozems’ (urban constructed soils), with growing lawn grass mixture. The sand-peat mixture was used to create the organic layer of the constructozems. The mixture included 30% of bank sand and 70% of lowland peat. The principal chemical features of the mixture were in accordance with the requirements of the certification system “Moscow Environmental Registry” (MER). Lawn grass mixture was chosen in accordance with existing standards (Rules.., 2002). Each experimental plot covered 2 m^2. Lawn grass was seeded in May 15, 2012. Cadmium was applied in the form of salt $Cd(NO_3)_2 \times 4H_2O$ at the rate 19.8 g per plot. The diatomite was added in the amount of 120 g per plot. Among the mineral fertilizers diammonium phosphate (N : P : K = 10 : 25 : 25) was used (48 g per plot) and ammonium nitrate (34% N) was implemented (21.2 g per plot). The final ratio of N : P : K in mineral fertilizers was 60 : 60 : 60 kg of active agent per 1 ha. Fertilizers, cadmium and diatomite were added 3 days before sowing, with minimal surface sealing. In the second year of the study, mineral fertilizer were added on April 25, diatomite and salt of cadmium were not re-introduced.

The following treatments were studied: I) control (without cadmium and fertilizers) (K); II) cadmium with fertilizer (КCd); III) cadmium and diatomite (СdД); IV) cadmium and fertilizers (CdNPK); and V) cadmium, diatomite and mineral fertilizers (CdNPKD). As an external control uncontaminated plots with the introduction of diatomite (KD), mineral fertilizers (KNPK) and their joint introduction (KNPKD) were considered. All the options were in three replicas. Meteorological conditions were monitored according to the weather station of LMSU, and were later adjusted according to RusFluxNet monitoring network (Vasenev et al., 2014). During growing season irrigation and mechanical weed control were performed. Grass samples were collected 8 times in 2 vegetation period with limited frame (0.25 m^2), two replicas per plot to account for the biomass and further research in the laboratory. The 2nd and 4th mowing were selected from each year since the plants in these periods are the least susceptible to influence of uncontrollable factors in the external environment. Mowed part of lawn grasses were weighed and fixed for 10 minutes at 90 °C, then dried at room temperature. All measurements were carried out in three replicas (Fig. 1).



A C

Fig. 1. Sampling scheme for biomass (B) and soil (C) in multi-factor field experiment (A)

Contents of total nitrogen, phosphorus, potassium were analyzed in the biomass samples by conventional methods [14]. Atomic-absorption method after dry combustion and dissolving the ash with a mixture of nitric and hydrochloric acids was implemented to analyze the content of Cd in plants. The content of total sugars, mono — and disaccharides were determined by the method of Bertrand with picric acid. All the measurements were carried out in three replicas. The results were processed and presented in MS Excel 2010.

RESULTS AND DISCUSSIONS

Climatic conditionsof the experiment

The meteorological conditions over the growing period of the lawn were similar to the long-term trends. Dynamics of air temperature and precipitation were, on average, corresponding to long-term data, which allows considering the results of the experiment as representative. On average, the summer-autumn period of 2013 was more humid than the same period in 2012. The average annual temperature in 2013 was 1.5 °C higher due to warmer winters, however, statistically significant differences of air temperature in the summer-autumn period between the years was not identified (Fig. 2).

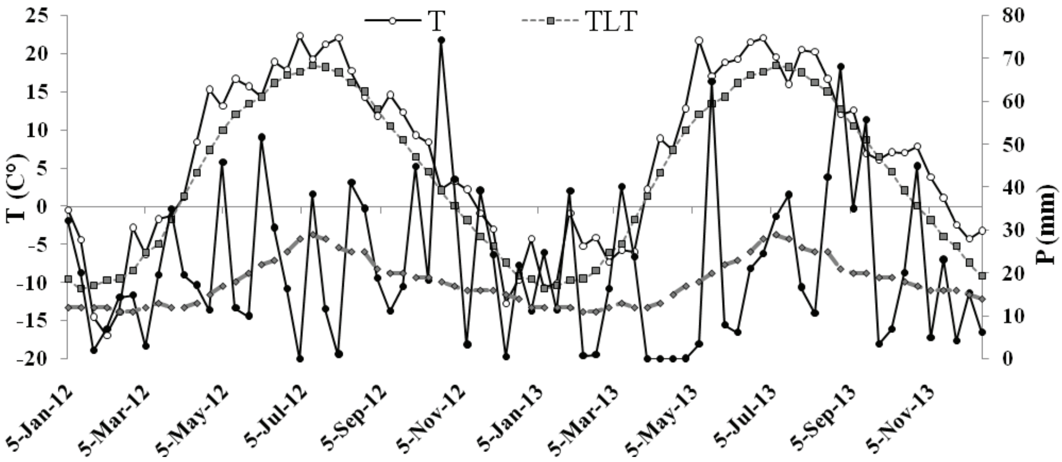


Fig. 2. Air temperatures (T) and precipitation (P) for the whole period of the experiment in comparison to the long-term trends (TLT) and precipitation (PLT)

The effect of contamination with cadmium on the grass biomass properties

The introduction of cadmium led to the increase in the grass biomass. A significant difference with the control was shown in 2012 (especially in the second harvest, when it exceeded the control 14 times). In 2013, an increase of cadmium content was obtained for the biomass of contaminated sites (particularly in the fourth mowing — 2.5 times compared to 2012). The absolute values of the average content of cadmium in the samples of biomass from the contaminated sites were similar, however the relative content compared to the control increased threefold (Table 1). The differences between the content of macro elements in biomass of the polluted and control sites were not significant.

In 2013, a silicon content in cadmium-contaminated variants increased 20% compared to control in the second mowing, and 2.5 times in the fourth mowing. The increase in silicon content in 2013 compared to 2012 was found for the control as well (3—8 times), however, for the contaminated samples the annual growth was much more significant (in 11—13 times). Apparently, in the process of growth and maturation of the lawn the accumulation of silicon in cell walls occurred. Silicon participates in the formation of skeletal parts of plants, strengthens the stem and root system.

Table 1

Dynamics in contents of macro elements and cadmium in the biomass of the studied lawn ecosystems (the second and fourth harvests (H2 and H4, respectively))

Treatment	N_{tot} (%)		P_2O_5 (%)		K_2O (%)		Si (%)		Cd (μg/kg dry matter)	
	H2	H4	H2	H4	H2	H4	H2	H4	H2	H4
2012										
K	3.36	1.86	1.45	1.28	3.46	3.27	0.06	0.05	0.53	2.15
KCd	2.79	2.7	1.41	1.11	3.11	4.13	0.06	0.05	8.34	3.01
CdD	2.7	1.78	1.4	1.16	3.29	2.9	0.05	0.05	9.41	6.05
CdNPK	3.04	6.34	1.43	1.24	3.40	4.13	0.06	0.05	16.28	5.96
CdNPKD	3.17	2.31	1.55	0.91	3.35	2.98	0.06	0.06	4.41	5.81
KD	2.61	3.51	1.34	1.06	2.99	3.34	0.06	0.05	1.55	3.43
KNPK	3.11	4.34	1.38	1.25	3.43	2.92	0.06	0.05	2.06	2.09
KNPKD	2.88	3.37	1.48	1.18	3.62	3.63	0.06	0.05	1.45	2.76
2013										
K	1.92	2.28	1.49	0.32	3.04	4.1	0.56	0.21	0.1	0.1
KCd	2.23	2.55	0.13	0.41	2.77	3.4	0.71	0.73	3.13	8.25
CdD	2.13	2.38	1.12	0.28	2.93	3.8	0.79	0.73	2.13	6.88
CdNPK	1.81	2.20	2.22	0.32	2.66	3.70	0.52	0.78	1.50	4.00
CdNPKD	2.16	2.18	0.82	0.18	2.51	3.4	0.64	0.88	0	9.38
KD	2.22	2.8	1.5	0.24	3.12	3.5	0.61	0.72	0	0
KNPK	1.86	2.97	1.19	0.3	3.19	3.9	0.58	0.41	0	0
KNPKD	1.68	2.21	1.01	0.23	2.87	4.1	0.7	0.29	0	0

Surprisingly, the cadmium pollution didn't decrease total biomass and in some cases even stimulated the growth. This corresponds to literature data that show that some doses of heavy metals are able to have a complicated and stimulating effect on the plants conditions [17]. Besides, considering the deficit of microelements in the investigated constructozems, cadmium could have a stimulating effect on plants, replacing some metals with similar chemical properties [8]. The cadmium pollution didn't result in significant changes in the amount of sugars in biomass, but the proportion of disaccharides in the biomass of the autumn harvest has decreased 15%, which may indicate a stressed condition of the lawn grasses (Fig. 3).

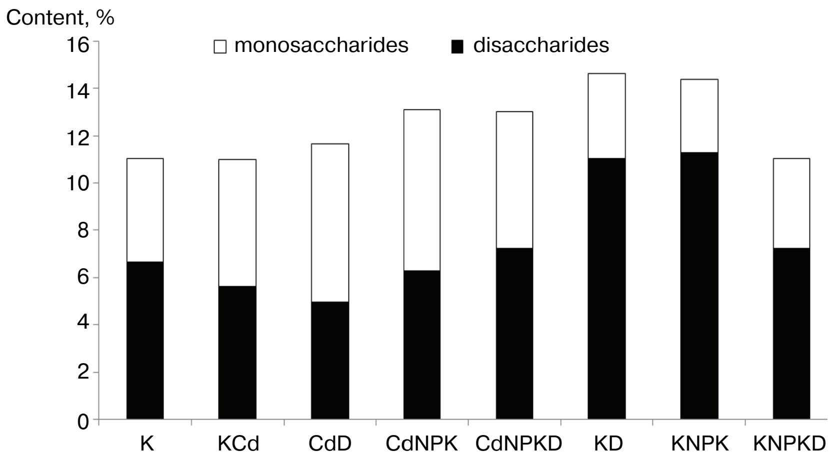


Fig. 3. The total sugar content, mono- and disaccharides in the biomass of experimental plots in autumn (3rd and 4th) mowing of 2013

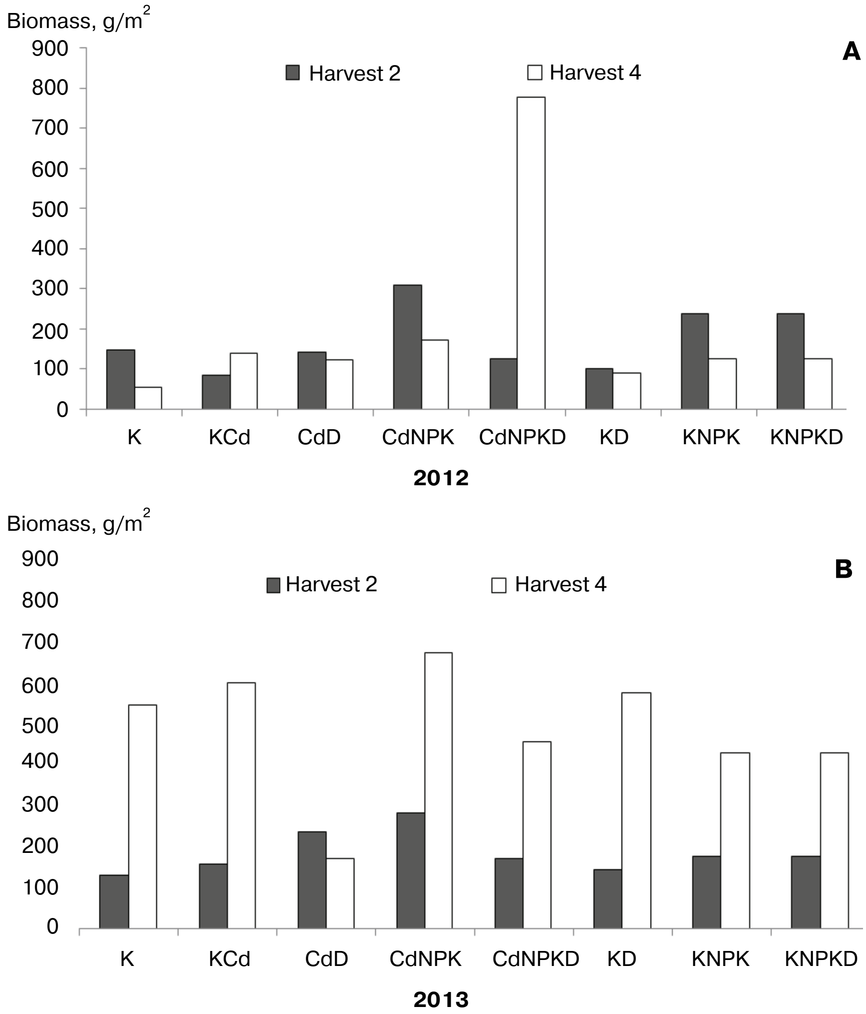


Fig. 4. Dynamics of the biomass of experimental plots in 2012 (A) and 2013 (B), respectively

In general, the average biomass of the lawns in 2013 increased 5—8 times, which could be explained both by favourable weather conditions and the maturation of the lawn. The increase of biomass from contaminated sites in 2013 compared to 2012 was less than for the control (Fig. 4).

Effect of diatomite on the lawn properties that had been contaminated with cadmium

The introduction of diatomite in the contaminated areas contributed to the significant increase of biomass (50—70%). The exception was in 4th mowing of 2013, which recorded unusually high biomass of the polluted area without diatomite, 15—20% higher than the control (Fig. 4). The total number of sugars in the biomass plots CdD was 6% higher than for KCd, however, the proportion of disaccharides was less than 10—15% and 20—25% in comparison with the polluted and non-polluted control respectively, for individual harvests and in average over the season (Fig. 3). Apparently, the introduction of diatomite in the specified concentrations without chemical fertilizers did not contribute to improving the sustainability of biomass to anthropogenic pressures, or the effect occurred later than the second year after application. Analyzing the effects of diatomite on the content of macro elements in biomass of contaminated sites, most notable is the decrease in the N content, which is probably associated with the "growth dilution", as well as the fact that the diatomite as silicon sorption type fertilizerthat absorbs nitrate and ammonia N from root layer. The phosphorus content in the biomass plots CdD was in average higher and potassium — lower than for KCd plots, however, a general reduction of elements content from 2012 to 2013 was also observed. The introduction of diatomite led to the increase in the silicon content in the biomass of contaminated sites, especially in 2013. The cadmium content in biomass of contaminated sites, where diatomite was introduced, was significantly higher than without introduction (up to 100% on the 4th mowing), but in 2013, a statistically significant effect of the introduction of diatomite on contaminated sites was not found (Table 1).

Dynamics of grass biomass properties contaminated with cadmium, with the introduction of diatomite and mineral fertilizers

Mineral fertilizers contributed to a visible increase in biomass (up to 4 times) compared with the control and contaminated sites (the exception was in 4th cut of 2013). Total sugar content increased by 13 and 19% compared to CdD and KCd. Moreover, an average content of sugars in the biomass in the autumn (3rd and 4th harvests exceeded those in unpolluted control by 18%. The application of mineral fertilizers without diatomite on contaminated sites has also contributed to the increase in the proportion of disaccharides. At the same time, the maximum effect was achieved with the joint application. The content of disaccharides in the biomass plot CdNPKD increased by 12, 15 and 27% compared to the KCd, and CdNPK and CdD respectively (Fig. 3). The content of nitrogen, phosphorus and potassium in the biomass of the polluted area with the introduction of diatomite with mineral fertilizers is higher than without those, but less than in the control plot.

CONCLUSION

Heavy metals pollution and, in particular, cadmium contamination is one of the most common pressures experienced by urban lawns, which can reduce the effectiveness of their environmental and aesthetic functions. It was shown that the cadmium pollution has led to a significant increase in the content of heavy metal and to reduction of macroelements' content in biomass of grasses, however the total biomass did not change significantly. In the result of the introduction of diatomite the uptake of cadmium by plants increased. When adding diatomite with the mineral fertilizers in the second year of the experiment the cadmium content in biomass increased 20—50%. The introduction of diatomite in combination with mineral fertilizers increases both the total sugar content, and the content of disaccharides in the biomass, which indicates the increase of plant resistance to stress is revealed. At the same time, the use of meliorates together with mineral fertilizers stimulated the removal of cadmium by crop plants. This pattern is promising for the development of technologies for phytoremediation of urban soils contaminated with heavy metal, which is very important for modern cities.

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REFERENCES

[1] Belobrov V.P. and Zamotaev I.V. Soil and green lawns of the sports and technical facilities. M.: GEOS, 2007, P. 115—203 (in Russian).
[2] Vasenev V.I. Agrochemical and microbiological characteristics of constructsem of Moscow and Moscow region / Agrochemical Vestnik, № 4, 2011. P. 1213—1218 (in Russian).
[3] Vasenev I.I., Vasenev V.I., Valentini R. Agro-environmental objectives of the analysis of greenhouse gas fluxes and soil carbon pools under the regional environmental monitoring RUSFLUXNET. Agroecology. No. 1, 2014. P. 8—12 (in Russian).
[4] Verkhovtsev N.V., Soloviev S.A., Soloviev A.S. Protection of lawn grass with natural siliceous agroores. Agrochemistry. No. 9, 2014. P. 87—96 (in Russian).
[5] Gerasimova M.I., Stroganova, M.N., Mozharova, N.V., T.V. Prokof'eva, Anthropogenic soils: Genesis, geography, recultivation. Textbook. Smolensk: Oikumena, 2003. P. 268 (in Russian).
[6] Egorov V.S., Gosset, D.D., Dzerzhinskaya, A.A. Effect of fertilizers on the content and behavior of cadmium in the system soil-plant on sod-podzolic soils. Problems of Agrochemistry and ecology. No. 9, 2009. P. 27—31 (in Russian).
[7] Ilyin V.B., Syso A.I. Microelements and heavy metals in soils and plants of Novosibirsk region. SB RAS, 2001 (in Russian).
[8] Koshkin E.I. Fiziologiya and sustainability of agricultural crops. Drofa, 2010 (in Russian).
[9] Kurbatovaa A.S., Bashkin V.N., Barannikova, Y.A., Gerasimov S.G., Nikiforova E.V., Reshetina E.V., Savelyev V.A., Savin D.S., Smagin A.V., Stepanov A.L. Ecological functions of urban soils. Moscow—Smolensk: Magenta, 2004. P. 232 (in Russian).
[10] Makarov O.A., Redko V.M., Guchok M.V. Ecological-economic and ecological-bonitirovka assessment of soil and land in the Moscow region. M.: MAKS Press, 2011. P. 262 (in Russian).
[11] Obukhov A.I., PlekhanovaI. O., Kutukova J.D., Afonina E.V. Heavy metals in soils and plants of Moscow // Ecological studies in Moscow and the Moscow region. M., 1990. S. 148—162 (in Russian).
[12] Ovcharenko M.M. Heavy metals in the system soil-plant-fertilizer. Avtoref. dis. ... doctor. agricultural sciences. M., 2000. P. 34 (in Russian).
[13] Rules for the establishment, maintenance and protection of green plantings of the city of Moscow. Moscow Government Resolution of September 10. 2002. No. 743. Moscow (in Russian).

[14] Practicum on agricultural chemistry (edited by Mineev V.G.). 2001. Publishing house MSU, Moscow (in Russian).
[15] Revich B.A. Environmental epidemiology. M.: Akademiya, 2004 (in Russian).
[16] Smagin V.A. The theory and practice of designing of soils. M.: Publishing house MSU, 2012 (in Russian)
[17] Titov A.F., Talanova V.V., Kaznina N.M., Laidinen G.F. The resistance of plants to heavy metals. Petrozavodsk: Karelian research center of RAS, 2007. 172 p. (in Russian).
[18] Tuldukov V.A., Cobozin I.V., ParahinV.B. Lawn sience and landscaping of populated areas. M.: Kolos, 2002 (in Russian).
[19] Castaldi, S., F.A Rutigliano and A. Virzo de Santo. Suitability of soil microbial parameters as indicators of heavy metal pollution. Water Air Soil Poll 158: 21—35, 2014.
[20] Epstein E. Silicon. Annual Review of Plant Physiology and Plant Molecular Biology, 50, 1999. P. 641—664
[21] Epstein E. Silicon: its manifold roles in plants. Annals of Applied Biology. 155, 2009. P. 155—160.
[22] FAO // Climate-smart agriculture. Sourcebook, 2013. E-ISBN 978-92-5-107721-4.
[23] Horiguchi, T., Morita, S., Mechanism of manganese toxicity and tolerance of plants. VI. Effect of silicon on alleviation of manganese toxicity of barley. J. Plant Nutr 10, 2299e2310, 1987.
[24] Kaye, J.P., I.C. Burke, A.R. Mosier, and J.P. Guerschman. Methane and nitrous oxide fluxes from urban soils to the atmosphere. Ecol Appl 14:975—981, 2004.
[25] Liang, Y.C., Wong, J.W.C., Wei, L. Silicon-mediated enhancement of cadmium tolerance in maize (Zea mays L.) grown in cadmium contaminated soil. Chemosphere 58, 475e483, 2005.
[26] Liang, Y.C., Yang, C.G., Shi, H.H. Effects of silicon on growth and mineral composition of barley grown under toxic levels of aluminum. J. Plant Nutr 24, 229e243, 2001.
[27] Lorenz, K. and R. Lal. Biogeochemical C and N cycles in urban soils. Environment International: 35, 2009. P. 1—8.
[28] Ma J.F. Silicon requirement in rice. III Silicon in Agriculture Conference, Ed. G.H. Korndorfer, 52—61. Uberlˆandia, Brazil: Universidad Federal de Uberlˆandia, 2005.
[29] Milesi, C. and S.W Running. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Environ Manage 36, 2005. P. 426—438.
[30] Pickett, S.T.A., M.L. Cadenasso, J.M. Grove et al. Urban ecological systems: scientific foundations and a decade of progress. J Environ Manage 92, 2011. P. 331—362.
[31] Raciti S.M., Hutyra L.R., Rao P. and Finzi A. Inconsistent definitions of “urban” result in different conclusions about the size of urban carbon and nitrogen stocks. Ecological Applications. 22, 2012. P. 1015—1035.
[32] Rogalla, H., Ro¨mheld, V. Role of leaf apoplast in silicon-mediated manganese tolerance of Cucumissativus L. Plant Cell Environ 25, 549—555, 2002.
[33] Svirejeva-Hopkins, A., H.J. Schellnhuber and V.L. Pomaz. Urbanized territories as a specific component of the global carbon cycle. Ecol Model 173, 2004. P. 295—312.
[34] Pickett, S.T.A., M.L. Cadenasso, J.M. Grove, P.M. Groffman, L.E. Band, C.G. Boone, W.R. Burch, C.S.B. Grimmond, J. Hom, J.C. Jenkins, N.L. Law, C.H. Nilon, R.V. Pouyat, K. Szlavecz, P.S. Warren and M.A. Wilson. 2008. Beyond urban legends: an emerging framework of urban ecology, as illustrated by the Baltimore Ecosystem Study. BioScience 58: 139—150.
[35] Castaldi, S., F.A Rutigliano and A. Virzo de Santo. 2004. Suitability of soil microbial parameters as indicators of heavy metal pollution. Water Air Soil Pollution 158: 21—35.

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АНАЛИЗ ВОЗДЕЙСТВИЯ ДИАТОМИТА И МИНЕРАЛЬНЫХ УДОБРЕНИЙ НА СВОЙСТВА ГОРОДСКИХ ГАЗОНОВ, ЗАГРЯЗНЕННЫХ КАДМИЕМ

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Загрязнение тяжелыми металлами — одна из наиболее распространенных нагрузок, испытываемых городскими газонами, которая приводит к снижению их экологического качества и выполняемых ими функций. Применение кремнийсодержащих удобрений и мелиорантов — перспективный способ повышения устойчивости газонных экосистем в условиях загрязнения. На основании полевого мелкоделяночного опыта изучено воздействие загрязнения кадмием на химические свойства и качество биомассы модельных газонных экосистем. Показано увеличение поглощения кадмия биомассой растений на второй год внесения диатомита на фоне минеральных удобрений. Как общая сумма сахаров, так и содержание дисахаридов в биомассе загрязненного участка с внесением диатомита на фоне минеральных удобрений было на 15—20% выше, чем в загрязненном контроле, что свидетельствует о благоприятном воздействии мелиоранта на стрессоустойчивость газонных трав.

Ключевые слова: тяжелые металлы, кадмий, загрязнение, газонные экосистемы, экологические функции, кремний, мелкоделяночный опыт, сахара, стрессоустойчивость

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THE PROBLEM OF DUST STORMS: PROTECTION METHODS AND MACRO-STRUCTURES IN LANDSCAPE ARCHITECTURE

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For people living in arid areas with an arid climate and constant dust-storms, there is a need to hide from the wind flow arises very often. Dust storms occur continuously on our planet, and the use of its power and the wind force developssustainably in the modern world. Sustainable development — is a model of natural resources use, the model of interaction between a human and nature, a model of civilization progress on the basis of innovation, which is achieved by quenching the vital needs of the modern generation along with environment saving, strengthening personal and public health, without losing this opportunity for future generations. Studied foreign experience allows to propose new methods of dealing with dust storms, as well as the new form of protective structures in urban space with the use of modern means of landscape design.

Key words: ecological disaster, dust storm, Kyzylorda environment, protection methods from dust storms, protection constructions from dust storms, the plants of the local flora, local rock formation, environmental design, environment sustainability within macro-structures in landscape

INTRODUCTION

Recently, dust (sand) storms, in their scale, can be attributed to global natural disasters, which can cause serious environmental problems later, storms are insufficiently studied, in connection with various atmospheric parameters that determine their occurrence and development.

Dust (sand) storm — is the rise caused by strong winds from the earth's surface and the air streams transfer of dust, sand, salt and other particle of less than one millimeter in size [1]. In the recent years the identification of source areas for dust storms has been an important area or research, with the Sahara (especially Bodélé) and western China being recognized as the strongest sources globally [9]. This phenomenon is widely spread in desert, semi-desert and steppe regions of the planet. One of such areas include the southern part of Republic of Kazakhstan, Kyzylorda city, where dust storms occur frequently. During strong storms in Kazakhstan, wind speeds can exceed 25—30 m/s. Storms belong to local micrometeorological phenomena, i.e. have a linear manifestation scale in amount of tens or hundreds kilometers. Areas, that capture dust storm are very diverse — from minor areas of several hundred square meters, up to colossal, hundreds or thousands and even millions of square kilometers. According to duration, this phenomenon can be short — a few minutes, as well as long — several days. A storm cause is considered to be a turbulent whirlwinds that arise in wind strengthening, and strong vertical currents are formed by heating of the Earth's surface. One of the reasons of dust storm occurrence is a strong soil dryness dustiness. The occurrence of its intensity also depend on the number and nature of precipitation [2]. Strong destruction and blowing of soil, as well as the transfer of sand, salt and other particles by air flows, provides great harm to a human health, first of all, and to is economic activity. In an urban environment, high dust content can be a consequence of serious ecological and genetic problems. On the basis of existing data for 2006 of Kyzylordaregion, the dust concentration in the air is 1.7 mg/m (MPC — 0.15 mg/m), and presence of harmful substances in the air: nitrogen dioxide (MPC — 0.2 mg/m) — 1.9 mg/m, ammonia (MPC — 0.2 mg/m) — 1.0 mg/m.

44.5% of the region diseases are the respiratory system diseases [3]. The environmental disasterterritory like Aral sea, as well as existing cosmodrome "Baikonur" are the parts of Kyzylorda region, that served as the negative influence of dispersion of dust, harmful particles and salts in the air. In relation to the existing environmental situation in Kyzylorda region and, in particular, in Kyzylorda city, at the present stage, the research of new forms in landscape architecture, contributing to the solution of this problem of heavy storms is essential. Therefore this paper aims to review methods considering the solution analysis of the problem.

Aims and goals. The aim of this study is to examine the nature of the dust storms, direction of the wind velocity and dust flow scheme. The aim of the study is also the research of new model of the macro-structure in the landscape, integrating in its structure both artificial and natural materials. the objective of the research is to find a landscape model of the space in which the shape and design of the macro-structure as a protective element. Macro-structure will help to reduce the flow velocity of the dust, silt detention, and in the absence of dust storms will form the basis of the composition for the organization of recreational space squares, boulevards and squares.

MATERIAL AND METHODS

The whole territory of Kyzylorda region is characterized by frequent and strong winds, especially in north-east direction. Their average annual speed is ranged from 3.1 to 6.0 m/s.The most dangerous storms are the storms, the speed of which exceeds 15—20 m/s. During strong storms in Kazakhstan, wind speeds can exceed 25—30 m/s. To prevent and reduce the dust storms effects, there is a use of several methods: the design of urban facilities (public and residential buildings), creations of forest shelter belts and hedges as well as artificial designs. This paper review the individual methods and evaluates the efficiency of those In the process of urbanization the natural environment changes., An artificial environment for humans is created due to efficient organization of urban systems, sustainable agricultural, forestry and industrial use of land and water resources. The knowledge of the laws of equilibrium between the primary and the urban environment will allow regulating urban planning processes properly, to produce optimal requirements for the planning and building of settlements, space-planning decisions of housing and community facilities, engineering networks, landscaping, taking into account the specific of an area climatic conditions [4].

In forming cities in areas with dust storms it is necessary to search for a compact, serried urban structures (reduction of the vehicle and pedestrian communication length, architectural compositionsisolation, etc.) that react to wind effects as a whole [5]. On the periphery of the settlements in the dust and wind flow path it is recommended to build rows of terraced houses with gardens.Two-storey construction will reduce the dust rate from 20—30% up to 80% [6]. Thus, the effective protection of the urban environment from dust storms will be achieved by comprehensive application of architectural, constructive and engineering tools according to specific local conditions.

Protective forest plantations — arethe artificially created forest plantations for protection from adverse natural and anthropogenic factors, including drought, water and wind erosion. These plantations can be in the form of forestlands, shelterbelts and clumps, designed to protect the natural, agricultural, industrial, municipal, transportation and other facilities. The protective effect of shelterbelts is expressed both in the immediate protection of soil and crops from dust storms, as well as in the creation of environment conditions to fight against them [7]. Shelterbelts are laid not only in the area, but also in the urban environment exposed to dust storms most of all. Shelterbelts are more effective not only for dust transportation detention, but for the riding air flows dedusting, what is the result of turbulent mixing in treecrowns. Dust-wind strips are placed on the edge of city building and mutually linked with the system of urban landscaping and complex of special ameliorative measures (soil improvement, organization of irrigation and drainage, plant protection from hot winds, etc.). In residential complexes, green spaces, strips are placed with a width of 10—12 m. along the buildings facades, playgrounds and sports complexes, and so on.To create forest plantations it is necessary to use resistant to the local (Kyzylorda region) climatic conditions tree species such as ash, poplar, elm, white willow and maple.

Hedge is another one frequently used element of modern landscape architecture. A hedge is designed to perform not only an aesthetic function, but it is also able to protect area securely from adverse climatic conditions, in particular, as a dust storm and strong wind.At the same time, it's a beautiful landscape design that could provide the urban environment with the natural appearance and attractiveness.Among the existing varieties of hedges, there is a living wall to deal with a storm. The height of living wall can reach 2.5 meters and above. The advantage of living wall is that it stops the massive wind flow, but remains breathable, it does not inhibit natural ventilation, what has a beneficial effect on all the surrounding landing (cannot impact positively on all landings). It is especially important during periods of heat and high humidity. Such fences in Kyzylorda region can be obtained by the use shrubs that are resistant to the local climate characteristics, such as: cingil, oleaster, rose, Russian olive, sea buckthorn.

The most feasible and reliable options can be constructions that consist of both natural and artificial materials. High constructions, as fences, special hedges, small architectural forms, can stop stronger wind. Such windproof models can be made of different materials like wood, polycarbonate, plexiglass, stone and other. This method can be developed and proposed by landscape architects, both in terms of design element in the city, as well as the solution of environmental problems. Such design solutions may be used as a visual sign in the urban environment. Visual signs of a landscape object can be objective and subjective, depending on a garden supervisor, the breadth of his vision and creativity in general [8].

By studying this method, we have identified several methods that will be used in our work to help create the most efficient design for protection against dust storms.

1. Metod of regenerate the nature — the creation of a sustainable development of the environment in the urban structure. The main purpose of this method is the formation of corners in the nature of a city by use of natural materials. That is, the proposed structure will not only create an "ecological shield", thereby stopping the flow of the wind during dust storms, as well as during a lull, will perform aesthetic functions in the city, using a natural component. The green component will strengthen the "ecological shield" by planting local flora, thus creating even a small shadow that is a significant factor in hot, dry climates. The term "natural materials" refers to the use of local stone (mineral) femolita. This breed has excellent construction performance, wide range of colors from white to various shades of gray, which can be used to create identical structures in different parts of the city and outside it in different areas. Natural regenerate method will create an ecological balance in the city.

2. Metod "trap" is based on the location of the proposed model depending on the direction and speed of wind storms. The main objective, which serves as a method of position macro-model, taking into account the arrangement according to the different angular degrees in the plane or in the opposite position to the wind direction. Also, this method supports the residents of the city at different time intervals: how macro-structure with shelter and safety functions, then as a resting place in the shade with natural ingredients in its structure, how identical the composition of the urban landscape.

3. Metod semantics scale — method considers the signs and semantic images in terms of their notional value. Its main idea is to design a tablet — picture the earth's surface, and the shape of the semantic macro-structure. For a stronger development of different aspects of the theme of the sign may be involved, associated with the area, such as — the city's history, national characteristics, national symbols, and others. Supposed as semantic sign will be ambitious and will form a single composition in space, characterized by a ratio of parts, size structures commensurate with the environment and for human comfort. The scale not only indicates the actual size of the audience macro-structure, but also gives it a semantic image required for this particular urban space. According to our model is the macro-structure of this article title, then there will be large-scale dimensions. The maximum size of the macro-structure is in the process of refinement, and a final alignment of the scheme will also be in terms of research.

In terms of implementation of such structures and in order to maximize economy, it is recommended to use materials of local origin, such as local stone (mineral) as femolit. This breed has excellent construction performance, wide range of colors from white to various shades of gray that can be used to create identical structures in different parts of a city, outside of it and in different areas.

As an example, the «Furnished shelter forth homeless at Sundholm» project in Copenhagen, which means "Furniture as a shelter for homeless people". The project is based on the constructions in landscape style, crafted from 94 plywood elements. These structures are different in heights, made of polycarbonate material with thickness of 4 mm, fastened together by bolts. This construction solved the problem for homeless people, helping them to hide from bad weather, because the construction is water-resistant, windproof and sound proof. This construction solved social, aesthetic and environmental problem. Environmental problem means not only protection from dust storms and moisture protection, but the planting of green component in the urban environment as well.

RESEARCH RESULTS

Dust storms over the last 50—60 years, due to several reasons have ceased to be studied intensively, so to accomplish the result of the study we have used historical data of the dust storms. We compared the at different times and the following results. The figures for the 20-year period allowed to establish non-uniformity of distribution of dust storms, both in time and in space. The figures for the 20-year period allowed to establish non-uniformity of dust storms distribution within both time and space. In the area of Kyzylorda region dust storms can occur in all months of the year. But, however, significant indicators (about 85%) are in warm season, from April to September.

The graph 1.2 [2] shows the repeatability of dust storms by month and its value as a percentage. As shown in Figure 1 in Kyzylorda oblast maximum wind shifted to May, as well as for the IV—IX period, the figure was 446.

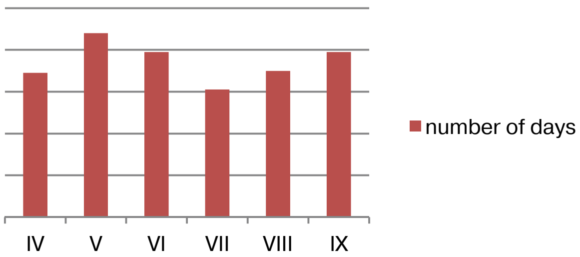

Figure 1. Repeatability (number of days) dust storms

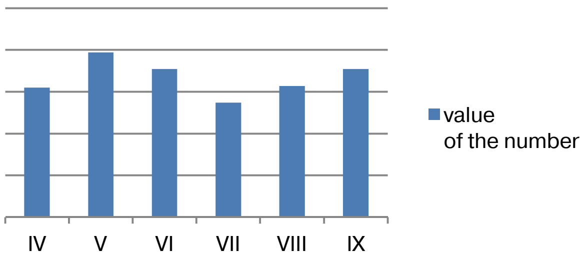

Figure 2. The average value of the number of days with dust storm

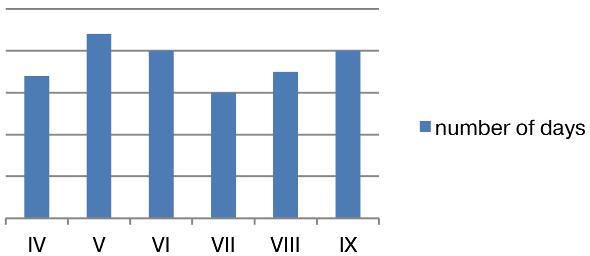

Figure 3. The maximum number of days with dust storm on months of the warm period

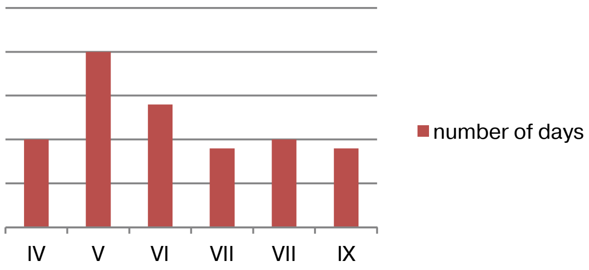

Figure 4. The maximum number of days with dust storm on months of the warm period

Cities of southern Kazakhstan, such as the Shymkent and Kyzylorda, are the heightened areas of dust storms occurrence, since they are in a desert area, within the boundaries of the sand massifs, Alakum and the right bank of Syrdarya river and the Eastern part of the Kyzylkumsands, little planted by vegetation, with patches of sand dunes. On the territory of Kyzylorda region the average number of days with dust storm is equal to 22.3. According to the schedule 3.4 [2] it can be seen that the average and maximum number of days with dust storm falls, as the month of May.

Strong dust storms in Kyzylorda region occur mainly in the Eastern and North-Eastern winds. In table 1, there is the data of wind speed in m/s, with dust storms > 12 hours and frequency of occurrence (%) speed > 15 m/s by month. All figures, shown in tables and graphs, will be taken into account in deciding the form of the proposed construction in urban environment, as well as the direction and scope of this construction. Historical characteristics of the city, its peculiarities, and the climatic conditions for plants use, that are resistant to these factors, are important.

Table 1

Wind speed in m/s, with dust storms > 12 hours and frequency of occurrence (%) speed > 15 m/s by month

Station	IV	V	VI	VII	VIII	IX	For IV— IX
Kyzylorda	12—28/88	17—20/100	20/100	—	—	10—17/80	12—28/88

Graph 5 [2] shows the performance of the highest duration of dust storms by month, which in Kyzylorda region is in August, the month of September.

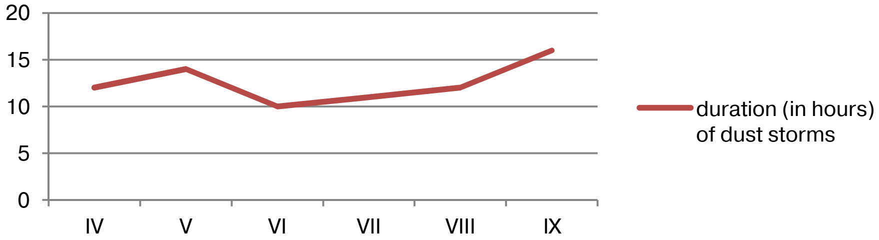

Figure 5. Maximum duration (in hours) of dust storms

Being at the stage of modeling the process of dust storms, including analysis of digital data by frequency and intensity of this process, we offer a use of macro-structure in the form of geo plastic forms of different sizes, that disrupts a power of wind flow and delay the dust particles on its surface, as a basic shield for this phenomenon. So, as a form of this construction, bionic form, resembling a rice grain is proposed. So, as a form of this construction, bionic form of tablet design, resembling a rice grain is proposed (Figure 6). Such grain figure is due to the fact that Kyzylorda region is on the first place for rice cultivation and its export to other cities. To make this model not monotonous, it is proposed to cut and make it different-leveled for planting shrubs and native flora serving natural shield to trap dust particles and for aesthetic reasons (Figure 7). For the construction, natural stone will be used, mined in the region and in the area of urban-type settlement of Zhanakorgan (Figure 8).

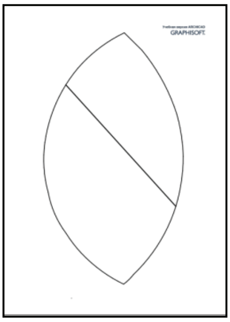

Figure 6. Tablet design

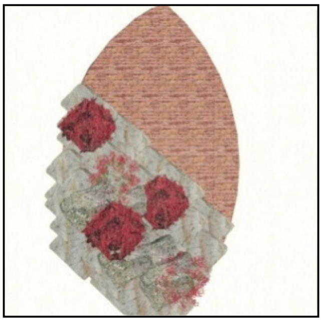

Figure 7. View from above

As the local flora is expected planting low shrubs that will create a more favorable and the natural environment in an urban environment (Figure 9).

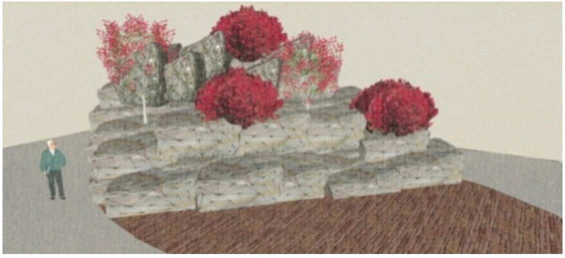

Figure 8. Macro view of construction

Figure 9. Commensurate scale

CONCLUSIONS AND RECOMMENDATIONS

Attempts to solve the environmental problem at different stages of its occurrence in several scientific studies, for example in the article "Macro-constriction in the urban landscape as a way of protection from sandy winds" in the proceedings of the international conference "Public space and urban landscape architecture. The search for new solutions". However it raises only questions of the problem of dust storms and there is a solution, and in this study we have found methods of ecological disaster adapt to the new landscape technology of XX-th century. They are based on the principles of sustainable landscape development for Kyzyordinskoy area. In view of the above methods, it is possible to make the first conclusions that shown and described construction will solve the environmental problems of the city of Kyzylorda, which scale is capable of stopping the flow of strong wind. Such a model of protection from dust storms related to sustainable development and will allow city residents to be Kyzylrda be in natural surroundings, but in the city structure. The position of elements of different size construction will depend on the wind direction and speed, which will be located in open spaces in the urban environment, which refers to the method "traps". Knowing the wind direction (north and northeast), we can assume that most locally and they will be located in the northeastern part of the city (Figure 10).

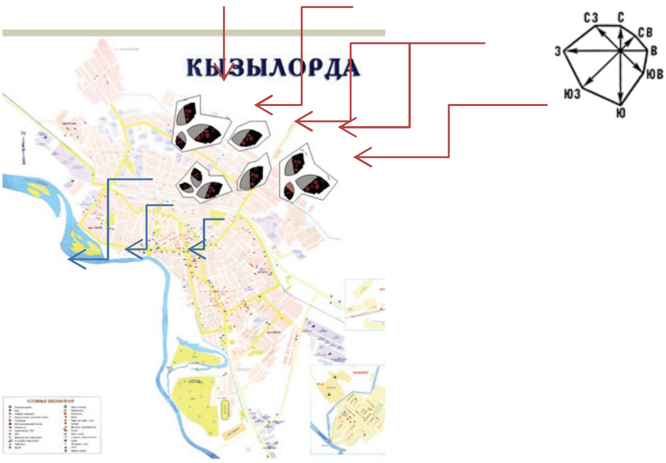

Figure 10. The position of the elements of design
[the Map taken from the official site of akimat of Kyzylorda city]

In Figure 10, we can observe how the construction data in this part of town and become an obstacle to defuse the wind moving north-east direction. In daily use, they are a new form of city park with macro-structures, which are arranged in a circuit different functional areas for recreation, sport, walking.

REFERENCES

[1] Semenov O.E. (2011) Introduction to experimental meteorology and climatology of the sand storms. Almaty, 580 p. (in Russian).
[2] Agarkova A.P. Dust storms and their prognosis. M.: Gidrometeoizdat, 1981 (in Russian).
[3] Ermuhanova N.B. Influence of natural and anthropogenic factors on the health of the population in the zone of ecological disaster: Dis. ... Phd. KSU KorkytAta. Kyzylorda, 2015. 5 (in Russian).
[4] Bektemisov A.S. Construction problems in the complex hydrogeological conditions in areas of dust storms in Kazakhstan // Collection of papers of Republican conference on the problems of design and construction in IV climatic area with dust storms and adverse engineering-geological conditions in cities and settlements of the Kazakh SSR. 1978. S. 1—5 (in Russian).
[5] Merkert I.A., Karch L.A., Roganova Z.N. Urban planning and typological features of design of residential and public buildings in areas with dust storm // a Collection of papers of Republican conference on the problems of design and construction in IV climatic area with dust storms and adverse engineering-geological conditions in cities and settlements of the Kazakh SSR. 1978. P. 7—10 (in Russian).
[6] Lakcevic, V.K., Darbinian, S.D. Issues of methodology for assessing the dustiness of the home and control // Collection of papers of Republican conference on problems of design and construction in the IVth climatic area with dust storms and adverse engineering-geological conditions in cities and settlements of the Kazakh SSR. 1978. S. 13—16 (in Russian).
[7] Zakharov P.S. Dust storms and fight with them. Rostov-on-don, 1961 (in Russian).
[8] Zaykova E.Y. Typological basis for the design of the iconic landscape environment // RUDN Journal of Agronomy and Animal Industries, No. 2, 2015, pp. 53—56 (in Russian).
[9] Andrew S. Dust storms: Recent developments // Journal of Environmental Management, Volume 90, Issue 1, January 2009, pp. 89—94.

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ПРОБЛЕМА ПЫЛЕВЫХ БУРЬ: МЕТОДЫ ЗАЩИТЫ И МАКРОКОНСТРУКЦИИ В ЛАНДШАФТНОЙ АРХИТЕКТУРЕ

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У людей, живущих в аридных районах, с засушливым климатом и пыльными бурями, очень часто возникает необходимость укрыться от потоков ветра. Пыльные бури происходят на нашей планете постоянно, и использование их мощности и силы ветра в современном мире приводит к неистощаемому, то есть устойчивому развитию. Устойчивое, неистощаемое развитие — это модель потребления природных ресурсов, при которой достигается удовлетворение жизненных потребностей современного поколения совместно с сохранением окружающей среды, упрочнением личностного и общественного здоровья без потери такой возможности для будущих поколений. Изученный зарубежный опыт позволяет предложить новые методы борьбы с пыльными бурями, а так же новую форму защитных конструкций в городском пространстве с использованием современных средств ландшафтного дизайна.

Ключевые слова: экологическая катастрофа, пыльные бури, экология Кызылорды, методы защиты от пыльных бурь, конструкции для защиты от пыльных бурь, растения местной флоры, местная каменная порода, экологический дизайн, устойчивость среды через макроконструкции в ландшафте

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BASAL RESPIRATION AS A PROXY TO UNDERSTAND SPATIAL TRENDS IN CO_2 EMISSIONS IN THE MOSCOW REGION

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Soil respiration (Rs) is an important terrestrial CO_2 efflux and receives significant attention at different scale levels. However, the sampling density is limited and global Rs databases are biased towards natural ecosystems. Urbanization is among the most important current land-use trends and its role will likely grow in the future. Urban soils store considerable amount of carbon and are very heterogeneous and dynamic, which affects Rs. Our understanding of the Rs spatial variability is limited, especially for the regions with heterogeneous bioclimatic conditions and high urbanization level. The methodological constraints of direct Rs measurements in the field limit the number of observations. As an alternative approach to approximate the spatial variability of Rs, we used basal respiration (BR) as an indirect measurement. We implemented digital soil mapping technique to map BR as a proxy of Rs in a heterogeneous and urbanized Moscow Region. Topsoil and subsoils BR maps were developed for the region and spatial variability per land-use and soil type was analyzed. BR averaged for the urban areas was lower than in forests and meadows, however, urban areas became the hotspots of BR's spatial variability in the region. Considerable contribution of subsoil layers to the total BR was also found with the maximal 30% contribution in urban soils. Although the absolute levels of respiration remained uncertain, the spatial patterns of BR are likely to correspond well with Rs patterns, determined by soil type, land use and allocation of urban areas.

Key words: urban soils, soil functions, microbial respirations, urbanization, digital soil mapping

1. INTRODUCTION

Soil respiration (Rs) causes an annual efflux of 80 Pg carbon to the atmosphere and is the largest carbon efflux of terrestrial ecosystems [49; 9]. This efflux is almost ten times that released by fossil-fuel emissions [45]. The CO_2 emissions by Rs are therefore likely to have a large influence on global climate. At the same time Rs impacts local soil quality. Therefore, the temporal and spatial patterns in Rs need to be well understood to assess changes in soil functions and ecosystem services [10; 15].

Rs depends largely on a range of soil abiotic and biotic parameters [13; 20]. Soil temperature, moisture regimes, and soil organic carbon (SOC) concentrations are considered to be the principal driving factors behind the local spatial variability of Rs [62; 32]. Regional and global Rs variability is typically represented by average Rs rates for different land-uses and soil types [45; 22; 24; 2]. So far, the spatial heterogeneity of Rs remains inadequately understood [54; 29]. In order to get a better understanding of Rs variability for a region, spatial patterns need to be described.

Studies on Rs variability often focused on natural and agricultural ecosystems [e.g. 26; 22; 33; 30]. Urban areas received very limited attention. Due to a number of specific factors and conditions, like soil sealing and zoning [48; 43], a very different spatial variability can be expected. Smooth changes in natural and agricultural ecosystems are substituted by a highly variable patchwork of zones with strict boundaries [56]. Urban ecosystems therefore require a specific approach to analyze the spatial distribution of Rs.

The most common approach to determine Rs is based on direct field methods where the CO_2 efflux from the soil surface is measured *in situ* and indirect methods where Rs is predicted based on auxiliary information or where Rs is measured under standardized conditions. Direct methods include conventional alkali absorption techniques [12] and a variety of chamber approaches (open-path, closed-path, and dynamic close chambers) [37; 5; 47]. They are widely used to study the temporal (diurnal or seasonal) dynamics in Rs, normally as a response to changes in soil temperature and moisture conditions. To apply this approach for larger regions, the study area is stratified (e.g. based on soil or land-use type) with chambers installed at a limited number of representative sites [39; 31]. By relying on these representative sites, the spatial variation within each strata is not considered. Whether direct measurements give satisfactory results in large and heterogeneous areas with a large number of different natural, rural, and urban ecosystems is questionable Alternatively, the spatial variability of Rs can be analyzed indirectly through a relatively easily measured proxy variable, which allows for a larger number of observation points.

Basal respiration (BR) is such a proxy. BR is defined as the steady rate of soil respiration, which originates from the mineralization of organic matter [42]. Together with soil microbe biomass, BR is a commonly accepted indicator to quantify changes in the activity of the soil microbial community and soil quality [61; 6]. BR is determined by measuring CO_2 produced by soil microorganisms after pre-incubation under standardized temperature and moisture conditions [3; 15]. BR thus characterizes the potential soil CO_2 emissions by microorganisms under the optimal conditions rather than the actual carbon efflux. Since the experimental conditions are standardized, the initial effect of field temperature and moisture regimes is eliminated [8]. As a result it allows for the comparison of different samples (e.g. taken at different locations or moments in time). Monitoring over a long periods is less important and many more samples can be taken throughout a region of interest with all the different strata.

This study implements BR as a proxy to understand the spatial heterogeneity of soil respiration in large, diverse and highly urbanized Moscow Region. So far, spatial patterns in Rs in this region remain poorly understood if one compares them with the EU and USA, where Rs is continuously measured through FLUXNET [60; 4].

2. MATERIALS AND METHODS

2.1. Moscow Region

Moscow Region extents over 46,700 km^2. The territory of the Moscow Region has a plain relief ranging from 100 meters in the east to 300 meters above sea level in the north and west. The region has a temperate continental climate. Its mean annual temperatures range between 3.5 °C to 5.8 °C. Average annual rainfall varies from 780 mm in the north to 520 mm in the south. In winter, average daily temperatures normally drop to approximately –10.0 °C, though there can be warm periods with temperatures rising above 0.0 °C. The average number of days with temperature below zero varies between the north and the south and between years, and averages between 130 and 190 [50; 38]. Parent material includes moraine loam and clay in the north and center, fluvioglacial sands in the east and west, and cover loam in the south. Vegetation varies with climate and includes three main bioclimatic zones: south-taiga, deciduous forests and steppe-forest) [50]. Soils include Orthic Podzols in the north, Eutric Podzoluvisols in the center, Orthic Luvisols and Luvic Chernozems in the south, Dystric Histosols in the East, and Eutric Luvisols in the flood-plains of the Moskva and Oka rivers [16; 17; 51]. Anthropogenic landscapes (agricultural, fallow-, and urban lands) occupy nearly 60% of the territory. The urban area is rapidly increasing and currently occupies more than 10%, including 68 cities and towns with 18.8 million inhabitants (including Moscow city). Moscow is the largest European city with a population of over 11.2 million people.

2.2. Analyzing spatial variability in basal respiration in the region

Soil sampling

In order to consider both natural and urban-specific factors in the region and to provide necessary data for digital soil mapping (DSM), a stratified sampling design was implemented that represents the variability in bioclimatic conditions and consider short-distance variability within the settlements. Sampling points were chosen in Moscow city and six settlements in the region in such a way that traditional (zonal soil type and land-use type) and urban-specific factors (functional zoning, age and size of the settlement) were considered. Inside the towns, samples were taken from different functional zones including industrial, residential and recreational zones. We also sampled forest, cropland and meadow areas outside the towns for comparison. In total 211 locations were observed (Fig. 1).

Inside each stratum, sampling plots were selected randomly. For each plot, 5 topsoil (0—10 cm) samples were taken from a 2 m^2 square plot (corners and center) and pooled into a single composite sample. A single sample was taken from the subsoil (10—150 cm) at the center of the plot. Considering the variability of regional soil conditions including the Luvic Chernozems with thick humus accumulation layers, likely contributing to BR, we expanded the subsoil included into the analysis to 10—150 cm. Considering budget limitations and the necessity to expand the sampling area to capture different factors of BR spatial variability in the Moscow Region for DSM approach, subsoil layers from 10 to 150 cm deep were mixed into a single sample per point. This gives an idea of the subsoil contribution to total microbial respiration. As far as we know, this has never been done at the regional level. However, it does not provide insight on the profile distribution of BR.

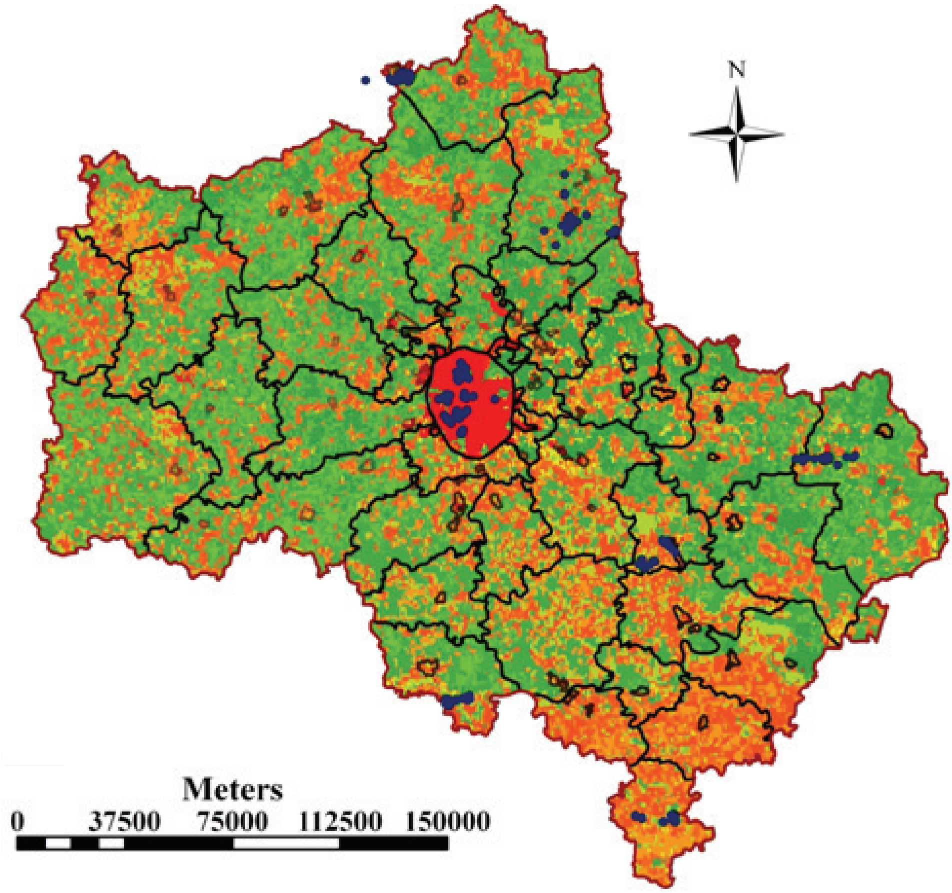


Figure 1. The level of urbanization in Moscow region ranging from natural (green) to urban (red) with the location of the observation points

Samples were sieved (2 mm) at the natural moisture content and all the fine plant root residues were removed. Due to geographical location and geomorphological features of the region with a plain relief and domination of loamy and clay parent material stone inclusions in soil are very rare, thus stoniness was not considered in the estimation of soil features including carbon stocks. At the same, we faced anthropogenic inclusions (bricks, concrete flags and service tubes) in the urban areas, which did not allow to sample up to the 150 cm depths at some points. To consider this we implemented correction coefficient on cut-off profiles when estimating BR in urban subsoil.

Mapping BR and analysis of variability

A DSM approach was implemented to map BR as a function of traditional (relief, climate, land-use, vegetation and soil type and complexity) and urban-specific (functional zoning, size and age of the city) factors. Since a strong correlation between SOC and BR is widely assumed and was reported for different ecosystems [3; 59; 2], the SOC content was also added as an explanatory variable, based on the 771 m resolution map of carbon contents and stocks derived for the region [58].

Land-use type, soil type, mean annual temperature, average annual precipitation, slope, normalized difference vegetation index (NDVI), and SOC content were used as explanatory variables in the natural and agricultural sites. In the urban areas urban-specific factors were added, including functional zoning (derived from NDVI), age and size of the settlements. Since only open (non-sealed) areas were included in sampling campaign, we considered BR estimation and mapping for impervious areas only. To achieve this we used correction coefficient, which was assigned as 0.90 for recreational zones and 0.50 for residential and industrial ones, based on the literature data and previous investigations for Moscow city and Moscow Region [57].

Normality of the distribution of BR values was checked by Shapiro-Wilk's W test and homogeneous of variances was checked by Levene's test. Since the regression kriging was not available due to the stratified sampling design, we implemented statistical general linear model (GLM), correlating BR to explanatory variables, to predict spatial patterns of topsoil and subsoil BR in the region. The GLM was obtained by a step-wise linear regression. The R^2 and R^2adj were used to keep or remove explanatory variables and to characterize the predictive power of the model. Based on the GLM two separate maps for topsoil and subsoil BR were developed with the resolution of 771 m for the region. Details on the implemented mapping and GLM approaches were published in Vasenev et al., 2014. Statistical analysis was performed in Statistica 6.0 [11]. Visualization and GIS analysis was carried out in ArcGIS [23].

The BR approach does not give insight into the temporal dynamics of Rs, although it provides an explicit picture of the spatial distribution of Rs. In order to characterize the spatial variation of Rs for different ecosystems and biomes and also to compare results from BR approach with ones from in situ method we aggregated BR maps into the different strata, representing different combinations of distinguished traditional and urban-specific factors. In addition, the CV for each strata was estimated to characterize spatial variability of Rs. Maps with the CV of topsoil and subsoil BR were created for the Moscow Region.

3. RESULTS

3.1. BR in the Moscow Region

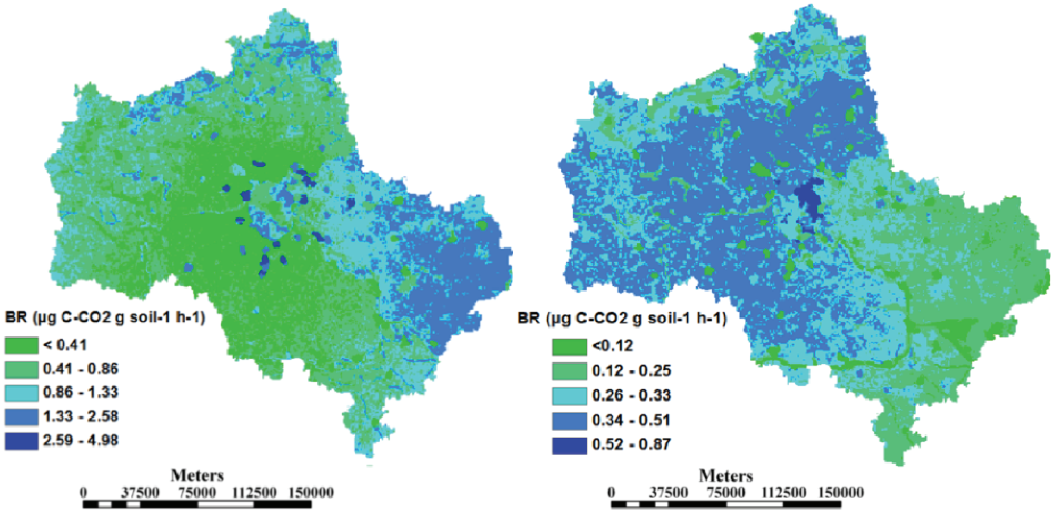
Modelled BR values for the entire Moscow Region showed a high spatial variability with averages of 0.75 ± 0.57 μg CO_2-C g^{-1} soil h^{-1} for the topsoil and 0.25 ± 0.17 μg CO_2-C g^{-1} soil h^{-1} for the subsoil. Spatial variability was similar for both layers. A significant positive correlation with SOC content was found for both layers ($p < 0.05$; $r = 0.43$ and $r = 0.37$ for topsoil and subsoil BR respectively). Land-use had an important impact on BR — the lowest values were obtained for urban areas, whereas BR for bogs and meadows was significantly higher than for all other land-use types. Different soil types presented different BR with the highest values for the Luvic Chernozems and lowest ones for Dystric Histosols and Eutric Luvisols. However, differences between soil types were not significant due to the large variability (Table 1).

Table 1

Basal respiration in Moscow region averaged over land-uses and soil types

Factor	N	Topsoil BR (μg CO_2-C g^{-1} soil h^{-1})			Subsoil BR (μg CO_2-C g^{-1} soil h^{-1})		
		mean	SD	CV (%)	mean	SD	CV (%)
Land-use							
Urban	46	0.64	0.45	69	0.27	0.20	74
Bogs	18	0.76	0.45	59	0.26	0.13	49
Arable	80	0.77	0.52	68	0.26	0.18	67
Forest	53	0.72	0.40	56	0.24	0.13	56
Meadow	13	1.11	1.41	128	0.20	0.21	107
Soil type							
eutric Podzoluvisols &	108	0.76	0.50	66	0.28	0.20	70
dystric Histosols eutric Luvisols	15	0.59	0.52	88	0.18	0.14	76
orthic Luvisols	43	0.73	0.41	55	0.24	0.13	55
luvic Chernozems	5	0.84	0.44	52	0.24	0.10	44
orthic Podzols	39	0.78	0.88	112	0.22	0.13	59

The spatial patterns differed between the topsoil and subsoil maps but patterns in BR corresponded to the patterns in soils and land-use for both. Topsoil BR was the highest in the east of the region with large areas occupied by bogs and Dystric Histosols. High topsoil BR was also found for the Orthic Podzols in the north and Luvic Chernozems in the south. Urban areas and especially the Moscow city showed high variation in topsoil BR with higher values in the green spaces and lower in the central built-up parts (Fig. 2 A). Subsoil BR followed the same trends. In general, subsoil BR was less variable than topsoil BR with the highest values found in the west with Eutric Podzoluvisols (Fig. 2 B).



A B

Figure 2. Basal respiration (μg CO_2-C g^{-1} soil h^{-1}) of topsoil (A) and subsoil (B) in the Moscow Region

3.2. Mapping BR spatial variability in the region

The maps allowed for a better understanding of the spatial variability of BR for the region in general as well as for separate land-uses, soil types and their combinations. The highest variability was shown in urban areas and bogs with average CVs exceeding 100%. We observed this pattern for both soil layers, although subsoil BR was more homogeneous with averaged CV up to 50—60%. The highest BR variability among the soil types was found in the topsoil of the Orthic Podzoluvisols and the subsoil of the Dystric Histosols and Eutric Luvisols which can be explained by the large and heterogeneous areas where these soil types are found (more than 70% of the total area of the region). The coefficient of determination for the models was 0.51 and 0.38 for the topsoil and the subsoil correspondingly.

Analysis of BR averaged per land-use and soil type provides information on the factors influencing its variability but it does not give a clear picture of the spatial distribution. More valuable is to analyze spatial variability per different strata, representing interaction of various environmental and management conditions. In order to obtain this information we aggregated the BR maps based on the combinations of traditional and urban-specific factors distinguished for the modelling and estimated CV values per each stratum. The highest variability of topsoil and subsoil BR was reported for the urban areas, which was clearly represented by hotspots on the maps, coinciding with the borders of settlements. The CV obtained for topsoil BR in the urban areas varied from 40—50% for recent settlements (< 50 years) of small and middle size (< 100 000 citizens) to 70—100% in small ancient towns (> 500 years) and Moscow megapolis. The same pattern was found for the subsoil BR although the CVs were almost half. CV values in industrial and residential areas were 20—30% higher than in recreational zones for both topsoil and subsoil BR (Fig. 3).

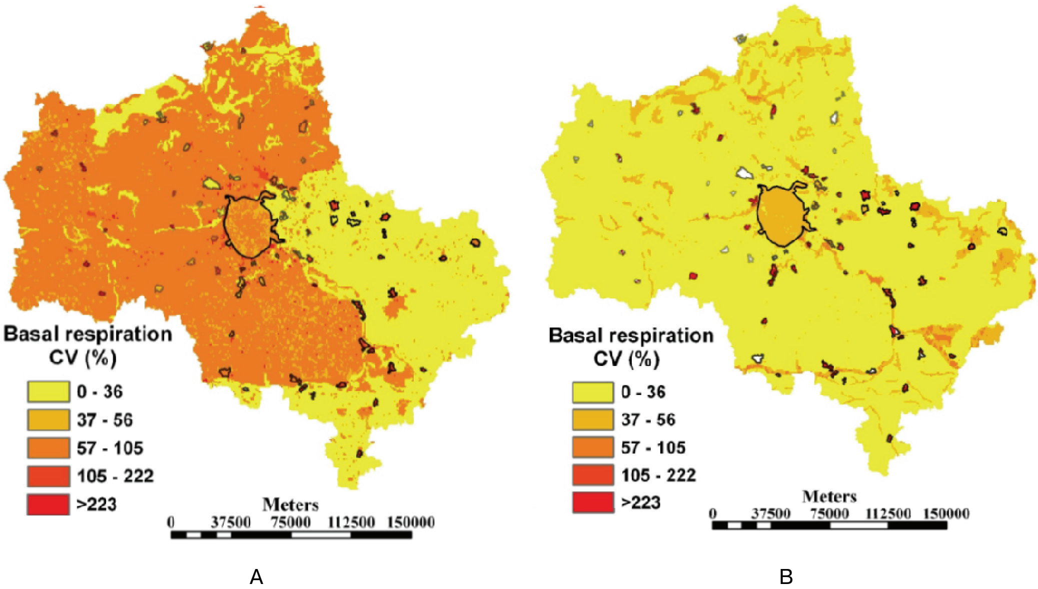


Figure 3. Coefficient of variance (CV%) of topsoil (A) and subsoil (B) basal respiration in Moscow region

4. DISCUSSIONS

4.1. Spatial variability of soil respiration in Moscow Region based on BR maps

BR observation for the Moscow Region in combination with DSM techniques resulted in 771 m resolution maps of topsoil and subsoil BR. As far as we know, this was the first attempt to analyze and map regional BR with this level of accuracy. The area of central Russia remains under-observed in many global assessment and databases of carbon stocks and fluxes [4; 9], thus the opportunity to evaluate our results based on ones from literature was very limited. Analysis, available at the country scale [40; 30] provides averaged values per soil type and land-use type, but lack the information of Rs's spatial variability within these clusters. Besides, this outcome is based on the direct extrapolation of point Rs data for the polygons of the 1 : 2.5 million soil map of Russia [18], thus uncertainty is very likely.

Patterns of BR between and within different soils types and land-uses were analyzed and showed a good correspondence with literature. All their studies report a significant negative correlation between soil microbiological activity and anthropogenic pressure levels. This was also confirmed by the results obtained at the test area. High topsoil BR values reported for Luvic Chernozems, Dystric Histosols and Orthic Podzols is in good coherence with SOC patterns described for the bioclimatic and soil zones in the region [50; 59] confirming the concept of BR as an indicator for respiration of soil organic matter — based microbes [15].

Different spatial variability described by CV for observed land-use types with the highest heterogeneity of BR in urban area also confirm existing opinion on high patchiness of urban environment [28; 56]. High variability of BR in urban areas is likely explained by the heterogeneous urban conditions that influence the limiting factors for soil microbiological communities: water and temperature regimes and nutrient contents. Several studies that report high spatial variability of C and N stocks in urban areas [27; 44; 35] indirectly confirm this outcome. We also found significant difference between topsoil and subsoil BR. In average for the region, BR in the topsoil was over four times larger with a more than double CV than subsoil BR. This corresponds to studies that indicate the major soil microbial community in the topsoil [74; 53]. However, 30% of the total BR in urban areas comes from the subsoil, which was higher than in croplands and meadows and comparative to forest. Considerable contribution of subsoil BR in urban areas refers to specific profile distribution of SOC in the settlement with high concentration not only in the surface, but also at a certain depth in the so-called "cultural layer" [1; 34; 57]. In general urban areas made the most significant contribution to the regional spatial variability of BR (vividly illustrated by red spots on the maps of the CV), which was the result of various urban-specific factors.

4.2. Uncertainties in BR maps of Moscow Region

Predictive power of the GLMs implemented for BR mapping estimated by $R^2_{adj} = 0.51$ and 0.38 for topsoil and subsoil correspondingly indicates that 50 to 60% of total variability remained unexplained ant thus the results are rather uncertain. Uncertainty of the obtained results is coming from the experimental design and assumption taken in the GLM and BR estimations. Additional source of uncertainty came from the simplifications and assumptions taken in the modelling process. For instance we technically could not separate residential and industrial functional areas and thus used it as single unit, although literature and previous research showed a significantly lower BR in industrial areas compared to all the other forms of land-use [19; 55]. We also introduced reduction coefficient to consider impervious soils, however there are evidences in literature that soil sealing results not only in decrease of Rs at the sealed areas, but also in increase of CO_2 emissions from adjacent open territories [52; 48]. Comparison between topsoil and subsoil BR also was not straightforward since differences in sampling approaches and aggregating 10—150 cm subsoil in a single soil sample, which, considering known strong correlation between microbiological activity and soil depth, may provide very rough results. However, it gave us an opportunity to guess on the contribution of the subsoil to total respiration and its variability, that is often left out of regional analysis.

4.3. ADVANTAGES AND CONSTRAINTS OF BR AS A PROXY TO UNDERSTAND THE SPATIAL VARIABILITY OF SOIL RESPIRATION

Implementation of BR and DSM techniques provided an opportunity to analyze and map the spatial variability of regional soil respiration based on a limited number of observations (n = 211). This would not have been possible with the traditional *in situ* chamber approach. In addition, BR can provide information on the respiration in different soil layers, whereas direct field measurements normally refer to the surface layer. However, the BR as a proxy of soil respiration obviously has some constrains. The main one is coming from different mechanisms and processes underlying Rs and BR. Total Rs includes autotrophic respiration of root systems and root-associated organisms and heterotrophic respiration of free-leaving microorganisms in the soil [14; 20], whereas BR refers only for the heterotrophic component. Moreover, disturbing and pre-incubation procedures influence the CO_2 production by microorganisms [15] and makes comparison between absolute values of BR and *in situ* Rs rather challenging.

So, BR is rather questionable as a tool to measure actual Rs, however it is a good proxy to understand the spatial variability. Recently, for many applications, including regional carbon sequestration assessment and climate mitigation analysis and modelling, understanding the Rs's spatial variability becomes essential. BR is probably the best option for spatial analysis, since direct measurements are not applicable and remote sensing approach predict Rs mainly based on the vegetation indexes [25] and thus much less related to the soil processes. The relevance of BR as a proxy is confirmed by significant predictive power of the developed models (R^2 = 0.51 and 0.38 for the topsoil and subsoil respectively). This result is comparative or better than some regional models of soil carbon stocks modelling [36].

5. CONCLUSIONS

Soil respiration (Rs) is an important terrestrial CO_2 efflux. Although the most comprehensive global Rs database [9] contains many respiration records, this dataset is still biased towards natural ecosystems and towards the USA and EU. This doesn't improve understanding of Rs's spatial variability. The methodological constrains of Rs measurements in the field likely limit the number of observations, especially in regions where scientific equipment and technology is poorly available.

We implemented indirect measurements of basal respiration (BR) to capture spatial variability of soil respiration for the Moscow Region. This relatively simple approach expanded the regional sampling scheme and formed the basis for mapping of BR for the Moscow Region. We digitally mapped soil BR as regional Rs proxy. Although our absolute BR remain uncertain, the BR spatial variability, however, corresponded well with one measured directly. Land use was a major factor determining the spatial heterogeneity of the regional soil respiration. Most of variation was coming from urban areas.

Soil respiration is currently getting increased attention as an important source of CO_2 emission, indicator of soil health and quality. Due to very high variability in space, following bioclimatic conditions and land-use change, understanding spatial trends of Rs gets even more important than more traditional estimation of averaged emission. Direct measurements of in situ Rs at the limited areas with further extrapolation regionally and globally don't correspond to the demand in spatially explicit information, highlighting necessity in alternative proxies. Our implementation of BR approximates this spatial variability and will considerably improve understanding of soil respiration patterns, especially for regions where direct measurements are unavailable. Although our result represent a preliminary study they contribute to implement our understanding of CO_2 emissions from urban soils and [21; 41] and provide evidence that the contribution of urban soils to regional carbon balance will be progressively more important in the future when urbanization and pollution will be among the most important factors affecting soil quality and health.

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REFERENCES

[1] Alexandrovskaya, E.I. and A.L. Alexandrovskiy. 2000. History of the cultural layer in Moscow and accumulation of anthropogenic substances in it. Catena 41: 249—259.

[2] Ananyeva N.D., E.A. Susyan, O.V. Chernova, and S. Wirth. 2008. Microbial respiration activities of soils from different climatic regions of European Russia. European Journal of Soil Biology 44: 147—157.

[3] Anderson TH, Domsch KH (1986) Carbon links between microbial biomass and soil organic matter / In: F. Megusar, M. Gantar (Eds.) Perspectives in Microbial Ecology. Slovene Society for Microbiology, Ljubljana, 467—471.
[4] Baldocchi, D., E. Falge, L. Gu, R. Olson, D. Hollinger, S. Running, P. Anthoni, C., Bernhofer, K. Davis, R. Evans, J. Fuentes, A. Goldstein, G. Katul, B. Law, X. Lee, Y. Malhi, T. Meyers, W. Munger, W. Oechel, U.K.T Paw, K. Pilegaard, H.P Schmid, R. Valentini, S. Verma, T. Vesala, K. Wilson and S. Wofsy. 2001. FLUXNET: A New Tool to Study the Temporal and Spatial Variability of Ecosystem — Scale Carbon Dioxide, Water Vapor, and Energy Flux Densities. Bulletin of American Meteorological Society 82: 2415—2434.
[5] Bekku, Y., H. Koizumi, T. Oikawa and H. Iwaki. 1997. Examination of four methods for measuring soil respiration. Applied Soil Ecology 5: 247—254.
[6] Bispo, A., D. Cluzeau, R. Creamer, M. Dombos, U. Graefe, P.H Krogh, J.P. Sousa, G. Peres, M. Rutgers, A. Winding and J. Römbke. 2009. Indicators for monitoring soil biodiversity. Integrated Environmental Assessment and Management 5: 717—719.
[7] Bloem, J. and Breure, A.M. (2003). Microbial indicators. In Markert, B.A., Breure, A.M., Zechmeister, H.G. (Eds.). *Bioindicators and biomonitors* (pp. 259—282). Oxford: Elsevier.
[8] Bloem, J., A.J. Schouten., S.J. Sørensen, M. Rutgers, A. Van der Werf and A.M. Breure. 2006. Monitoring and evaluating soil quality. In J. Bloem, A. Benedetti and D.W. Hopkins, editors. Microbiological Methods for Assessing Soil Quality. CAB International. Wallingford. Oxfordshire. UK.
[9] Bond-Lamberty, A. and A. Thomson 2010a. A global database of soil respiration data. Biogeosciences 7: 1915—1926.
[10] Bond-Lamberty, A. and A. Thomson 2010b. Temperature-associated increases in the global soil respiration record. Nature 464: 579—582.
[11] Borovikov, V. 2003. Art of computer data analysis. Piter. Saint-Petersburg.
[12] Buyanovsky, G. A., G. H. Wagner and C. J. Gantzer. 1986. Soil respiration in a winter wheat ecosystem. Soil Science Society of America Journal 50: 338—344.
[13] Carlyle, J.C. and U.B. Than. 1988. Abiotic controls of soil respiration beneath an eighteen-year old Pinusradiata stand in south-eastern Australia. Journal of Ecology 76: 654—662.
[14] Chapin, III F.S., G.M. Woodwell, J.T. Randerson, E.B. Rastetter, G.M. Lovett, D.D. Baldocchi, D.A. Clark, M.E. Harmon, D.S. Schimel, R. Valentini, C. Wirth, J.D. Aber, J.J. Cole, M.L. Goulden, J.W. Harden, M. Heimann, R.W. Howarth, P.A. Matson, A.D. McGuire, J.M. Melillo, H.A. Mooney, J.C. Neff, R.A. Houghton, M.L. Pace, M.G. Ryan, S.W. Running, O.E. Sala, W.H. Schlesinger and E.D. Schulze, 2006. Reconciling Carbon-cycle Concepts, Terminology, and Methods. Ecosystems 9: 1041—1050.
[15] Creamer, R.E., R.P.O. Schulte, D. Stone, A. Gal, P.H. Krogh, G.L. Papa, P.J. Murray, G. Peres, B. Foerster, M. Rutgers, J.P. Sousa and A. Winding. 2014. Measuring basal soil respiration across Europe: Do incubation temperature and incubation period matter? Ecological Indicators 36: 409—418.
[16] Egorov, V.V., V.M. Fridland, E.N. Ivanova, N.I. Rosov (Eds.). 1977. Classification and diagnostics of soils in USSR. Kolos. Moscow.
[17] FAO. 1988. Soils map of the world: revised legend. Food and Agriculture Organization of the United Nations, Rome.
[18] Fridland, V.M. (ed.). 1988. Soil Map of the Russian Soviet Federative Socialist Republic at scale 2.5 M. All Union Academy of Agricultural Science, Government Administration on Geodesy and Cartography (GUGK). USSR. 16 sheets.
[19] Gavrilenko, E.G., E.A. Susyan, N.D. Anan’eva and O.A. Makarov. 2011. Spatial Variability in the Carbon of Microbial Biomass and Microbial Respiration in Soils of the South of Moscow Oblast. Eurasian Soil Science 44: 1125—1138.

[20] Gomes-Casanovas, N., R. Matamala, D.R. Cook and M.A. Gonzalez-Meler. 2012. Net ecosystem exchange modifies the relationship between the autotrophic and heterotrophic components of soil respiration with abiotic factors in prairie grasslands. Global Change Biology 18: 2532—2545.
[21] Grimmond, C.S.B., T.S. King, F.D. Cropley, D.J. Nowak and C. Souch. 2002. Local-scale fluxes of carbon dioxide in urban environments: methodological challenges and results from Chicago. Environmental Pollution 116: 243—54.
[22] Hamilton, J.G., E.H. DeLucia, K. George, S.L. Naidu, A.C. Finzi and W.H. Schlesinger. 2002. Forest carbon balance under elevated CO_2. Oecologia 131: 250—260.
[23] Harder, C., T. Ormsby and T. Balstrom. 2011. Understanding GIS: An ArcGIS project workbook. ESRI press.
[24] Houghton, R.A. 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850—2000. Tellus 55B. 378—390.
[25] Huang N., J.S. He and Z. Niu. 2013. Estimating the spatial pattern of soil respiration in Tibetan alpine grasslands using Landsat TM images and MODIS data. Ecological Indicators 26: 117—125.
[26] Islam, K.R. and R R. Weil. 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agriculture, Ecosystems and Environment. 79: 9—16.
[27] Jo, H.K. and E.G. McPherson. 1995. Carbon Storage and Flux in Urban Residential Greenspace. Journal of Environmental Management 45: 109—133.
[28] Kaye, J.P., R.L. McCulley and I.C. Burkez. 2005. Carbon fluxes, nitrogen cycling, and soil microbial communities in adjacent urban, native and agricultural ecosystems. Global Change Biology 11: 575—587.
[29] Kudeyarov, V.N., G.A. Zavarzin, S.A. Blagodatsky, A.V. Borisov, P.U. Voronin, V.A. Demkin, T.S. Demkina, I.V. Evdokimov, D.G. Zamolodchikov, D.V. Karelin, A.S. Komarov, I.N. Kurganova, A.A. Larionova, O.V. Lopes de Gerenu, A.I. Utkin, O.G. Chertov. 2007. Carbon pools and fluxes in terrestrial ecosystems of Russia. Nauka. Moscow.
[30] Kurganova, I.N. 2010. Emission and balance of carbon dioxide in terrestrial ecosystems of Russia. Doctoral thesis. Moscow State University. Moscow.
[31] Kurganova, I.N., V.O. Lopes de Gerenyu, T.N. Myakshina, D.V. Sapronov and V.N. Kudeyarov. 2011. CO_2 Emission from soils of various ecosystems of the southern taiga zone: data analysis of continuous 12 year monitoring. Doklady Biological Sciences 436: 56—58.
[32] Kuzyakov, Y. and O. Gavrichkova. 2010. Review: Time lag between photosynthesis and carbon dioxide efflux from soil: A review of mechanisms and controls. Glob Change Biology 16: 3386—3406.
[33] Larionova, A.A., I.N. Kurganova, V.O.L. de Gerenyou, B.N. Zolotareva, I.V. Yevdokimov and V.N. Kudeyarov. 2010. Carbon dioxide emissions from agrogray soils under climate changes. Eurasian Soil Science 43: 168—176.
[34] Lorenz, K. and E. Kandeler. 2005. Biochemical characterization of urban soil profiles from Stuttgart, Germany. Soil Biology Biochemistry 37: 1373—1385.
[35] Lorenz, K. and R. Lal. 2009. Biogeochemical C and N cycles in urban soils. Environment International: 35, 1—8.
[36] Minasny B., A.B. McBratney, B.P. Malone and I. Wheeler. 2013. Digital mapping of soil carbon. Advances in Agronomy. 118. 1—47.
[37] Nakadai, T., H. Koizumi, Y. Usami, M. Satoh and T. Oikawa. 1993. Examination of the methods for measuring soil respiration in cultivated land: Effect of carbon dioxide concentration on soil respiration. Ecological Research 8: 65—71.
[38] Naumov V.D. (Ed.). 2009. 145 years to forest experimental station of RSAU-MTAA. RSAU-MTAA. Moscow.
[39] Nilsson, S., A. Shvidenko, V. Stolbovoi, M. Gluck, M. Jonas, M. Obersteiner. 2000. Full carbon account for Russia. Laxenburg.

[40] Nortcliff, S. 2002. Standardization of soil quality attributes. Agriculture, Ecosystems and Environment 88: 161—168.
[41] Pataki, D.E., R.J. Alig and A.S. Fung. 2006. Urban ecosystems and the North American carbon cycle. Global Change Biology 12: 2092—2102.
[42] Pell, M., J. Stenström and U. Granhall. 2006. Soil Respiration. In: Bloem J, Hopkins DW, Benedetti A (Eds.), Microbial Methods for Assessing Soil Quality. CAB International, Wallingford, Oxfordshire, U.K.
[43] Pickett, S.T.A., M.L. Cadenasso, J.M. Grove, C.G. Boone, P.M. Groffman, E. Irwin, S.S. Kaushal, V. Marshall, B.P. McGrath, C.H. Nilon, R.V. Pouyat, K. Szlavecz, A. Troy and P. Warren. 2011. Urban ecological systems: scientific foundations and a decade of progress. Journal of Environmental Management 92: 331—362.
[44] Pouyat, R.V., I.D. Yesilonis and D.J. Nowak, 2006. Carbon storage by urban soils in the United States. Journal of Environmental Quality 35: 1566—1575.
[45] Raich, J.W. and A. Tufekcioglu. 2000. Vegetation and soil respiration: correlations and controls. Biogeochemistry 48: 71—90.
[46] Russian Federation State Statistic Service (RFSSS). 2012. Population of Russian Federation. Moscow.
[47] Savage, K.E. and E.A. Davidson. 2003. A comparison of manual and automated systems for soil CO_2 flux measurements: trade-offs between spatial and temporal resolution. Journal of Experimental Botany 54: 891—899.
[48] Scalenghe, R. and F.A. Marsan. 2009. The anthropogenic sealing of soil in urban areas, Landscape and urban planning 90: 1—10.
[49] Schulze, E.D. 2006. Biological control of the terrestrial carbon sink. Biogeosciences 2: 147—166.
[50] Shishov L.L. and N.V. Voinovich (Eds.). 2002. Soils of Moscow Region and Their Use. Dokuchaev Soil Science Institute. Moscow.
[51] Shishov, L.L., V.D. Tonkonogov, I.I. Lebedeva and M.I. Gerasimova. 2004. Classification and Diagnostics of Russian Soils. Dokuchaev Soil Science Institute, Moscow (in Russian).
[52] Smagin, A.V. 2005. Soil gas phase. Moscow University. Moscow (in Russian).
[53] Susyan, E.A., D.S. Rybyanets and N.D. Ananyeva. 2006. Microbial Activity in the Profiles of Gray Forest Soil and Chernozems. Eurasian Soil Science 39: 859—867.
[54] Trumbore, S. 2006. Carbon respired by terrestrial ecosystems — recent progress and challenges. Global Change Biology, 12: 141—153.
[55] Vasenev, V.I., N.D. Ananyeva and O.A. Makarov. 2012. Specific features of the ecological functioning of urban soils in Moscow and Moscow oblast. Eurasian Soil Science 45: 194—205.
[56] Vasenev, V.I., N.D Ananyeva and K.V. Ivachenko. 2013a. Influence of contaminants (oil products and heavy metals) on microbiological activity of urban constructed soils. Russian Journal of Ecology 6: 475—483.
[57] Vasenev, V.I., J.J. Stoorvogel and I.I. Vasenev. 2013b. Urban soil organic carbon and its spatial heterogeneity in comparison with natural and agricultural areas in the Moscow region. Catena. 107: 96—102.
[58] Vasenev, V.I., J.J. Stoorvogel, I.I. Vasenev and R. Valentini. 2014. How to map soil organic stocks in highly urbanized region? Geoderma 226—227: 103—115.
[59] Wardle, D.A. 1992. A comparative assessment of factors which influence microbial biomass carbon and nitrogen level in soil. Biological Review 67: 312—358.
[60] Wilson, K.B. and D.D. Baldocchi. 2000. Seasonal and interannual variability of energy fluxes over a broadleaved temperate deciduous forest in North America. Agricultural and Forest Meteorology 100: 1—18
[61] Winding, A., K. Hund-Rink and M. Rutgers. 2005. The use of microorganisms in eco-logical soil classification and assessment concepts. Ecotoxicology and Environmental Safety 62: 230—248.
[62] Yuste, J.C., D.D. Baldocchi, A. Gershenson, A. Goldstein, L. Misson and S. Wong. 2007. Microbial soil respiration and its dependency on carbon inputs, soil temperature and moisture. Global Change Biology 13: 2018—2035.

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ИСПОЛЬЗОВАНИЕ БАЗАЛЬНОГО ДЫХАНИЯ ДЛЯ АПРОКСИМАЦИИ ПРОСТРАНСТВЕННОГО РАЗНООБРАЗИЯ ЭМИССИИ CO_2 ПОЧВАМИ МОСКОВСКОЙ ОБЛАСТИ

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Почвенное дыхание (ПД) — важный источник эмиссии CO_2 наземными экосистемами. Несмотря на большое внимание, уделяемое анализу ПД на различных пространственных уровнях, в глобальных исследованиях преобладает информация о природных экосистемах и практически не упоминаются городские экосистемы. Урбанизация — одна из основных тенденций изменения современного землепользования, важность которой, вероятно, возрастет в будущем. Городские почвы содержат значительные запасы углерода и являются очень неоднородными и динамичными системами. Информация о пространственной изменчивости дыхания городских почв очень ограничена, особенно для регионов с различными биоклиматическими условиями и высоким уровнем урбанизации. Методология прямых измерений ПД в полевых условиях ограничивает число наблюдений. В качестве альтернативного подхода к аппроксимации пространственной изменчивости ПД рассмотрено базальное дыхание (БД). Использованы методы цифровой почвенной картографии (ЦПК), для картирования БД как «прокси» ПД на примере неоднородной и высокоурбанизированной Московской области. Были построены цифровые карты БД для разных видов землепользования и типов почв для верхних и подстилающих почвенных горизонтов. Средние показатели БД для городских территорий были ниже, чем в лесах и на лугах, однако было показано, что именно территории поселений оказали основной вклад в пространственное разнообразие БД в регионе. Для городов был также показан значительный вклад нижних горизонтов в общее БД, достигающий 30%, что значительно выше по сравнению с фоновым почвами. Несмотря на высокую неопределенность абсолютных значений ПД в регионе невелика, выявленные закономерность распределения БД по видам землепользования и типам почв не вызывают сомнений.

Ключевые слова: городские почвы, функции почв, микробное дыхание, урбанизация, почвенное картографирование

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