Soil Functional-Environmental Evaluation and Monitoring in Urban Ecosystems: Principal Functions, Background Objects and Uniform Algorithms of Assessment

Ivan I. Vasenev[1,2(✉)]

[1] Russian Timiryazev State Agrarian University (RTSAU), Moscow, Russia
ivvasenev@gmail.com
[2] Far Eastern Federal University (FEFU), Vladivostok, Russia

Abstract. The paper presents the regional automated system of soil functional-environmental assessment (RASSCA) reflecting soil provincial genesis and functional features. It allows evaluating soil integral functional and environmental quality even in heterogeneous land plots. The RASSCA identifies and quantifies the limiting factors and principal parameters of soils' functional quality and environmental status as well as priority issues of their land-use. The RASSCA conducts environmental computer simulation, search and target prediction of soil quality changes and environmental problems' solution that improve the effectiveness of land-use decision-making – by prior functional-environmental analysis and comparison of the various scenarios of their outcomes and consequences. The RASSCA was used for the functional-environmental analysis of urban soils in the Chernozemic region of Russia (Kursk city), where natural soils are dominated by Chernic Phaeozems and Luvic-Chernozems. We focused on the polluted urban soils to identify the key environmental problems of soil technogenic degradation. The RASSCA allowed evaluating soil limiting parameters and environmental factors to identify the priority issues and to model the target changes in the integrated functional-environmental quality of soils by improving their limiting parameters. Conducted monitoring of Kursk soil technogenic successions highlighted the importance of soil metamorphic and migration processes. The over-compaction in urban soils was up to 0.3 g cm^{-3} $year^{-1}$; an average rate of humification/dehumification – 3.0 g kg^{-1} $year^{-1}$; acidification/alkalization −0.1 pH $year^{-1}$ and heavy metals migration – up to 50–60 g cm m^{-2} $year^{-1}$. Some of these data considerably extend the known ranges of elementary soil processes rates "in situ" and allow for better estimation of the real potentials of soil functioning in different landscape-environmental conditions of forest-steppe zone.

Keywords: Ecology · Soil evaluation · Soil function · Monitoring · Soil assessment algorithm · Soil contamination · Urban ecosystems · Urban soils

1 Introduction

The possibilities of sustainable development in urban areas are crucially limited, often due to the acute and complex environmental conditions. This problem is evident in a variety of modern soil research such as investigations of production-improvement

V.I. Vasenev et al. (eds.), *Megacities 2050: Environmental Consequences of Urbanization*,
Springer Geography, https://doi.org/10.1007/978-3-319-70557-6_17

processes in agriculture and forestry, and developing general solutions to particular environmental problems in urban areas [1–3]. Modern renovation of land ownership [4] and urban conditions [5] in Russian Federation add to the complexity and relevance of both environmental and assessment and monitoring problems. The gap that exists between the research and the applied and practical use of the results is still one of most fundamental problems of the modern environmental soil science fields in Russia for executing effective land monitoring and management.

The urban setting induces a set of specific soil-driving and limiting ecological factors: extreme short-distance spatial variability and dynamics, the age of settlement and complicated land-use history, zoning, human-altered soil profiles, temperature and moisture regimes. Urban soil's health and cover patterns have significant and variable impacts on air and water quality, biodiversity and bio-productivity in urban ecosystem as well as the landscape sustainability and the overall quality of life.

Intense anthropogenic degradation of modern soils increased spatial variability and complexity of soil cover patterns. It's important to develop an adequate tool and regulatory databases for effective evaluation of the environmental roles of soils currently fulfilling economic and environmentally-important functions [6, 7].

The diversity and variation of the size, type and compositions of urban zones results in extreme spatial variability of various soil-environmental functions (SEFs). This is important to recognize and evaluate for urban planning and when developing environmentally-friendly land-use designs. Soil profile variability and distribution generates complex spatial heterogeneity of SEFs [8–10].

The issues of urban soil monitoring refers to the degree of deviation of principal soil diagnostic parameters (PSDP) from their reference or optimum values. In the case of soil functional assessment, the degree of its suitability for environmental and socio-economical performance is considered by mapping a specialized set of SPDP with established criteria and regionally adapted applied evaluation scales [11–13].

A distinctive feature of soil evaluation involves the assessment of the soil's functional quality and ecological status. Current research on the environmental functional assessment of technogenic altered and often contaminated urban soils is under active methodological and normative-methodical developments. The optimal use of such assessments is the practical application by experts of different authorities to determine land use patterns gets possible by developing decision support systems (DSS) with capabilities of automated land evaluation, searches and normative predictions [7–14].

Specialized frameworks for functionally and regionally adapted automated land evaluation systems (ALES) [6, 7, 12] are growing in importance for identifying critical environmental problems and for determining rational versions of urban land-use. This model incorporates the potential for rapid changes in the soil functions by using functional and multiplicative evaluation algorithms-making it a multi-factor regulatory framework.

2 Methodology

The environmental-functions monitoring of urban soil is understood to be organized in time and space as a function of periodic investigation of representative soils' content, structure, regimes and fluxes in their interaction with other components of ecosystems (biota, surface and groundwater, snow, air and so on). Ultimately, this monitoring generates recommendations for the appropriate use of soils in terms of environmental function, while conserving the basic environmental functions and ecosystem services, and minimizing environmental impact risks of urban land-use, and maintaining [4, 11].

The evaluation of the environmental function of soil is a key component of this monitoring. It is an effective tool for identifying and evaluating the critical environmental problems and soil functions, the limiting ecological factors and soil principal diagnostic parameters, and the level of soil improvement in specific urban ecosystems. The quality of such assessment is determined by the reasonable set of soil principal diagnostic parameters – sufficient but not excessive for quantitative analysis, search and normative prediction of concrete types of problematic environmental situations. For each SPDP standard data base is developed with normalized variations of its value from optimal ones varied per different soil subtypes and land-use issues [12, 13].

The issue of local soil standards (soil background object) is especially difficult for the case of urban ecosystems with different anthropogenic impacts and different background soils landscapes. Verification of local soil standards should consider the detailed morphogenetic investigation of soil cover patterns in the reference natural or less disturbed areas with comparative mesorelief, parent material and land-use history. Neglecting these conditions constrains the assessment of urban soils' formation, processes, functions and degradation. Soil environmental zoning (e.g. industrial, residential or recreational) is also relevant for justification of regional and local soil standard. However, especial attention shall be paid on the variability of soil profiles within landscape, subsoils, parent materials texture and other principal features.

Last achievements of soil reference bases development and modern information technologies created good framework conditions for developing regional expert information systems for assessment and modeling ecological state of soils (SAMESs). They are widely used in RF European regions with increased spatial variability and fast development of traditional and new urban areas.

The regional automated system for soil complex assessment (RASSCA) was developed in the RTSAU Lab of agroecological monitoring, ecosystem modeling and prediction (LAMP). The RASSCA system is based on the 4-level algorithms of evaluation (1–4) based on the suggested earlier method of soil quality ecological evaluation [13]. The following principles are considered:

- A particular evaluation of each simple variable quality for uniform soil cover;
- A generalized evaluation of soil quality per its main ecological or environmental functions (using functionally diagnostic groups of soil-environmental parameters);
- An integral quality evaluation of the homogeneous soil cover;
- An integral quality evaluation of the heterogeneous soil cover.

Particular evaluations have been determined from the logistic or model equations, which are valid in the range from critical to optimum values of parameter (1):

$$q_i = \left(p_{t,i} - p_{k,i}\right) / \left(\left(p_{t,i} - p_{k,i}\right) + \left(p_{o,i} - p_{t,i}\right) exp\left(-p_i/a_i\right)\right) \quad (1)$$

where $p_i = (p_{t,i} - p_{k,i})/(p_{o,i} - p_{t,i})$, a_i*- index of influence of a parameter i,* $p_{t,i}$, $p_{k,i}$, $p_{o,i}$*- actual (measured), critical and optimum values of a parameter i.*

The RASSCA system was adapted to the natural and man-changed soil types and subtypes that dominate in the investigated urban ecosystems. The main aim (and distinctive feature) of soil environmental assessment is to place its current phase state on the curve (or at the surface) of the soil environmental function and concrete SPDP (Fig. 1). Soil environmental quality is usually determined by soil morphogenetic, physical-chemical, biological parameters and contamination characteristics. The reference of every parameter for logistic equation includes its optimum and critical values, influence index and degradation crisis rate, calculated by RASSCA. The influence index is described as soil quality variety range, which system retains rather stunted changes of its states in. The degradation crisis rate is the maximum of logistic equation simplified derivative for parameters of regional-genetic soil subtype.

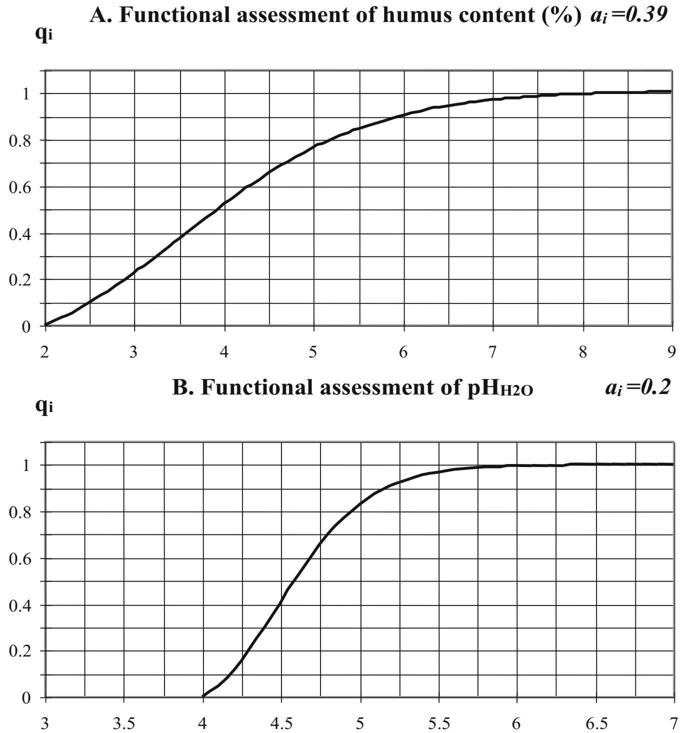

Fig. 1. Graphical presentation of soil humus and pH environmental evaluation for Luvic Chernozems and urban soils in the Central Chernozemic Region of Russia.

Generalized evaluation of quality can be calculated per 3–8 functionally diagnostic groups of parameters. The principal list of them usually includes the following ones: (*a*) soil chemical factor of bio productivity; (b) soil physical factor of plant uptake, soil support for infrastructure; (c) soil spatial heterogeneity factor; (d) soil profile factor of fertility stability and reclaiming potential; (e) soil microclimatic factor; (f) soil phyto sanitary factor; (g) soil contamination factor; (h) soil factor of ecological buffer capacity. Especial attention is taken on soil green house gases (GHG), water and energy fluxes, which are estimated by localized pedotransfer functions or measured in situ [14, 15]. Multiplication functions and harmonic/algebraic mean calculation are useful for generalized (2) and integrated (3) evaluation with universal applied interpretation (Table 1).

Table 1. Interpretation table for soil functional environmental evaluation

Factor	Soil ecological and environmental functions assessments according to their values					
	1-0.96	0.95-0.76	0.75-0.51	0.50-0.26	0.25-0.01	0.0
A.	LAND with high	LAND with increased	LAND with average	LAND with low	LAND with very low	LAND unproductive
	Bio productivity					
B.	very good	good	rather good	bad	very bad	extremely bad
	Support for infrastructure					
C.	homogeneous	weak	semi-	high	unsuitable for use in	
		heterogeneous			grass loans	parks
D.	not requiring	requiring insignificant	requiring significant	requiring	requiring general reclamation	
	Potential for reclamation improving					
E.	very		rather		very	extremely
	favorable			unfavorable		
	Soil microclimatic conditions					
F.	very good	good	rather good	bad	very bad	extremely bad
	Phytosanitary state					
G.		relative	un-	relative	not enough	un-
	satisfactory sanitary-ecological state			suitable for agriculture		
H.	high	increased	average	low	very low	deprived
	resistance to pollution					
Q_Σ	optimal	good	satisfactory	unsatisfactory	very bad	critical
	SOIL INTEGRAL FUNCTIONAL and ENVIRONMENTALSTATE					

$$Q = m\Pi\left(q_i^n\right) / \Sigma\left(\Pi\left(q_i^n\right)/q_i^n\right) \quad (2)$$

where m - number of the factor analyzed parameters; n - parameter stability index.

$$Q = \sqrt[8]{A * B * C * D * E * F * G * H} \quad (3)$$

Generalized and integrated evaluation involves the observable complex of SPDP with special emphasis on limiting parameters and factors. The method assesses the resilience (buffer) indexes of soil ecological state and environmental functions. Soil cover patterns and heterogeneity coefficients are considered for assessment an integral quality evaluation of the heterogeneous soil cover [13].

Most difficult and crucial issues of soil functional environmental assessment are (*1*) to set up the characteristic-factor/quality-requirement subsystems; (*2*) to choose main SPDP for one's partitioning. Usually we used for soil assessment up to 35 primary characteristics and add to principal equations of particular and generalized evaluation specialized simulation models. Special attention is focused on procedures of simulation for GHG fluxes and soluble pollutant migration in the landscape.

Developed system on soil functional environmental evaluation RASSCA reflects their main provincial-genetic features and allows: (1) to give robust assessments of soil environmental state; (2) to reveal and to estimate quantitatively the priority of main ecological (environmental) problems; (3) to carry out computer simulation and predictions of problem situation development; (4) to simplify the process of an administrative solution acceptance in environmental field.

3 Research Area

We tested this framework evaluation system for the case of Kursk city – the administrative center of Kursk region, with biggest population and urban extent in the west part of Central Chernozemic region of Russia. It is located in the central part of the Middle Russian upland, beyond the probable limits of maximum glaciation, within the large-hilly strongly dissected area. The territory is located in the central part of the forest-steppe zone with precipitation/evapotranspiration index around 1 and domination of Haplic and Luvic Chernozems. Kursk-city soils include urban soils and semi-natural Haplic and Luvic Chernozems and Chernic Phaeozems with different intensities of anthropogenic disturbance. The parent material varies from sandy loam to clay silty loams. Deep humus profile, fine structure, favorable physical-chemical properties and high supplies of nutritions characterize the natural soils in the region. Haplic and Luvic Chernozems are often studied in the Central Chernozemic Reserve, located close to Kursk and representing the undisturbed standards of Chernozem formation [16, 17].

Considering worsening of ecological state currently occurring in the Russia Chernozemic regions [4, 18], complex functional environmental investigations are needed to identify critical environmental problems and to develop the most suitable solutions in terms of land-use optimization.

Kursk city has a long history. The research sites were located in the old industrial district with urban soils based on Chernic Phaeozemas and Luvic Chernozems. The reference natural soils of an undisturbed forests and virgin steppes at the 15 km distance from the research sites were monitored for comparative analysis.

4 Results and Discussion

The results obtained urban soils based on the Luvic Chernozem indicated their degradation due to intensive human impacts for last 50 years (Table 2). Soil contamination was the main factor decreasing soil ecological state, however, critical values were also reported for pH_{KCl}. Evaluation modeling showed that improvement of only two soil parameters could already essentially increase the integral quality of this soil after its lime treatment.

Table 2. Functional environmental assessment (FEA) of urban soils based on the Luvic-Chernozem and Chernic-Phaeozemin Kursk

Soil pit #	Soil ecological (environmental) factor (SEF)	Factor FEA	Limiting SPDP/factor	SPDP value	SPDPFEA	Factor FEA after improvement of limiting factor	
						1-st	2-nd
Urban soils based on the Luvic Chernozem							
11	Soil contamination factor	0.46	$Pb_{mob.}$, ppm	56	0.22	0.81	0.91
	Soil factor of ecological buffer capacity	0.73	pH_{KCl}	4.9	0.41	0.95	0.99
	Soil profile factor of fertility stability & reclamative state	0.71	pH_{KCl}	4.9	0.41	0.96	0.99
	Soil chemical factor of bio productivity	0.71	pH_{KCl}	4.9	0.41	0.96	0.99
	Soil physical factor of plant uptake and soil workability	0.99	No			1.0	
	Integrated evaluation	0.70	Soil contamination factor			0.93	0.98
Urban soils based on the Chernic Phaeozem							
12	Soil contamination factor	0.90	$Pb_{mob.}$, ppm	38	0.76	0.90	0.92
	Soil factor of ecological buffer capacity	0.33	Bulk density, g cm^{-3}	1.55	0.14	0.56	0.82
	Soil profile factor of fertility stability & reclamative state	0.38	Bulk density, g cm^{-3}	1.55	0.14	0.51	0.93
	Soil chemical factor of bio productivity	0.56	Humus, %	3.06	0.24	0.56	0.93
	Soil physical factor of plant uptake and soil workability	0.41	Bulk density, g cm^{-3}	1.55	0.14	0.79	0.98
	Integrated evaluation	0.55	Soil physical factor			0.65	0.93

The results obtained urban soils based on the Chernic-Phaeozemin the old industrial zone, indicated decreasing of soil buffer capacity as the principal limiting factor. However, a negative influence of over-compaction was also essential. Evaluation modeling showed that even improvement of three limiting soil parameters could not essentially increase the integral quality of this soil. In this case, especial attention shall be given to the 2-nd level limiting parameters and multi-version modeling of their potential improvement consequences on the soil quality.

The outcomes obtained for urban soils based on the Chernic-Phaeozem are typical for the analysis of soil buffer capacity in case of contaminated urban soils (Table 3). In case of urban soils exposed to recreation degradation and chemogenic transformations, soil acidity dominated the limiting factors. Therefore, liming could solve the principal problem situation and improve the two other limiting SPDP (i.e CEC and its saturation) essentially. As for the urban soils, based on the Chernic-Phaeozemthe principal problem situation could be solved only after essential increasing of 2-nd limiting parameter - humus content and 3-rd limiting parameter - CEC. The costs of soil reclamation for the second case were substantially higher.

Table 3. Ecological buffer capacity assessment and modelling of urban soils based on the Luvic-Chernozem and Chernic-Phaeozem in Kursk: assessment and modelling results

Soil pit #	SPDP	Value	Limit #	FEA	Predicted	
					Value	FEA
Urban soils based on the Luvic Chernozem						
11	Clay content, %	44	No	0.99		
	Humus content, %	5.64	3	0.87	6.5	1.0
	CEC, mEq kg^{-1}	193	4	0.94	200	0.95
	CEC saturation, %	70	2	0.65	95	1.0
	pH_{KCl}	4.9	1	0.41	6.5	1.0
	Bulk density, g cm^{-3}	1.07	No	1.0		
	Ecological buffer capacity			0.73	0.99 (*1, 2, 4*), 1 (*1–4*)	
Urban soils based on the Chernic Phaeozem						
12	Clay content, %	42	No	0.98		
	Humus content, %	3.06	2	0.24	5.0	0.85
	CEC, mEq kg^{-1}	174	3	0.78	200	0.95
	CEC saturation, %	94	No	0.99		
	pH_{KCl}	6.5	No	1.0		
	Bulk density, g cm^{-3}	1.55	1	0.14	1.25–1.15	1
	Ecological buffer capacity			0.33	0.56 (*1*), 0.90 (*1–3*)	

The factor of ecological buffer capacity was the most important in our study of the contaminated soils (see Table 1). This factor was limited by the pH and bulk density. Increasing these limitation factors is challenging especially in soils with sandy and sandy-loam texture.

The application of the RASSCA tools in the ecological monitoring of industrially polluted city garden lands in the neighborhood of the Kursk Tannery has resulted in almost 10 times reduction of the total area of the initially planned output of land-use – due to detailed investigation of strong spatial differentiation of soil chromium contamination and their resistance to pollution. A similar analysis of the other city garden soil contamination with copper, nickel and lead also showed the statistically significant negative correlation of their mobility indexes with humus content and pH values, identifying limiting SPDP of soil health and resistance to heavy metals contamination.

Urban impact monitoring in Kursk has shown (Table 4) wide ranges of variation in rates of soil migration and accumulation processes in case of their various anthropogenic transformations with significant intensification of these processes for soils with low ecological buffer capacity.

Table 4. Rates range of accelerated soil processes in urban soils, based on the Luvic-Chernozem and Chernic-Phaeozem in Kursk

Soil processes	SPDP	Rates range
Litter degradation	*Litter stock*–kg m^{-2} $year^{-1}$	up to 3–5
Over-compaction	*Density* –g cm^{-3} $year^{-1}$	up to 0.3
Dehumification	*Humus*–g kg^{-1} $year^{-1}$	1–3
Humification	*Humus*–g kg^{-1} $year^{-1}$	0.6–2
Acidification	*pH*	0.05–0.1
Alkalization	*pH*	0.02–0.03
Carbonisation	*Carbonates*–g kg^{-1} $year^{-1}$	1–1.3
Leaching	*Carbonates*–kg cm m^{-2} $year^{-1}$	1–3
HM contamination	*MAC* $year^{-1}$	up to 0.5–1
HM migration	*Pb, Cr, Cu* – g cm m^{-2} $year^{-1}$	20–30 (60)

Substantial pollution with heavy metals resulted in severe alteration of properties and function of Urban soils based on Chernic Phaeozems and Luvic Chernozems. The irreversible changes in soil functions could result in transformation to the new subtype of urban soils – Chemogenic Urbosoils. These Chemogenic Urbosoils are formed under intensive long-term (20–30 years) technogenic atmospheric impact sand reveal a clearly diagnosed heavy metals migration (Pb, Cd, Ni, Zn, Cu), The depth of this migration can be at 1 m or more, even in the case of loam soil with high humus content. The results of the average annual migration rate research in Kursk city garden lands showed the maximum migration in urban soils based on Luvic-Chernozem- 20–30 g cm m^{-2} $year^{-1}$ for lead and 50–60 g cm m^{-2} $year^{-1}$ – for chromium. The verified models of HM migration allow predicting the future soil environmental quality in case of different level industrial impacts and to diagnose in advance the principal environmental problems in soil regulation function disturbances.

5 Conclusions

The paper presents the regional automated system of soil functional-environmental assessment (RASSCA). Implementing the RASSCA system (i) reflects soils' provincial genetic and functional features; (ii) allows evaluating the integral functional and environmental quality of soils even in conditions of heterogeneous land plots; (iii) gives the effective tools to identify and quantify the limiting factors and principal parameters of the functional quality and environmental status of soils and priority issues of their land use; (iv) provides the useful platform to conduct environmental computer simulation, search and target prediction of soil quality further changes and problem environmental situations solution; (v) helps to improve the effectiveness of land-use and land conservation decision making – by prior functional-environmental analysis and comparison of the various scenarios.

The functional-environmental analysis of polluted urban soils based on Chernic-Phaeozem and Luvic-Chernozem stressed the environmental problems of soil technogenic degradation in Kursk city and neighborhoods. Adapting the RASSCA system to the environmental conditions and factors of the research area allowed to evaluate soil limiting parameters and environmental factors, to identify the priority issues that require urgent improvement, and to model the target changes in the integrated functional-environmental quality of soils by improving the priority set of its limiting parameters.

Conducted monitoring research of Kursk soil technogenic successions showed strong activation of soil typomorphic metamorphic and migration processes in urban soils. The over-compaction in urban soils was up to 0.3 g cm^{-3} $year^{-1}$; an average rate of humification/dehumification – 3.0 g kg^{-1} $year^{-1}$; acidification/alkalization −0.1 pH $year^{-1}$ and heavy metals migration – up to 50–60 g cm m^{-2} $year^{-1}$. Some of these data considerably extend the known ranges of elementary soil processes rates "in situ" and allow for better estimation of the real potentials of soil functioning in different landscape-environmental conditions of forest-steppe zone.

A substantial increase in HM migration rates in urban soils has been observed. The main-driving factors included sandy loam texture, acidification and sharp decreasing of humus content in the profiles without geochemical (lithological, acid-base or redox) barriers. The obtained results can be used for current assessment and forecasting of environmental pollution problem development in urban areas with soil characteristics similar to those investigated in Kursk city.

Acknowledgments. This work was supported by the RF President grant# NSh-10347. 2013.11.

References

1. Addiscott, T.M., Wagenet, R.J.: Concepts of solute leaching in soils: a review of modelling approaches. J. Soil Sci. **36**, 411–424 (1985)
2. Bouma, J.: Land evaluation for landscape units. In: Sumner, M.E. (ed.) Handbook of Soil Science, pp. E-393–E-412. CRC Press, Boca Raton (2000)
3. Sumner, M.E. (ed.): Handbook of Soil Science. CRC Press, Boca Raton (2000)

4. Tchernogorov, A.L., Tchekmaryov, P.A., Vasenev, I.I., Gogmachadze, G.D.: Land Agroecological Evaluation and Land-Use Optimization, 268 p. Moscow University Press, Moscow (2012). (in Russian)
5. Vasenev, V.I., Stoorvogel, J.J., Ananyeva, N.D., Ivashchenko, K.V., Sarzhanov, D.A., Epikhina, A.S., Vasenev, I.I., Valentini, R.: Quantifying spatial-temporal variability of carbon stocks and fluxes in urban soils: from local monitoring to regional modeling. In: Muthu, S.S. (ed.) Carbon Footprint Handbook, pp. 185–221. CRC Press, Boca Raton (2015)
6. Rossiter, D.G.: A theoretical framework for land evaluation. Geoderma **72**, 165–190 (1996)
7. van Lanen, H.A.J., Hack-ten Broeke, M.J.D., Bouma, J., de Groot, W.J.M.: A mixed qualitative/quantitative land evaluation methodology. Geoderma **55**, 37–54 (1992)
8. Prokof'eva, T.V., Gerasimova, M.I., Bezuglova, O.S., Bakhmatova, K.A., Gol'eva, A.A., Gorbov, S.N., Zharikova, E.A., Matinyan, N.N., Nakvasina, E.N., Sivtseva, N.E.: Inclusion of soils and soil-like bodies of urban territories into the Russian soil classification system. Eur. Soil Sci. **47**, 959–967 (2014)
9. Salvati, L., Ferrara, C., Ranalli, F.: Changes at the fringe: soil quality and environmental vulnerability during intense urban expansion. Eur. Soil Sci. **47**, 1068–1075 (2014)
10. Greinert, A.: The heterogeneity of urban soils in the light of their properties. J. Soils Sed. **15**, 1725–1737 (2015)
11. Vasenev, I.I., Buzilev, A.V., Kurbatova, J.A., Chistotin, M.V., Rudnev, N.I., Tiunov, A.I.: Agroecological modelling and design. In: Vasenev, I.I. (ed.) 264 p. RTSAU, Moscow (2010). (in Russian)
12. Vasenev, I.I., Buzilev, A.V.: Land Agroecological Evaluation Automated Systems, 172 p. RTSAU, Moscow (2010). (in Russian)
13. Vasenev, I.I.: Soil and land-use planning. In: Nortcliff, S. (ed.) Task Force: Soil Matters – Solutions Under Foots, pp. 100–104. GeoEcology Essays, Catena Verlag (2015)
14. Wagenet, R.J., Hutson, J.L.: Soil quality and its dependence on dynamic physical processes. J. Environ. Qual. **26**, 41–48 (1997)
15. Vasenev, I.I., Vizirskaya, M.M., Vasenev, V.I., Valentini, R., Raskatova, T.V.: Comparative analysis of principal factors of spatial-temporal variability of CO2 emission from Moscow urban soils with various levels of anthropogenic impact. Izvestia Timiryazev Agric. Acad. (Special Issue), 11–23 (2012)
16. Mikhilova, E.A.: Botanical composition, soil and forage quality under different management regimes in Russian grasslands. In: Mikhilova, E.A., Bryant, R.B., Post, C.J., Cherney, D.J.R., Vassenev, I.I.: Agriculture, Ecosystems and Environment, vol. 80, no. 3, pp. 213–226 (2000)
17. Mikhilova, E.A., Bryant, R.B., Vassenev, I.I., Schwager, S.J., Post, C.J.: Cultivation effects on soil organic carbon and total nitrogen at depth in the Russian Chernozem. Soil Sci. Soc. Am. J. **64**, 738–745 (2000)
18. Sarzhanov, D.A., Vasenev, V.I., Sotnikova, Y.L., Tembo, A., Vasenev, I.I., Valentini, R.: Short-term dynamics and spatial heterogeneity of CO2 emission from the soils of natural and urban ecosystems in the Central Chernozemic Region. Eur. Soil Sci. **48**(4), 416–424 (2015)