Mapping of Soil-Ecological Conditions of a Medium-Size Industrial City (Birobidzhan City, Jewish Autonomous Oblast, FarEast of Russia as an Example)

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Abstract. The authors analyze soil relations with other elements of the city ecosystem (the position in the landscape, soil-forming rocks and lithology, vegetation and its state) to develop the legend and map of soils in the City of Birobidzhan (scale 1:25 000). The focus of study is the morphological structure of urban soils with different degree of disturbance of these relations under the impact of technical effects, economic and recreational activities of the city population. The soil cover structure is composed of four large ecological groups of soils: natural untransformed, natural with a disturbed surface, anthropogenic soils and technogenic surface formations. Using cartometry of the mapped soil contours the authors created the scheme of soil-ecological city zoning, which in a general way depicts the state of soil ecological functions in the city as well as identified zones of soils with preserved, partially and fully distured ecological functions and zones of local geochemical anomalies at the initial formation stage (environmental risk zones).

1. Introduction

Modern surveys of ecological situation in cities are focused on studies of soil cover and their ability to serve certain ecological functions, e.g. provide a microclimate (moisture, air, and heat exchange) in urban areas, regulate geochemical fluxes which get into surface and groundwaters, support survivability and longevity of plantation and biodiversity in natural urban environments [1-3]. Recently, special attention is also paid to the economic functions of urban soils, which they perform in conditions of various uses and diversity of forms of land ownership. More and more often urban soils act as objects of market relations, in which their value is determined by properties, functions and quality [4, 5].

Various anthropogenically transformed soils and technogenic deposits increasingly become typical to many large cities and industrial centers [6-9]. There are practically no soils as natural formations. In small and medium-size cities natural processes of soil formation are often not much suppressed by technogenic effects. Therefore, development strategies of small towns should include the solution of the problem of "man-environment-soil" and be based on the surveys of conditions and properties of the existing natural soil resource, its careful management and rational development and use [3, 10]. The experience of soils studies in different cities of Russia shows that the term “urban soils” actually implies economical activities in the city. Over 50 papers at symposiums and sections of the VI Congress of the Dokuchaev Soil Science Society in Moscow in 2012 discussed these and other issues

of anthropogenic transformation of soils in urban areas.

Modern methodology of urban soils studies in Russia were initiated in the 1990es, when general guidelines and main principles of systematics of urban soils, diagnostics and mapping of soils in big cities were worked out [4, 6, 11, 12]. However, problems in studies of urban soils still remain to great extend unsolved [8, 12, 13].

The goals of our work are to study, classify and map soils in Birobidzhan, a relatively young and developing city of the Amur Region. The obtained results are the first stage of the continuing complex research on monitoring and assessment of the geo-ecological situation in the city.

2. Materials and Methods

2.1. Study area

The authors selected Birobidzhan soils as an object of study because this city is the administrative and industrial center of Jewish Autonomous Region (figure 1) and is ranked as a medium-size city in the southern part of the Far East of Russia. At present Birobidzhan like many cities in this region has the impetus for growth and development. This is largely due to its location in the Middle-Amur basin in the transboundary area between Russia and Heilongjiang Province of China [14]. The geographical coordinates of Birobidzhan are 30 ° 33 '31 "-31 ° 18' 38" N, 118 ° 28 '08 "-119 ° 38' 40" E. Its area is 200 thousand km^2; the population in 2014 reached 74,791 people.

Figure 1. Scheme of Birobidzhan location.

Birobidzhan is situated mostly on low accumulative surfaces (within a high floodplain and 1 st terrace above floodplain of the Bira River). Alluvial deposits are mostly composed of sandy loams, sands, gravel-pebble materials. Sandy and ferruginized clay are less abundant. An elevated relief elements in the form of denudation remnants of low mountains (hills) and erosion-accumulative foothills with slightly undulating surface occupy western and south-western parts of the city. Here, the soil-forming rocks are eluvial-deluvium deposits of bedrock weathering products, mainly effusive (andesite, andesite-basalt, quartz porphyry). The slopes of low mountains are covered with oak-broad-leaved and deciduous-forb woods with numerous representatives of the Manchurian flora. Swampy

sedge-reed grass meadows and grass-moss marshes bound the city in the northeast and east, and large massifs of high-floodplain grasslands are located in the city south. Its central part (the city proper) has undergone several stages of construction and redevelopment that greatly altered natural landscapes and soils.

2.2. Data and sources

The authors' field studies of soils and soil-grounds in different functional zones of Birobidzhan provided materials for the present research. The basis for soil mapping was a topographical map (scale 1:25 000). The authors also used unpublished cartographic materials from archives of some scientific and research institutions on Quaternary deposits, geomorphology and hydrological conditions of the city (scale 1:50 000). Data on vegetation are provided in this paper [15].

2.3. Methods

Basic research methods used were comparative geographic studies (geographic interpolation method), field routing and semi-stationary methods of soils and grounds analysis and the method of thematic mapping [16-19]. All the works were based on a systematic approach, i.e. on the analysis of interrelations of soil and other elements of the city ecosystem and taking into account the disturbance of these relations due to technogenic impacts, economic and recreational activities of the city population [7, 20]. Field works included making and describing soil profiles in different functional zones of Birobidzhan (industrial, residential, intercity areas of organized recreation, recreational-landscape and others).

The soil map was compiled using a traditional method [16, 19]. The soil contours on the map were defined by their genetic content with the help of traditional diagnostic characteristics of the soil morphological structure. The authors would like to stress that the main focus of the present study is the analysis of the degree of anthropogenic disturbance of the morphological structure of soils. The map was digitized using ArcView GIS software [17].

3. Results and discussion

3.1. Soil map and Legend

Soil and environmental studies have made it possible to identify four large ecological groups of soils and non-soil substrates in the territory of Birobidzhan: (1) natural relatively untransformed soils; (2) natural soils with a disturbed surface; (3) anthropogenic soil; (4) technogenic surface formations (TSF) [21]. According to these groups, the legend of the map of Birobidzhan soils has four sections and 23 cartographic units. The legend in the full paper version of the map is in the form of a table, which systematizes information about the relief, soil-forming rocks and the vegetation cover. The paper presents an ArcView GIS version of this map (figure. 2).

3.2. Detail description of ecological groups of soils

3.2.1. Natural relatively untransformed soils

Soils of this group are mainly found in the natural environment (outskirts of Birobidzhan) and presented by brown forest soils, sod-brown soils, sod- meadow gley, bog peaty- and peat-gley soils and complexes of floodplain soils. The terms used correspond to the legend of the 1:2.5 M Soil Map of the Russian Federation [22]. The indexation of soil horizons used accordingly [23]. These soils retain specific to natural morphological composition of the soil profile. The brown soils are common within hills under oak-broadleaf forests. By granulometric composition these soils are loam or even clay, gravelly to varying degrees, and depending on the position on the slopes are divided into the brown soils with a small-profile (not fully developed), typical and gleyic. Profile composition is typical brown soils - AY–BM–C, gleic brown soils - AY–BMg–Cg. Within the flat part of the city sod-brown soils and residual alluvial soils with favorable physical and hydro-physical properties (of light

granulometric composition, good permeability) are formed on the elevated bars of the first terrace above the floodplain under the oak-broadleaf forests. Profile composition is AY–[BM–C] al. Sod-meadow gley and peaty-(peat)-gley soils under wet reed-sedge meadows and lowland swamps are most common soils of this group. Profile composition is AY–G–CG and T–G–CG. Complexes of Bira-floodplain soils include sod layered under developed (W–C ˜ ˜), sod meadow gleyic (AYg–Cg˜ ˜) and wetlands silty-gley soils (Hmr–G–CG˜ ˜). Soils of the 1st group have undisturbed (or weakly disturbed) ecological functions due to the preserved connection with the lithogenic basis and the vegetation cover and the integrity of the soil profile.

3.2.2 Natural soils with a disturbed surface

The main feature of these soils is the preserved connection with the parent rocks (untransformed middle and lower horizons are always observed in the soil profile). At the same time connections with the vegetation cover are partly or mostly completely disturbed. Changes in the morphological composition and structure in these soils are associated with the upper part of the profile up to 50 cm, where the "urbic" U horizon is formed [6, 8]. These soils are proposed to be called "urbosoils". Profile formular is U (AU)–B–C. Depending on the specifics of anthropogenic impacts the soils may be without upper genetic horizons, called urboabrazems and soils of little farms with a cultivated profile, called urboagrozems. Special varieties of urban soils are formed with the recreational use of natural soils. Under this influence, organogenic horizons of soils valuable in the biogeocenotic terms (forest litter, grass felts humus horizons) are transformed. In general, natural superficially-disturbed soils have in comparison with undisturbed, lower ecological potential, their ecological functions are partially preserved or transformed.

3.2.3 Anthropogenic soils

These soils are typical for built-up Birobidzhan areas. They are diagnosed by the absence of genetic horizons inherent to natural soils. They are primarily formed due to mechanical (and often chemical) soil destructions over 50 cm deep. Urbotechnozems with profile TG–C (TG) are most common in the city. They were formed (and are currently formed in areas of multi-storey housing) from dump, repeatedly mixed on the ground and imported soils. Urbotehnologic profiles consist of soil layers, different in color, thickness, lithology and dumping time and always include fragments of soil horizons, construction, household and industrial wastes in different amounts.

Along with urbotechnozem, created by the technical activity of man, the researchers distinguish in the group of urban anthropogenic soils proper urban soils, the formation of which is associated with the historical accumulation of the cultural layer - a homogeneous dusty-humified substrate with anthropogenic inclusions [6, 8]. However, such soil formations in the surface deposits of Birobidzhan are insignificant because of the youth of the urban settlement and the features of the aerial accumulation of matter. Among the anthropogenic soils on the territory of the city, we should also mention replantozems, the formation of which is associated with the deposition of a relatively fertile layer on bulk (mainly sandy-gravel) soils. Replantozems are mainly soils of lawn and flower beds. Profile formula is U (Utg) –B–C or U–TG–C. Soil fragments (mostly hydromorphic), everywhere buried under asphalt, buildings and accumulations of sand and gravel are classified as ekranozems. In some localities, mainly in industrial and communal areas of the city, there are urbotechnozems significantly contaminated with heavy metals (lead, copper, zinc), petroleum products (oils, fuels, lubricants) and other toxic substances. These variants of urbotechnozems are called intrusions. It was impossible to show all variety of anthropogenic soils on the map of scale 1:25000, that is why, these soils in the old (central) part of the city are shown as urban soil complexes which differ in history and development technologies, a modern economic and functional structure and the percentage ratio of the areas of their natural soils, soils with a disturbed surface and anthropogenic soils (see legend to figure 2).

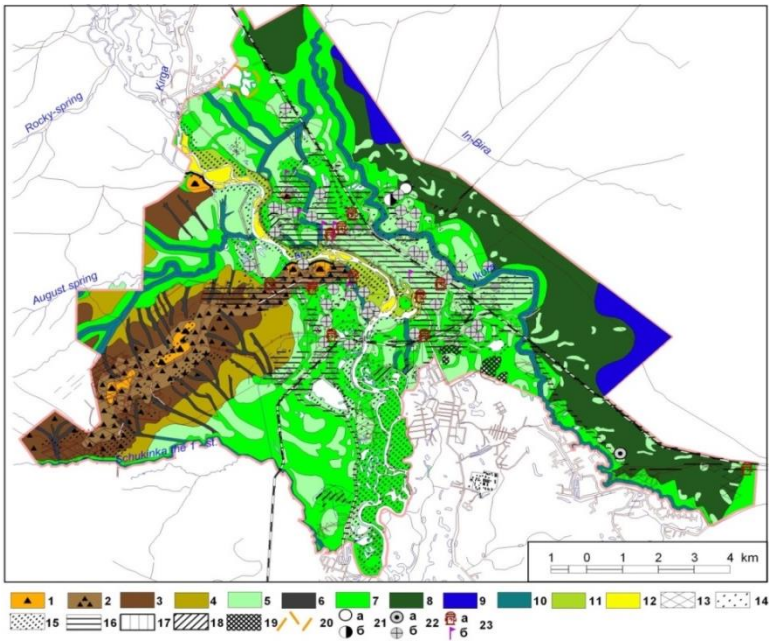

Figure 2. Soil Map of Birobidzhan (original scale 1:25 000).

Legend: **I.** ***Natural relatively untransformed soil***: 1 – *primitive brown earthquakes fragmentary gravelly-stony with outcrops of bedrock to the surface; 2 – small profile (thin) brown soils with lot of or not so much debris; 3 – typical predominantly loamy brown soils with little debris; 4 – gleyic and gley loam and clay brown soils; 5 – brown soils and sod residual alluvial brown soils combined with sod-gley and peaty-gley sod soils; 6 – sod-humus gley soils in the upper parts of bars on deluvium-proluvium sediments; 7 – meadow gley soils in combination with meadow-bog- and peat-sod-gley soils; 8 – peat-bog and peat-gley soils of a lowland type; 9 – bog peat-gley and peat soils of heterotrophic bogs; 10 – floodplain bog peat-gley soils; 11 – floodplain bog silt-gley and gley soils on silty sand and sandy loam; 12 – floodplain weakly-sod layered (gleyic) soils on the sands.* **II.** ***Natural soils with a disturbed surface***: *13 – soils in gardens, greenhouses and farms; 14 – soils of private landholdings; 15 – soils in landscape-recreational zones.* **III.** ***Anthropogenic soils***: *16 – urban soil complex of type I, composed of 75-95% of anthropogenic soils (urbotechnozems, replantozems, ekranozems) and 5-25% of natural soils with a disturbed surface; 17 – urban soil complex of type II, composed of 50-75% of anthropogenic and 25-50 % of natural soils with a disturbed surface; 18 – urban soil complex of type III, composed of less than 50% of anthropogenic and more than 50% of naturally-disturbed soils, 19 – a soil complex of city cemeteries (nekrozems).* **IV.** ***Technogenic surface formations (TSF)*****:** *20 – spoil grounds in areas of existing and developed (filled with surface waters) quarries; 21 – ash disposals: a – in use, b - closed (reclaimed); 22 – landfills of municipal solid wastes: a – authorized, b – unauthorized; 23 – soil-grounds (intruzems) contaminated with petroleum products, oil, fuel oil, heavy metals, rubber products, etc. in the areas of: a - fuel stations, b - car services (parking lots, car wash, tire repairs, etc.).*

3.2.4. Technogenic surface formations (TSF)

TSF in Birobidzhan spread steadily and increasingly. TSF are open dumps and accumulations of natural and technogenic soils (mining wastes, ash dumps, landfills of domestic and industrial wastes, including unauthorized). TSF systematics and diagnostics are at the development stage. On the map they are shown with extra-scale signs. Ecological functions of TSF are completely lost, their effects on the urban environment are characterized as destabilizing and TSF require measures to reduce their negative effects (recultivation).

3.3 Soil-ecological zoning

The created soil map of Birobidzhan and the analysis of morphological and genetic characteristics of several soil types made possible the zoning of soil-ecological conditions of the city. Four soil-ecological zones are distinguished according to the degree of disturbance of soil ecological functions (figure 3). Zones of soils with fully preserved, partially preserved and completely lost ecological functions occupy 54%, 23% and 14% of the total Birobidzhan area. A potentially environment-hazardous area was also identified in the city. It occupies 8% of the city area and may cause the formation of geochemical anomalies in soils.

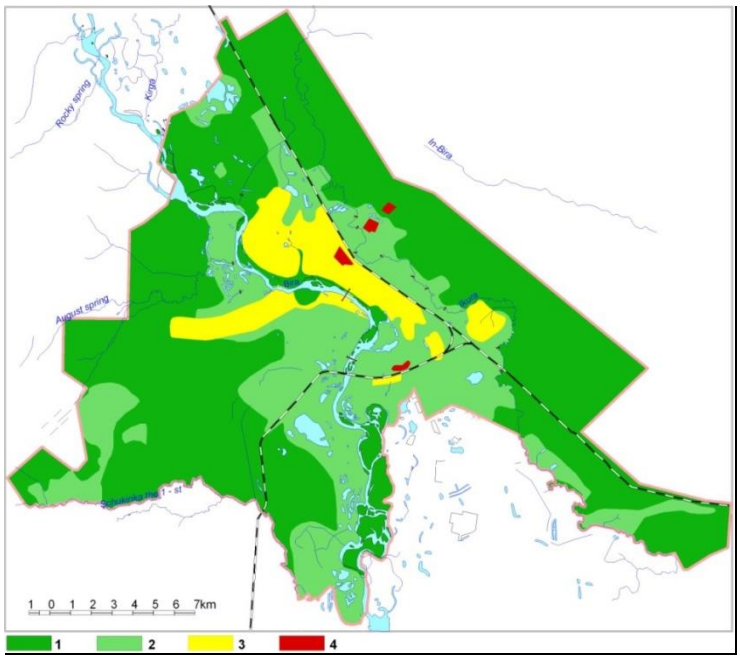

Figure 3. Zoning of Birobidzhan area by the degree of ecological disfunction of the soil cover (original scale 1:25 000).

Legend: *1 – areas with preserved ecological functions of the soil cover; 2 – areas with partially preserved ecological functions of soils; 3 – areas with fully lost ecological functions of soil; 4 – areas with a potentially environment-dangerous anthropogenic soil cover.*

4. Conclusions

The created soil map of Birobidzhan (scale 1:25000) reflects the diversity of soils and non-soil formations in the city. It presents a range of environmental characteristics of the soil cover, sources of potential pollution (landfills, gas stations, car service centers, etc.) and allows to determine the percentage of soils with different levels of disturbance. The schematic map of soil-ecological zoning reflects the summarized state of ecological functions of urban soils, which makes it valuable for the analysis of the overall ecological situation in Birobidzhan. It is important to note that 54% of the city soil cover is made of soils with preserved ecological functions. They are mainly located in the Birobidzhan outskirts, which are open spaces and are potential reserve areas for urban environmental planning and rational land management [3].

References

[1] Dobrovolsky G and Nikitin E 1990 *Soil functions in the biosphere and ecosystems* (Moscow: Nauka) p 261
[2] Kurbatova A and Bashkin V 2004 *Ecological functions of urban soils* (Moscow: Magenta) p 232
[3] Narbut N and Matyushkina L 2005 The ecological role of open spaces in urban area (Khabarovsk as an example) J *Geography and natural resources* **1** pp 46–50.
[4] [Stroganova M, Prokofieva T, Prokhorov A, Lysak L, Sizov A and Yakovlev A 2003 Ecological status of urban soils and economic evaluation of lands *J Soil Science* **7** pp 867–875.
[5] Xue Desheng, Huang Gengzhi, Guan Jingwen and Lin Jiarong 2014 Changing Concepts of City and Urban Planning Practices in Guangzhou (1949–2010) An Approach to Sustainable Urban Development *J Chinese geographical science* **24(5)** pp 607–619.
[6] Gerasimova M et al 2003 *Anthropogenic soils: genesis, geography, restoration Textbook* (Smolensk: Ojkumena) p 268
[7] Likhachev E, Timofeev D, Zhidkov P et al 1997 *City - ecosystem* (Moscow: Media – Press) pp 185–199
[8] Prokofieva T, Martinenko I and Ivannikov F 2011 Systematics of soils and soil-forming rocks of Moscow and the possibility of their inclusion in the general classification *J Soil Science* **5** pp 611–623.
[9] Qu Tao, Zhang Yun, Liu Ran and Dong Mali 2009 Social Effect of Environmental Pollution on Valley-cities in Western China *J Chinese geographical science* **19(1)** pp 008–016.
[10] Narbut N, Antonova L, Matyushkina L and Karavanov K 2002 *Strategy for forming ecological carcass of urban area (Khabarovsk as an example)* (Vladivostok – Khabarovsk: FEB RAS).
[11] Agarkova M, Tselishcheva L and Stroganova M, 1991. Morphological and genetic characteristics of urban soils and their systematics *J Vestnik Moskov. Univ*. Ser. 17, Soil Science. **2**: pp 11–16.
[12] Stroganova M, Myagkova A and Prokofieva T 1997 Classification of urban soils. Problems of anthropogenic soil formation Proc. Int. conf. (M.: V V Dokuchaev Soil Institute RAAS) **2** pp 234–239.
[13] Deeva N and Kerzhentsev A 1998 Methodological problems of soil-ecological mapping. *Soil Science* **9** pp 1112–1118.
[14] Ganzei S 2004 *Transboundary geo-systems in the south of the Russian Far East and in Northeast China* (Vladivostok: Dalnauka).
[15] Kalmanova V 2005 Comprehensive assessment of functional significance and ecological state of Birobidzhan dendroflora *J Regional problems* **6-7** pp 67–72.
[16] Trofimov B 2007 *Ecological-geological maps. Theoretical bases and methods of compolling (ed)* (Moscow: Vysshaya Shkola).
[17] Simakova M 2008 *Guide for medium-scale soil mapping using GIS (ed)* (Moscow: VV Dokuchaev Inst.)
[18] Kalmanova V B 2010 Selection and justification of methods to assess the ecological state of urbanized areas. *Regional problems* **13 (2)** pp 67–71.
[19] Mapping of soils on a large scale (methods, theory, practice) 1971 (Moscow: Nauka)
[20] Doncheva A B 1979 A systematic approach to assessing the impact of an industrial facility on the natural system. In: Problems of geographic forecast (ed) (Moscow: Moscow University Press) pp 93–98.
[21] Matyushkina L and Kalmanova V 2011 Map of soil and environmental conditions of Birobidzhan: structure and content *J Geodesy and Cartography* **9** pp 49–54.
[22] Soil Map of the Russian Federation Scale 1:2.500 000 (1988) In Fridland VM (ed) Dokuchaev Institute of Soil of the Russian Academy of Agricultural Science, GUGK USSR. VASKHNIL, Moscow.
[23] Shishoff L 2004 *Classification and diagnosis of soils of Russia* (Smolensk: Ojkumena).