General scientific and regional conceptual approaches to compilation of Red Data Books of Soils

A M Prokashev¹,² and A V Tyul’kin²

¹Vyatka State University, 36, Moskovskaya Str., Kirov, 610000, Russia
²Vyatka State Agricultural Academy, 133, Oktyabrsky Ave., Kirov, 610000, Russia

E-mail: am_prokashev@vyatsu.ru

Abstract. The authors explain the need to compile the Red Data Book of soils similar to the existing Red Data Books of plants and animals. The paper reveals some theoretical and methodological approaches from general scientific and regional points of view relevant for the compilation of such works. The main soil objects in the pedosphere of the Kirov region that meet the zonal standards are identified, i.e. rare, unique and endangered soils. These soils are to be included in the environmental documents mentioned above. The results can be used to develop a local network of specially protected natural territories due to a new – pedogenic – category of objects of conservation of natural heritage as part of reserves, micro-reserves, soil monuments of nature. These materials are of interest to the scientific community and environmental services of the Kirov region and other constituent entities of the Russian Federation.

1. Introduction

The idea of compiling the Red Data Book of soils is based on the provision that unique and irreplaceable soil cover performs a number of important biospheric functions. According to G.V. Dobrovolskij and E.D. Nikitin [1], these functions are biodiversity preservation, ensuring bioproduction process, maintaining stable gas composition of the atmosphere, chemical composition of natural waters, and, consequently, the preservation of life on Earth. This movement, which was born in the late 1970s, was inspired by our domestic scientists E.D. Nikitin, G.V. Dobrovolskij [2–6]. At first, it was informal since the country’s environmental legislation did not have an appropriate regulatory framework.

The situation changed in 2002 when the government of the Russian Federation adopted Federal law No. 7 on Environmental Protection, Article 62 of which states, “Rare and endangered soils are subject to state protection, and the Red Data Book of soils of the Russian Federation and the Red Data Books of soils of the constituent entities of the Russian Federation are established for the purpose of their registration and protection...” [7]. The latter served as an incentive to intensify work in this direction by enthusiasts from a number of country’s regions [8–13]. These works focused on the foundation of scientific approaches to compiling the Red Data Book of soils, determining the taxonomic rank and list of soil objects which need priority protection. At the suggestion of one of the paper’s authors, the first edition of the Red Data Book of soils of Russia [14] included passport data on a series of valuable soil objects, identified by him in the 1980–90s in the territory of the Kirov region.

To date, we have collected representative materials on typical and rare components of the soil cover of the Kirov region necessary to set an urgent goal – to prove the need to compile the Red Data
The aim of this paper is to propose and discuss conceptual approaches to compiling the regional Red Data Book of soils taking into account general scientific and regional aspects.

2. Theoretical and methodological provisions
In our opinion, the following principles and approaches should be considered the general scientific provisions on the compilation of the Red Data Books of soils (Table 1).

| Principles                                      | Approaches            |
|------------------------------------------------|-----------------------|
| 1. phenomenological principle                  | 1. regional approach  |
| 2. principle of equivalence of soil cover components | 2. zonal approach     |
| 3. principle of priority of virgin soil objects | 3. azonal approach    |
| 4. principle of representativeness             | 4. catenary approach  |
| 5. principle of rarity of soil cover components | 5. natural historical approach |

The phenomenological principle implies the recognition of the importance of any component in the pedosphere, as well as in the composition of nature as a whole, as an original natural historical body that should be studied and preserved. This was recognized by V.V. Dokuchaev at the dawn of the genetic soil science in the provision on the unique soils as the “fourth kingdom” of nature along with plants, animals and minerals. In the second half of the 20th century, it was developed in the form of the doctrine of the irreplaceability of soil cover for a number of biospheric and anthropospheric functions, including the preservation of life on Earth.

The principle of equivalence of soil cover components is the relative equivalence of soil cover components regardless of the occupied area due to their possible irreplaceability as an ecological niche for the inhabitants of local biomes that are closely related to soils as their living environment.

According to the regional approach, the local natural conditions and features of the soil cover of any constituent entity of the Russian Federation are taken into account. For the Kirov region, these include: location in 3 subzones, terrain heterogeneity, diversity of parent and underlying rocks, belonging of soils to podzolic, gray forest, slob, peat, alluvial types of pedogenesis, polygenetic soil cover and some others, as described below.

The principle of representativeness implies the inclusion of the main zonal, azonal and intrazonal soil cover components in the Red Data Book of soils, which reveal the diversity of local soils, modes and processes of pedogenesis.

According to the principle of the priority of virgin soil objects, they are considered as the only reference samples of natural – virgin – soil cover, which serve as a reference point for assessing the primary state – morphology, substantive properties, functioning, dynamics, development, evolution of the local pedosphere – under the conditions of possible technogenic transformation of soils. At the same time, they are the natural, reproductive and evolutional habitat of most flora and fauna species, including the microbiota.

The zonal approach implies the mandatory inclusion of background soil cover components in the Red Data Book of soils. In the Kirov region, located in the subzones of the middle, southern taiga and mixed forests, podzolic, sod-podzolic and gray soils on clay-loam soil-forming types are to be included in the Red Data Book of soils.

The azonal (lithogenic) approach is an addition to the zonal approach with a selective sampling of soil-forming types according to two complementary criteria: a) typicality and homogeneity – for zonal standards; b) exoticism or uniqueness of soil-forming substrates on which certain soil differences, which are interesting from scientific and other points of view, were formed. In the Kirov region, cover loam is considered to be the optimum alternative of soil-forming types for zonal soil standards. They are known in all the subzones and most geomorphic positions and are a good option due to their stable properties: the homogeneity of granulometric and chemical-mineralogical composition, addition, etc. Phosphate Jurassic-Cretaceous deposits of the Vyatka-Kama district and exceptionally rare in the
region post-carbonate siliceous montmorillonite clay – limestone leachate of the Kazan layer of Perm found by the authors in the area of Atarskaya Luka (Nolinsky district) are rare and unique soil-forming types.

The catenary approach is a conjugate representation of soil types and subtypes of eluvial, semi-hydromorphic and hydromorphic series of different subzones developed on homogeneous soil-forming types. This allows us to reveal soil geographical regularities of soil functioning and lateral material energy exchange between them more fully in a comparative aspect.

The natural historical approach implies the selection of objects taking into account the regional history of soil cover in the post-glacial period and/or earlier stages of nature evolution. This approach is of particular importance for the Vyatka region due to the location of its southern and central parts near the boreal ecotone of European Russia in comparison with taiga and forest-steppe biomes. At a very dynamic-post-glacial stage of development – in the pre-boreal, boreal, Atlantic, sub-boreal and sub-Atlantic stages of the Holocene – it caused significant climate changes and migration of landscape zones [15–17]. An important consequence of this was the formation of a number of soil types with clear morphological and analytically fixed signs of polygenesis in the form of relict – residual and buried – humus horizons, etc. In particular, these are soils with the so-called second humus horizons, which are now widely known as part of several background types of watershed soils as well as valley landscapes on various soil-forming types.

The principle of rarity of soil cover components is closely related to the above approach. It consists in ranking soil cover components taking into account their scientific value, biospheric role, productivity, threat of degradation and extinction of certain taxa. This principle refers to almost all soils with a polygenetic profile of the Vyatka region as well as intensively exploited soils of the gray forest type.

3. Objects and results

In the light of the above mentioned, the following group of reference and rare soils are to be included in the Red Data Book of soils (Table 2).

Table 2. Groups of reference and rare soils of the Vyatka region

| I. Reference soils | II. Rare soils |
|-------------------|---------------|
| a) primary standards | a) unique soils |
| б) local standards | б) rare soils on the territory of RF |
| в) reference complexes | в) rare soils on the territory of the region |
| г) endangered species | |

Zonal types and subtypes of soils – podzolic, sod-podzolic, gray – formed under upland conditions under virgin or conditionally indigenous forests on cover loam, known in the corresponding subzones of the region are considered to be primary standards. However, when moving to the south, it is difficult to sample virgin geosystems due to the high degree of agrogenic transformation of land. Another difficulty is the partial preservation of traces of former pedogenesis in the profile of sod-podzolic and gray soils in the form of second humus horizons, i.e. relics of the boreal-Atlantic time of the post-glacial period. Sod-podzolic soils under secondary forests are, in fact, often derivatives of the most eluvial differences of soils with second humus horizons.

The criteria for the selection of local standards are the features of the lithology of soil-forming types, topography, hydrothermal regime or historical development. On the territory of the Vyatka region, soils developed on morainic loams, eluvium of Permian bedrock or on binomial deposits (sands on clays and vice versa) are local standards. They are quite common in the middle, southern taiga and, in part, mixed forest landscapes of our region.

The flat-undulating plateaus of the southern right bank of the Vyatka river are zonal reference complexes with soil combinations due to meso-and microrelief. Here, along the slopes, you can distinguish the following soil series: gray humus – gray dark humus – gray dark humus gleyic – gray dark humus gley soils.
Rare soil standards are usually the soils that are formed in sparsely distributed soil-forming types, under unusual hydrothermal conditions, characterized by a complex history of development, which affected the appearance and properties of soils. According to the natural historical approach, reflecting the complex history of the formation of the soil cover of the Vyatka region in the post-glacial period, first of all, this category should include soils with second humus horizons and with buried humus horizons. These polygenetic soils are both rare, unique, and/or endangered because they are relics of earlier Holocene stages. Their traces have been preserved to this day in the morphology, properties of the mineral and organic phase.

We have studied such rare pedoobjects using physical, chemical, biochemical, physical-chemical, geochronological ($^{14}$C) methods as part of a series of soil types and subtypes in the south of the Kirov region. They are found mainly among the intertidal areas – sod-podzolic, humus-gray, gray gleyic, sod-carbonate – and, to a lesser extent, valley landscapes – paleoalluvial, etc. The most typical among them are soils with remnants from earlier stages of pedogenesis of the second humus horizons lying at the level of modern near-surface-humus-accumulative AU(B)\[hh\], accumulative-eluvial AEL[hh] or, less often, middle – illuvial-textural B[hh] – horizons. Regardless of the depth of occurrence – from 15–50 to 100–120 cm – the second humus horizons reveal the close (about 5–8 thousand years or more) age of humic acids in the composition of organic matter which corresponds to the early and middle Holocene. These soils with a binary humus profile were formed during the temporary shift of natural zones to the north, with a different combination of pedogenetic factors, more appropriate to the former forest-steppe environments.

Starting from the second half of the Holocene, they entered the phase of accumulative-eluvial soil formation following the return migration of natural zones and the expansion of boreal landscapes to the south. As a result, they provoked the degradation processes of organic (and mineral) phase that is why the traces of early Holocene accumulative stage of pedogenesis are partly preserved in the appearance and substantive properties of soils. Among them are residual mafic second humus horizons, ancient age, humate-calcium compound of organic matter of second humus horizons and other markers of former intensive bio-accumulative stage of soil genesis. If the direction of the spontaneous evolution established about 5 thousand years ago remains, we can expect complete erasure of the soil map of the area of soils with second humus horizons in the near or distant future. This explains the relevance of the priority inclusion of these polygenetic soils in the Red Data Book of soils. Their presence in our region throws further light not only on the history of the development of soil and vegetation cover, climate and landscapes in general in the late-post-glacial period (12–0 thousand years ago), but also has a significant potential for predicting scenarios for the future state of the pedosphere and landscapes of the Vyatka region.

The soils with a binary humus profile are of high scientific value due to the discovery of gray residual-carbonate soils with second humus horizons and insite paleocarbonate pedospheric relics, theoretically predicted earlier by N.A. Karavaeva, A.E. Cherkinsky and S.V. Goryachkin [18], but unknown until our research on the right bank of the lower Vyatka [16]. The sod-podzolic soils with second humus horizons developed on the boulder-loam sediments of the Chepetsko-Kilmezskaya upland (the suburbs of the village Medvezhena) should also be included in the Red Data Book of the region. No less valuable are gray soils with second humus horizons and buried humus horizons on the floodplain terraces of the Gon’binka river in the Malmyzhsky district.

4. Conclusion

The obvious conclusion is that the soil cover is unique, especially in the areas of cover loam of the middle and southern Vyatka basin and strongly transformed during agricultural development. In agricultural landscapes, most soils with relict phenomena have almost disappeared due to plowing second humus horizons and subsequent water erosion. Therefore, it is necessary to urgently conserve certain areas of unique bodies containing biotic and abiotic components that are disappearing at present – the priceless natural heritage of the Vyatka region – for science, biosphere and society. The
first steps in this direction should be the Red Data Book of soils, soil reserves and mini-reserves with reference zonal, rare, unique and endangered soils.

References
[1] Dobrovolsky G V and Nikitin E D 1990 Soil Functions in the biosphere and ecosystems (ecological significance of soils) (Moscow: Nauka)
[2] Nikitin E D and Girusov E V 1979 Shagreen skin of the Earth: Biosphere-soil-man (Moscow: Nauka)
[3] Chernova O V 1996 Planning the red data book of natural soils of Russia Eurasian Soil Sci. 28(7) 72–9
[4] Klimentiev A I, Chibilev A A, Blokhin E V and Groshev I V 1998 The Red data book of soils and the system of specially protected soil areas of the southern Urals Soil Sci. 3 347–58
[5] Tashninova L N 2000 The Red data Book of soils and ecosystems of Kalmykia (Elista)
[6] Chernova O V and Matveev Yu M 2001 Methodological foundations for creating regional Red data soil books, in: Reserve Management and Studies: Scientific and Tutorial Notes of the Commission on the Conservation Case vol 8 pp 60–73 (Moscow)
[7] Federal law of 10.01.2002 “On environmental protection” no 7-FZ
[8] Dobrovol'skii G V, Chernova O V, Semenyuk O V and Bogatyrev I G 2006 Principles of selecting reference soils for the Red data book of Russian soils Eurasian Soil Sci. 47(3) 216–22
[9] Klimentiev A I, Chibilev A A, Blokhin E V and Groshev I V 2006 Red book of soils of the Orenburg region (Yekaterinburg: Instit. of the steppe URO RAS)
[10] Nikitin E D 2010 Life basis of the Earth: soil – Russia – civilization (Moscow: MAX-Press)
[11] Nikitin E, Sabodina E P and Skvortsova E B 2014 Red Data Book of Eurasian Soils: Russia and contiguous countries Eurasian Soil Sci. 47(3) 216–22
[12] Kliment'ev A I, Kuksanova E V and Kuksanov V F 2014 Scientific and legal aspects of the red data book of soils Eurasian Soil Sci. 47(4) 334–8
[13] Chernova O V and Bezuglova O S 2018 Principles and features of the compilation of the red data book of soils of the steppe regions (on example of the Rostov oblast) Arid Ecosyst. 8(1) 28–37
[14] Dobrovolsky G V and Nikitin E D 2009 Red book of soils of Russia: Objects of the red book and cadastre of especially valuable soils (Moscow: MAX-Press)
[15] Prokashev A M 2009 The Genesis and evolution of soils in the basin of the Vyatka and Kama (Kirov: VyatSU)
[16] Prokashev A M 2012 Humus pedorelicts in soddy calcareous soils of the Vyatka-Kama interfluve Eurasian Soil Sci. 45(11) 1013–22
[17] Prokashev A M, Soboleva E S, Chepurnov R R et al 2016 Sod-podzolic soils with a complex organic profile of the southern Vyatka River basin IOP Conf. Ser. Earth and Environmental Sci. 41 1–9
[18] Karavaeva N A, Cherkinsky A E and Goryachkin S V 1986 The Concept of «Second humus horizon»: experience of genetic and evolutionary systematization Advan. in Soil Sci. Soviet soil sci. to the XIII Int. Congr. of soil scientists (Moscow) pp 167–73