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Chapter 14

Managing Chernozems for advancing SDGs

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Introduction

Increased awareness of the humankind of the challenges of increasing population, changing climate and progressing anthropogenic impact on the environment resulted in the articulation of Sustainable Development Goals (SDGs) that would give us a chance to pass through the perils of tomorrow. The key issue in the planning of the future is sustainability that should be based on the resilience of the nature and society. Healthy soils are essential for sustainable development, and thus their role in reaching the SDGs was recently highlighted (FAO 2015, Lal 2015, 2016b). Being soil scientists, we have to provide reliable and up-to-date information on the state, dynamics and potential behavior of soil systems under changing climate and increasing anthropogenic pressure.

Soil is a complex system closely linked with the other components of the environment, such as atmosphere, lithosphere, hydrosphere, and biosphere. In the past decades the significance of environmental functions of soils have been outlined (Dobrovolsky 1996, Giller et al. 1997, Doran 2002), which regard soils as the major link in the interaction between the geological and biological cycles of elements on Earth. Soil acts as an important regulator of the composition of atmosphere both on global and local levels; it is able to sequester carbon and nitrogen thus reducing greenhouse gases concentration in the atmosphere. Soils are active natural bodies able to exchange particles, molecules and ions with percolating rainwater, groundwater or irrigation water. This property makes soil a global filter that significantly affects the composition of the hydrosphere. Soil is also known as one of the biggest pools of biological diversity. Millions of microorganisms and invertebrates reside in soils being responsible for the sustainability of soil as life support system. Every year hundreds of new species are discovered in soils: it shows that we hardly know the extent of this enormous species reservoir. Global soil ecosystem functions influence ecosystem services related to soils as all the terrestrial ecosystems include soils as active components (Robinson et al. 2009). In the ecosystem soil is responsible for providing supporting services such as food supply, flood regulation, and water purification. Food supply is associated with soils, because most soils are fertile natural bodies able to support higher plants. Flood regulation is also soil-dependent ecosystem service, because soil water-holding capacity makes possible retention of big mass of water when flooding risk exists. Water purification is a service originated from the global filtering function of soils. Soil is also involved in the provisioning services. It is often regarded as an indirect source of food: though soil is not consumed directly, with few exceptions, the production of crops and feed for animals is impossible without soils. Soil is also a source of medicines such as antibiotics. Soil serves as a construction material and for pottery. It is also exceptionally important for regulating ecosystem services, including carbon sequestration and thus for global climate regulation. Waste decomposition and detoxication is also driven by microorganisms and invertebrates that are present in soil. As mentioned previously, soil regulates the composition of water and air. Cultural services of soils are also important, especially because the majority of cultures use soils for burial rituals. Soil is mentioned in many myths and legends both as the birthplace and final destination for humans. It is also recognized as "mother earth", giving food for people. Deep respect for soil is typical for all the agrarian cultures all over the world. Many tribes in the past and in present use soils as pigments for colouring the skin and hair (Ollier et al. 1971).

External soil functions are products of internal pedogenetic processes, which, in their turn, depend on environmental conditions (Targulian & Krasilnikov 2007). It means that the ecosystem services of soils are dependent on their properties, which, in their turn, are summarized in the taxonomic name of soils. Though soil taxa do not necessarily reflect exact set of soil properties (Krasilnikov et al. 2009), there is a good correspondence between soil taxonomic units on the highest level, such as Orders (USDA Soil Taxonomy) or Reference Groups (WRB), with the most important soil properties and functions. Moreover, each Reference Group corresponds to a specific set of soil-related ecosystem services (FAO 2015).

Sustainable soil management is a tool for achieving the SDGs. Recently, commitment was made to achieve sustainable development through the Sustainable Development Goals by 2030: these include 17 goals with 169 associated targets that are integrated and indivisible. Soils are inherent part of four targets and could indirectly contribute to other targets (FAO 2015):

SDG#2 is to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Target 2.4 demands to **ensure sustainable food production systems and implement resilient agricultural practices that progressively improve land and soil quality**. Maintaining healthy soils is a pre-condition to produce enough and nutritious food for all now and in the future. This goal can be achieved by transformation of farming systems, landscapes and entire agricultural community in accordance with environmental requirements.

SDG#3 aims to ensure healthy lives and promote well-being for all at all ages. Part of a goal Target 3.9 is to reduce the number of deaths and illnesses from hazardous chemicals and air, water and **soil pollution and contamination**. Therefore, practices of irresponsible mining must be counterbalanced by measures such as wastewater management and polluted dust control.

SDG#12 moves to ensure sustainable consumption and production patterns. Through Target 12.4 it aims to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and **significantly reduce their release** to air, water and **soil in order to minimize their adverse impacts on human health and the environment**. Soil contamination by mining, waste disposal and agriculture inputs constitutes a serious threat to human and environmental health. Actions should be taken to implement safeguarding and remediation practices, also to educate society about the impact of their actions on soil health. A key issue in the assessment of the current radioecological situation in regions of the European part of Russia contaminated by ^{137}Cs due to the Chernobyl accident in 1986, is to establish the parameters of the transition of the radionuclide in vegetation, which is directly used for human food or used for feeding to farm animals, which ultimately causes an increase in radiation doses to the population transferred through food chains (Paramonova & Romantsova 2013)

SDG#15 demands to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, **and halt and reverse land degradation and halt biodiversity loss.** Target 15.3 states to **restore degraded land and soil**, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world. One of the causes of soil degradation is the overuse of agricultural inputs. Instead, we should maintain and increase the organic matter content of the soil by promoting crop rotation and diversification, by choosing the proper agricultural technology and economic approach. For example, the changing in the economic situation after the collapse of the USSR resulted in a marked increase of the area of fallow land in Russia. So according to Federal State Statistics Service (2005), in the first ten-year period, the reduction of arable land occurred on 14.8 million hectares. The reduction of arable land had a positive impact on the ecosystem in general and on the restoration of a number of soil characteristics such as the stock of soil organic carbon. The rate of accumulation of organic carbon in soil after establishing meadow vegetation on the fallow land averaged from 33 to 99 gC/m^2 per year (Post & Kwon 2000, Guo & Gifford 2002, Kurganova & Lopes 2008). Summing up the interim Rothamsted experiment, Jenkinson (1990) established a negative effect of termination of fertilization on the organic carbon balance in the soil, in other experiments, for example, in Russia, there was the positive effect (Shevtsova et al. 2003, Smith et al. 2001). However, recommendations should be made based on reliable knowledge about the history of land use in a particular region. It is known that the content of potassium in the soil, which should be in the forms available to plants, is an important factor in the regulation of root consumption of ^{137}Cs. The system of protective measures for the rehabilitation of victims of radiation of farmland was built on the antagonism of these elements: it was recommended to apply higher doses of potassium fertilizers in the radionuclide contaminated areas (Aleksakhin & Korneev 1992).

Some other SDG's targets are connected with soil functions: Target 6.1, which stands to achieve universal and equitable access to safe and affordable drinking water for all. As we know, healthy soil is a natural filter to groundwater flows. The Target 11.4 is to strength the efforts to protect and safeguard the world's cultural and natural heritage. Thanks for their cultural services, soils are also important, especially because the majority of cultures use soils for burial rituals. Soil is mentioned in many myths and legends. Healthy soils are the basic resource for food, fuel, fiber and medical products. Targets 12.2 and 12.8 demand to achieve the sustainable management and efficient use of natural resources and to ensure that people everywhere have relevant information and awareness for sustainable development and lifestyles in harmony with nature. They can be reached through the implementation of sustainable management of soil resources (SSM). However, SSM needs a political commitment, which referred to Target 17.16 – enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries. The conservation and responsible management of soils is thus central to improve governance of the limited soil resources of the planet in order to guarantee healthy and productive soils for a food secure world, as well as support other essential ecosystem services, in accordance with the sovereign right of each State over its natural resources (FAO 2012).

Chernozems: definition, distribution, and functions

"Chernozems" is a folk name for black soils in Russia and Ukraine, which has been used in soil inventories in Russian Empire since 18th century. In the folk tradition the word was used in a broad sense almost for any dark-coloured soils, including well-decomposed peat (Krasilnikov et al. 2009). Later Russian scientific school narrowed the meaning of the name to dark-grey to black deep soils commonly found under graminaceous vegetation in steppe and forested steppe. In the World Reference Base for Soil Resources (IUSS Working Group WRB 2014) Chernozems are defined as soils with dark, humus-enriched, well-structured *chernic* topsoil horizon and *protocalcic properties*, i.e. with secondary carbonates, within the first meter depth. Further we will use the term Chernozems in the WRB understanding, because there are many differences in the understanding of these soils in national classifications. For example, in current Russia classification there are two soil types: chernozems *sensu stricto* and clay-illuvial chernozems. The latter group corresponds to Luvic Chernozems in the WRB, but not completely, because Russian concept of clay-illuvial chernozems includes also soils with deep secondary carbonates and those with migration carbonates (pseudomycelia, carbonate infillings in fine pores), which are not regarded as *protocalcic properties* in WRB because of their ephemeral nature. In the US Soil Taxonomy (Soil Survey Staff 1999) there is no single group that corresponds to Chernozems: many Great Groups in the Mollisols Order may be correlated with this WRB Reference Group, but most of them also overlap Phaozems, Kastamozems, Rendzic Leptosols and Mollic Gleysols. Some other classifications have similar concept that partly repeat the structure of Soil Taxonomy, for example the CHERNOSSOLOS Order in the Brasilian soil classification (EMBRAPA 1999) or Isohumisols in the Chinese classification (Gong Zitong 1994). Some overlapping of Chernozems with Kastanozems and Phaeozems (IUSS Working Group WRB 2014) may be also observed for Tschernosem and Kalktschernosem in German soil classification, Tschernosem in Austria, Chernozemic soil order in Canada, csernozjom talajok in Hungary, or Chernic Tenosols in Australia (Krasilnikov et al. 2009). Other classifications use a concept that completely fits the frames of Chernozems in the WRB, for example, CHERNOSOLS HAPLIQUE, CHERNOSOLS MELANOLUVIQUES, and CHERNOSOLS TYPIQUES in France, Czarnoziemy in Poland, Černozem in Czech Republic, Cernoziom in Romania, and Chernozems un Bulgaria (Krasilnikov et al. 2009). Most of national scientific schools regards Chernozems as with an A–C profile, in contrast to Russian understanding of Chernozems as soils with a developed B horizon with evident accumulation of clay and/or secondary carbonates.

The study of Chernozems has a long history (Krupenikov et al. 2011): in ancient Greece already in the 5th century DC "the father of history" Herodotus mentioned exceptionally dark and deep soils in Skythia. People working on these soils valued them for their natural fertility, and used for denominating them their black colour as the most obvious feature. The name "Chernozem" was widely used in Russia in the statistical books on land tenure and later appeared at the first general soil maps of European Russia. The distribution and origin of Chernozems was also addressed in the 19th century AC by German agrogeologists, who studied them in Eastern Europe and Russian Empire. A critical review of their views was given by Vasiliy Dokuchaev in 1883 in his seminal book "Russian Chernozem" (Dokuchaev 1967). Before this publication black soils of South-Eastern Europe were regarded either as marine sediments (e.g. the theories of R. Murchinson and A. Petzgold) or dried peatlands (e.g., E.I. Eichwald, F.F. Wangenheim and some others), but Dokuchaev argued that Chernozems were terrestrial soils formed under a combined effect of specific climate, vegetation, parent material, topography and the age of the landscape; this book is considered to be the first publication that outlined the principles of modern soil science (Krupenikov 1993). It should be recognized that folk understanding of the origin of Chernozems was correct from the very beginning: the farmers believed that Chernozems form due to the continuous accumulation of decayed plant roots. Also several researchers before Dokuchaev (e.g., M.V. Lomonosov and F.I. Ruprecht) believed that Chernozems are contemporary soils formed under graminaceous vegetation (see Krupenikov 1993). However, Vasiliy Dokuchaev made the biggest step in the understanding of the genesis and geographical regularities in the distribution of Chernozems. His book "Russian Chernozem" (Dokuchaev 1967) was based on his Doctor dissertation, which summarized his extensive studies in the frames of the project on the properties and distribution of Chernozems in European Russia, supported by the Imperial Free Economic Society.

The study included field survey of soils in the area of distribution of Chernozems in Russia with a laboratory study of organic matter content in soils; in the report Dokuchaev (1967) produced a map of spatial distribution of humus in Chernozems (Fig. 14-1). Later on the analysis of geographical distribution of Chernozems and their spatial relation with other soil groups has led Dokuchaev to the concept of latitudinal soil zonality. This concept was successfully applied for the soil map of European Russia produced by Dokuchaev and co-workers for the World Exhibition in Paris in 1900 (Fig. 14-2). The map legend included several groups of Chernozems: "chocolate" ("southern"), "ordinary", "fat", "northern" ("degraded"), "loamy sandy" and "skeletal"

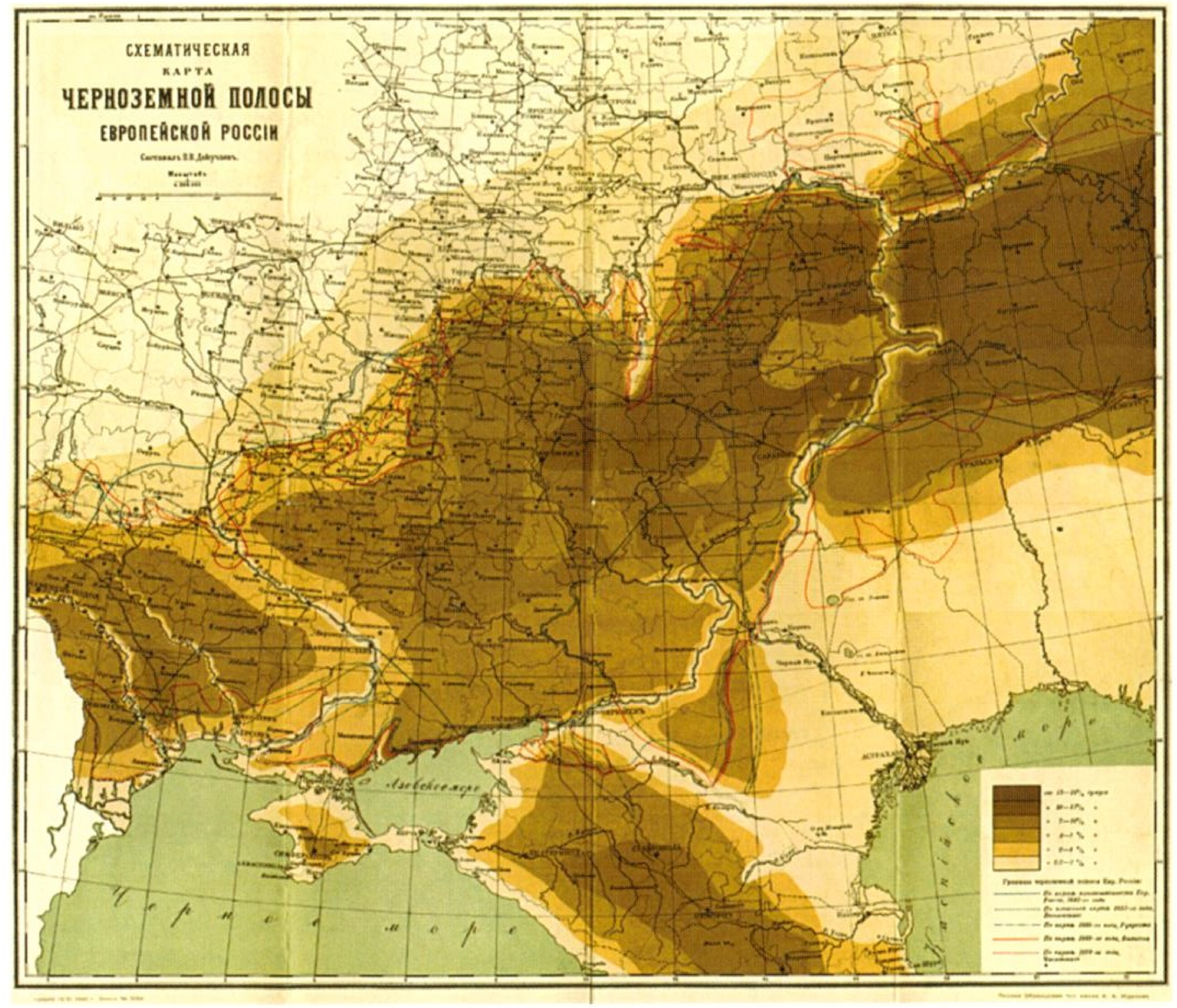

Fig. 14-1. Dokuchaev's map of humus content in Chernozem soils of the European part of Russia (Dokuchaev 1967).

chernozems. Partly these soils followed latitudinal zonal sequence from dry steppes to forested steppes, and partly indicated specific parent material. Since Chernozems were considered to be the most productive soils in Russian Empire, numerous early soil fertility studies were done also in the Chernozem zone (Krupenikov 1993).

Chernozems were identified and studied also in Central and Eastern Europe: in Germany, Romania, Bulgaria and especially in Hungary, where they covered a significant part of the country's area. At the American continent the presence of Chernozems was disregarded for a long time until the beginning of extensive soil survey of agricultural lands in the USA at the end of the 19th century.

The initial Dokuchaev's concept of Chernozem profile was relatively simple: he considered that it has humus-enriched A horizon, transitional B horizon and parent material – C horizon (Dokuchaev 1967). The B horizon was not regarded as a specific horizon with any unique properties. In German concept this idea is expressed even more evident: Chernozem is supposed to be an A-C soil (Krasilnikov et al. 2009). However, current soil classification of Russia recognizes the presence of an individual B horizon in Chernozems, which either has secondary carbonates or evidences of their leaching and consequent clay illuviation (Arnold 2001). The WRB concept

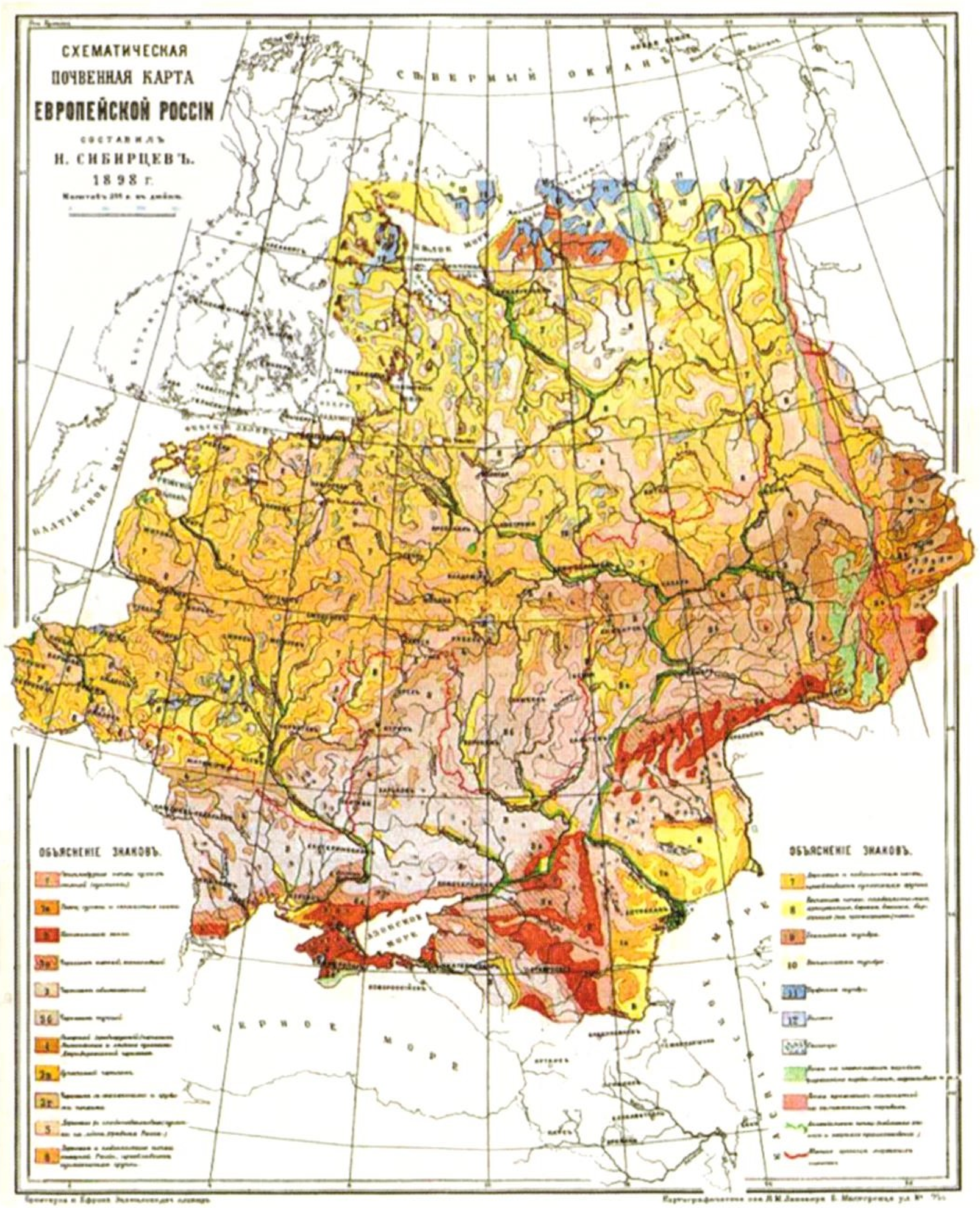

Fig. 14-2. Soil map of the European Russia of the scale 60 verst (1 verst = 1.06 km) in 1 inch.

is flexible: the variety of modifiers allows including in the Chernozems Reference Group both soils with a specific B horizons and having a simple A-C profile (IUSS Working Group WRB 2015).

The total area soils with a dark-colored *mollic* diagnostic horizon, is 8.23 x 10^6 km^2 in the world, which is 6.49% of the Earth's land surface, home to 6.6% of the world's population

(Blum 2013). The area occupied by Chernozems *sensu stricto* is much smaller – about 230 million hectares (2.3 x10^6 km^2). With a fairly wide strip they pass through all of Eurasia from the Hungarian Pasht to the uplands of Mongolia and the great plains of Northern China. They are formed mainly in the steppe conditions of Eurasia and North America, north of the zone with Kastanozems, which form under dryer and hotter climate. Figure 14-3 provides an overview of their main distribution areas.

Fig. 14-3. World distribution of Chernozems, generated using SoilGrids250m (Hengl 2017).

In Europe, the zone of Chernozems partly covers Hungary, Bulgaria, Austria, southern Germany, the Czech Republic, Slovakia, Romania, the Balkan Peninsula. A vast territory with Chernozem is reported in Ukraine – 27.8 million hectares (Mha). In Moldova, Chernozems cover 75% of the territory of this small republic that equals to 2.54 Mha. However, the largest areas fall to Russia – 122 Mha. These are the Central Chernozem region of Russia, the Volga region, the Northern Caucasus, the Southern Urals, Western Siberia. Further to the east, Chernozems occur in the plains and foothills of the Altai, on the outskirts of the foothills of the Eastern Sayan. Chernozems are widespread in the northern part of the Republic of Kazakhstan and occupy 25.5 Mha, or 9.5% of the territory of the republic. One of the three largest black earth zones in the world is in China, here they are concentrated on the largest in the PRC North-East plain, and are often characterized by a loam. Chernozems are also found in Mongolia. In North America, the zone of chernozems is confined to the south of Canada and the western part of the USA, where it borders on Phaeozems that cover the major part of American prairies.

Chernozems are generally recognized for their natural fertility, but they are responsible also for other soil-based ecosystem services. In the Report on the Status of World Soil Resources (FAO 2015) the contribution of the main soil types to major ecosystem services (food security, climate regulation, water regulation and socio-cultural provisions) was estimated at a scale from zero to five. The ratings were based on soil characteristics and quality as measured by: suitability for growing crops, organic carbon content, water holding capacity, and capacity to support infrastructure and store archaeological remains. Chernozems got the third score among all the soils overtaken by Anthrosols and Histosols. Chernozems received the highest score for food production, 4 points for climate change mitigation, 4 points for water regime and water quality regulation, and 1 point for cultural services. The rating is debatable, because it is difficult to agree that the ability to preserve archeological artifacts has the same value as food security. Also the introduction of the support of biological diversity could change the sequence of soils in the rating, because Chernozems are known for a very high level of the diversity of microorganisms and soil invertebrates (Orgiazzi et al. 2016).

Importance of Chernozems for SDGs

As mentioned above, the main ecosystem service of Chernozems is related to food security, and thus corresponds to the Target 2.4 of SDGs that demands to ensure sustainable food production systems and implement resilient agricultural practices that progressively improve land and soil quality. High fertility of Chernozems is provided by a unique combination of very favorable chemical and physical properties. More than half of their area is cropland – maize, wheat, sugar beet and sunflower are the main crops (FAO 2015). The average yield of grain crops on Chernozems is higher than that on other soils, especially of wheat (*Triticum aestivum*), which is demanding of soil conditions. The main limiting factor for increasing yields on Chernozem is the demand for water, thus the productivity of these soils is higher in the northern forested steppe areas with more humid climate than in the south with insufficient rainfall under dry steppe vegetation.

Though Chernozems are recognized as very fertile soils, it is interesting to note that the yields in the countries where most crops are cultivated on Chernozems and similar soils are low compared with that of the countries where Chernozems occupy small areas or completely absent. For example, the yield of grain crops in Russia is around 2.5 Mg per ha, while in The Netherlands it is 9.0 Mg per ha and in the United Kingdom comes up to 10.0 Mg per ha. It should be mentioned, of course, that the values mentioned above are not soil specific, but the yields reported for winter wheat for Chernozems in Russia are also not very impressive: they lie between 3.0 in average and 5.0–6.0 Mg per ha for the advanced farms (Biryukova et al. 2015). This phenomenon may be explained by two reasons. The first reason is water demand that is higher in dry and hot areas of southern Russia, where irrigation is not applied, and most of the water storage is formed in winter and spring periods; this issue is discussed in details below. The second reason lies in an insufficient use of mineral fertilizers in Russia and in the Post-Soviet space in general. Actually, the doses of NPK fertilizers applied in Russia hardly reach 16 kg per ha of arable land that is about 10 times less than in USA and India and 35 times less than in China. Low intensity agriculture like in Russia has both benefits and disadvantages. On the one hand, application of reduced doses of chemicals may be regarded as beneficial for the environment. On the other hand, low yields reduce food security; also the lack of chemical fertilizers results in "nutrient mining", when the crops extract necessary elements from the stable mineral and organic compounds (FAO 2015). It has not been shown that extensive rather than intensive agriculture may contribute to soil conservation. Conversely, the extensive way of agricultural development commonly causes soil degradation and consequent drop in the yields. Chernozems are thankful soils, and if managed with care can produce high yields of a broad variety of crops, but they are also vulnerable to degradation processes, such as wind and water erosion, nutrient depletion, and organic carbon loss. Infamous dust storms in the Midwest of USA and in the virgin lands of Northern Kazakhstan are the most evident examples of improper Chernozem management. The highest yield of wheat obtained on Russian Chernozem was 10.4 Mg per ha, and the highest ever recorded in Canada –17.0 Mg per ha (Biryukova et al. 2015). It means that the improvement of soil management in Russia can increase the yield of winter wheat from average 3.0 Mg per ha at least three times, and in the case of sustainable intensification – more than five times. There is a big gap between their current and potential productivity. Consequently, Chernozems may serve as a potential "bread basket" for the future, when world agriculture would face the need for feeding increased population of our planet.

Target 3.9 aimed at the reduction of soil pollution and contamination together with other environments is close to Target 12.4, which aims to achieve the environmentally sound management of chemicals, including prevention of their release to soil. Though these targets may seem to be independent of specific soil groups, there are some peculiarities of Chernozems that make them important for reaching the targets mentioned above. All the soils on the Earth are affected by technogenic pollution, but different soils have different buffering capacity and different capability to immobilize toxicants. In this respect Chernozems are effective filter for the environment, because these soils absorb most of heavy metals and organic pollutants due to high content of active humic substances with large specific area. Also neutral or slightly alkaline reaction of Chernozems and the presence of fine calcium carbonate favor immobilization and fixation of multiple trace elements, which are active in acid and strongly alkaline solutions. It does not mean that Chernozems may be fearlessly polluted, but at least the presence of Chernozems facilitates the task to reduce contamination to tolerance level.

The SDG Target 6.1 stands to achieve universal and equitable access to safe and affordable drinking water for all. Healthy soil is known to be a natural filter for groundwater. Target 6.4 aims at solving the problems of water scarcity and aims to ensure the availability of sufficient quantities of water for the population, economy and environment by improving water use efficiency in all sectors of society. Guaranteed satisfaction environmental water requirements – that is, the preservation of sufficient quantities of water in the environment at a particular point in time to ensure the sustainability of natural processes is critical from the standpoint of maintaining the health and resilience of ecosystems (closely related to target SDG 6.6 and 15).

Considering sustainable use of water resources with reference to the Chernozems it is necessary to answer the following questions: How the transformation of moisture regime of Chernozems affects pedogenetic processes in these soils? What risks of degradation processes exist for unsustainable use of water resources on Chernozems? What economic benefits will be received under the sustainable use of water resources in the area of distribution of Chernozems? Currently one can observe the development of complex combinations of various pedogenetic processes in Chernozems caused by waterlogging: an active process of rising the surface saline groundwater, salinization and compaction.

Current agronomical activities causing an abrupt transformation of the hydrological regime of the soils and their degradation, the most significant incidence are the compaction of subsurface horizons as a result of processing by heavy machinery and the use of heavy vehicles. The danger of this phenomenon, which is common on the vast modern agricultural fields, is the "rolling" of the soils over the entire area. There is no way for a comparative visual assessment of damage to agricultural production and environmental condition of the soil. However, the damage is significant. It is associated primarily with the forced redistribution of surface and subsurface runoff as the result of soil compaction.

Irrigation in the Chernozem zone is one of the most powerful factors which affect the natural trends in the development and functioning of soil, which leads to the occurrence of side and often negative effects, threatening the harmonious development of the natural environment, and often leads to critical environmental situation. It is created and artificially maintained soil water regime, which is not characteristic for natural conditions and requirements to obtain maximum yield of agricultural products. This circumstance has a significant impact on the ecology of landscapes, changing its climate parameters, hydrology, vegetation, biota and soil. Irrigation promotes the conversion of biological objects of nature to an artificial ecological system. The feature of this system is that it is not sustainable and requires constant external intervention. This leads to disruption of the ecological balance in the environment. Ecosystem, of course, has a large capacity for self-regulation and resilience. However its capability is not boundless, and we are increasingly faced with the vulnerability of the natural environment at local and regional levels. Irrigation, moreover, is accompanied by deterioration of water quality in rivers and reservoirs – the main sources of irrigation water – as a result of discharge of collector-drainage water, and contamination of surface and groundwater with salts, fertilizers, pesticides etc. Due to the lack of fresh water in the Chernozem zone for irrigation it is increasingly applied the water of high salinity (2–4 g per dm^3). The use of saline water for irrigation leads to degradation changes in soils in the first 2–3 years (Gennadiev et al. 1993).

Numerous studies related to the problem of irrigation of Chernozems showed that they are extremely complex objects for irrigation. The opinion of the high buffer capacity of Chernozems in relation to their response to additional moistening was insolvent. The processes arising in the Chernozems under irrigation, their direction and intensity often lead to such degradation changes, which are difficult to predict, especially in the long term. The high content of humus and clays of smectite type provides high buffering against pollution, but, at the same time, leads to an extraordinary sensitivity to additional moistening (Rozanov 1989).

In Chernozems under irrigation almost always there is an evident of loss of calcium due to leaching. Soil humus is also extremely sensitive to changes of the environmental conditions. Irrigation as a factor that changes not only the hydrological regime of the soil, but also the environmental condition of the landscape, certainly influences the humus state of soils. Despite the inconsistency of judgments about the pathways of organic matter under irrigation and, in general, humus state of soils, we should recognize the inevitability of its change. The nature of the changes, their direction and depth are determined by many factors, which complicates their prediction (Rozanov 1989).

One of the clearest manifestations of the negative effects of a powerful anthropogenic impact on Chernozems is a progressive increase of the degree of waterlogging in natural ecosystems (Bezuglova & Nazarenko 1998). This is reflected in the rise of groundwater level (GWL) and the formation of depression with waterlogged soils. They appear in the forms of spots among the automorphic soils and, once established, will never disappear, and the Chernozems for a short time transform in soils with hydromorphic features, almost always with signs of salinization and gleyezation, depending on lithological and hydrochemical conditions of a particular landscape. As a result, the agricultural value of cropland is also reduced. Some portion of the lands falls out of agricultural land use that creates difficulties in their management in the future.

The anthropogenic factors that creating the conditions for waterlogging the soil and causing increased complexity of the soil cover are the following:

- Blocking surface and subsurface flows by shelterbelts, field roads, road barrow, etc., which are constructed in most cases without respect to the direction of movement of the surface, subsurface and groundwater, hindering the free flow of moisture.
- Purposeful changing in the water balance of Chernozems in the direction of increasing its income to improve the water regime, ensuring stable water supply of agricultural crops. This massive irrigation of the Chernozems leads to the change of non-leaching water regime of the soils that contributed to the widespread rise in groundwater levels. In addition, resulting in a variety of soil cover on the rate of humidity in the irrigated areas.
- Regulating of the flow of the rivers that is a powerful intervention in the ecology of the region. Rivers turn thus into chains of stagnant water, silting and overgrown marsh vegetation. They cease to perform the role of natural drains and backwater from them is spreading to a considerable distance, resulting in a regional rise of the groundwater table, contributes to the appearance of flooded land.
- Soil compaction under the influence of heavy machinery. The result of soils compaction leads to the reduction of water permeability and stimulating further stagnation of moisture on the surface of the soil.

The transformation of Chernozems into hydromorphic soil, in addition, reduces the agronomic value of arable land, leads to loss of Chernozems, as the unique soils in the world, which is practically non-renewable natural resource. Transformed soils lose their ability to perform certain ecological functions developed in the long process of evolution of the steppes. Firstly, they lose the functions of controlling the composition of the lithosphere and hydrosphere that determine the water balance for the steppe landscapes and groundwater. In addition, it is necessary to assess the impact of irrigation on agricultural economics in the changing climate for deeper understanding of the need for sustainable use of water resources of Chernozems.

Russia has extensive land resources and in the near future is focused on increasing agricultural production (Ministry of Agriculture of Russian Federation 2012). However, different consequences of global warming require a differentiated approach to decision-making (Uskov & Yakushev 2009). Hence, the scenario analysis methods were used along with forecasting in agriculture and assessing the impact of global warming on production processes, the consumer market and the State, in general. An econometric model – IMPACT, allows making scenario forecasts for the development of agriculture in different countries of the world, taking into account climate change (Rosegrant et al. 1995). The number of regions in the basins of the Volga river and the Black sea with an abundance of Chernozems, for example, Krasnodar, will face an increase in droughts and decrease in grain yield up to 15% (Kiselev et al. 2013). Irrigation systems allow farmers to reduce climate risks, particularly droughts. According to the National report (2013), in, 2010, when there was a drought in the European part of Russia the yield of wheat by 37% in non-irrigated land compared to the previous year, whereas in irrigated land it was decreased only by 12%.

Evidence-based implementation of sustainable and systematic exploitation of irrigation systems can help to maintain moisture in the soil and increase the fertility of the land, which will be reflected in the growth of crop yields. In the model IMPACT-3 irrigation leads only to a positive effect, because the higher yields originally set in irrigated lands. It must be borne in mind when interpreting the forecasts, and that irrigation should not be considered as an exclusive benefit only, but rather as an opportunity of sustainable agriculture in compliance with all other standards in agriculture and ecology.

The results show that the first scenario (expansion of irrigated areas) more favorable to agricultural producers – their profits will grow by 11% and consumer welfare by reducing consumer prices will increase slightly – by 0.4%, thus, total welfare of Russia will increase by 2% (the module was determined on well-being 2030). Such an increase in welfare only through expanding irrigation suggests the need for irrigation development in the country (Kiselev et al. 2016).

The other important Goal is to "take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy". Especially soils may be addressed in the target 13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries". In this context we should consider the resilience and adaptive capacity of Chernozems to the climatic change; also it is useful to discuss their role in mitigation of global warming. It is known that the limiting factor in the production of high yields on Chernozems is a lack of moisture, and the increase in the frequency of drought would affect the properties of soils. This is due primarily to the fact that the period of biological activity of the soil, its duration and intensity, are associated with the accumulation of humus, determine its qualitative composition. This is confirmed by studies conducted in the south of Russia, which proved that there is a direct correlation between biological indicators and annual rainfall and the reverse – with the temperature amplitude. It is shown that the humus content increases with increasing humid climate: a change in the average annual precipitation by 100 mm leads to a change in the humus content in the upper horizons of the soil by 0.98%. To a lesser extent, the humus content depends on the temperature parameters. Thus, climate aridization would likely lead to a change in the air and water regime of Chernozems, and, in general, will adversely affect its properties: reduce the intake of plant residues, decrease humus and nutrient content, especially nitrogen, deteriorate the structural state. In the light of the foregoing, the warnings of serious scientists about the shortage of food to come in one to two decades are very timely (Blum 2013). In brief, Chernozems would be rather vulnerable to climatic change, and the loss of big amounts of carbon would have a dramatic effect on the emission of greenhouse gases to the atmosphere. However, the application of low-carbon management practices, application of stable organic fertilizers, reducing tillage may increase the stock of carbon in Chernozems and thus mitigate the climatic change (Minasny et al. 2017). Since Chernozems in their natural state could have a significant storage of organic matter, they may serve as a stock for carbon under appropriate management.

Target 15.3 states to restore degraded land and soil, and Chernozems are in the first line for restoration as the most productive soils in the world. There are some specific details in Chernozem restoration and remediation. Like many other soils, strongly eroded Chernozem is difficult to restore, because the development of it's a horizon lasts for millennia. However, Chernozem is less vulnerable to sheet water erosion and deflation, because the humus-enriched horizon is deep, and even the loss of upper 10–20 cm is not as dramatic, as it would be for shallow soils. Chernozems commonly lose their famous structure due to compaction or crushing of aggregates. In this case leaving the soil under fallow with natural grass vegetation may be a good option. Chernozem salinization and sodification are common degradation phenomena related to irrigation, which should be treated with care. Combination of irrigation with drainage, gypsum application and other ameliorative techniques may be effective, but the best way is to avoid irrigation in the cases if salinization or sodification hazard exists. Soil restoration is an expensive process, but for Chernozem the benefits would be high.

Conclusions

Dokuchaev believed that Chernozem is more valuable than gold. Under the pressure of the challenges of increasing food demand, climatic change and increasing contamination we can easily lose this valuable natural resource, because it suffers an intensive pressure of agricultural management under dryer climate and increasing population. To protect it from extinction we should recall SDG Target 17.16 – to enhance the global partnership for sustainable development. We need a political will to reduce radically soil degradation, especially of the most fertile soils in the world – Chernozems. There are many initiatives aimed at soil sustainable use and management, and there should be more of them. We would like to mention one of them directly related to Chernozems. Global Soil Partnership, an umbrella initiative of FAO for international cooperation for sustainable soil management, initiated a subsidiary partnership – an International Network of Black Soils. It is supposed to attract attention to the specific issues related to soils with deep organic matter-rich soils, including Chernozems, which are located in the most important grain-producing areas of the world. For many years these soils were regarded as bottomless bread-baskets, but now we need action to prevent the decline of their fertility and loss of their ecosystem services.

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Chapter 15

Sustainable Development Goals and the International Union of Soil Sciences

Rattan Lal

Introduction

Restoration and sustainable management of soil health are inherently built into the program of all Divisions, Commissions and the Working Groups of the International Union of Soil Sciences (IUSS). Through numerous activities, Divisions of IUSS promote research and outreach on themes such as: conservation of soil and water, soil organic carbon sequestration and management, sustainable intensification of soil of the managed ecosystems, and climate-resilient agriculture. The focus of IUSS is to promote research and outreach to strengthen provisioning of ecosystem services by restoring soil health. The latter is directly and indirectly related to advancing Sustainable Development Goals (SDGs) of the U.N. or the Agenda 2030.

International meetings of pedologists commenced with that of a small group that met in Budapest in 1909. It is this group that formally established the International Society of Soil Science (ISSS) at the 4th International Conference of Pedology held in Rome, Italy from May 12–19, 1924. The primary objective of ISSS was to increase research on soil globally and develop standard methods of soil analysis (Van Baren et al. 2000, Hartemink 2015). The ISSS was organized into six soil commissions: **(I)** Physics, **(II)** Chemistry, **(III)** Biology and Biochemistry, **(IV)** Cartography, **(V)** Classification, Nomenclature and Mapping, and **(VI)** Rural Engineering and Drainage. The newly formed ISSS held its first triennial Congress in Washington, D.C. on 13–22 June 1927. The first President of ISSS was J.G. Lipman (1924–1927), Dean of the College of Agriculture and Director of the Experiment Station at Rutgers University and State University of New Jersey (Anonymous 1924a, b, Keen 1927). The Executive Committee of the First Triennial Congress of IUSS comprised of Dr. Schreiner and Dr. McCall of the U.S. Bureau of Soils and Dr. Shutt of Canada. The President of ISSS, Dr. J.G. Lipman managed to procure $75,000 to organize the first Congress followed by a soil tour of North America. The Congress was attended by about 400 soil scientists from around the world with prominent attendance from Russia (20), Germany (10), and U.K. (7) (Keen 1927). Prof. K. Glinka of Leningrad, Russia was the leading scientist on Classification, Nomenclature and Mapping. Other scientists who attended the first Congress consisted of Dr. Woods and Dr. Baker of the U.S. Bureau of Soils, and Dr. Weir and Mr. Goll of USDA, Sir John Russel and Dr. B.A. Keen of U.K., Prof. Lemmerman of Berlin, and Prof. Sigmond of Budapest. The Congress was addressed by President Coolidge, 30th President of United States (Keen 1927)

The name International Union of Soil Sciences (IUSS) was adopted in 1998. Altogether, ISSS/IUSS has thus far organized 20 World Congresses of Soil Sciences (WCSS). The 20th WCSS was held in Jeju, South Korea in 2014, and the 21st Congress is held in 2018 in Rio De Janeiro, Brazil. The latter is hosted by the Brazilian Society of Soil Sciences. Among its major accomplishments, IUSS facilitated the development of the soil map of the world (Dudal & Batisse 1978) and