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Secondary Salinization of Soils in Russia

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Abstract. Secondary salinization is one of the most widespread types of soil degradation in Russia. It is most widely spread on irrigated lands in steppe and dry-steppe regions of the country. Based on data obtained over the past 30 years, the database on secondary salinization of soils in Russia has been updated. As a basis the data of the uniform state register of soils of Russia which is completely compatible to a format of the Soil and geographical database of the European Union are used. The information on prevalence of secondary saline soils and secondary sodic soils has been specified. It is shown that in Russia, in contrast to other countries of the world, a greater danger is secondary sodification of soils. The results are presented as vector layers in geoinformation format.

1. Introduction

The mankind faced with the anthropogenic-initiated salinization in soils already at the dawn of agriculture, which historically emerged in relatively favourable conditions of subtropical, subhumid climate on fertile lands of river valleys. The disaster that suddenly befell farmers in those distant times, which manifested itself in the widespread soil salinization buried many ancient civilizations, which turned out to be absolutely helpless facing with the ecological disaster, the reasons for which, from the point of view of modern science, were unskilled land exploitation. The transition to industrial agriculture in the world, which coincided with an unprecedented increase in scientific knowledge about land, made it possible to conceptually assess the role and significance of salt migrations and accumulations in soils initiated by anthropogenic influence.

Despite some success in the diagnosis, prevention and elimination of secondary salinization, this type of degradation still occupies one of the world's leading positions. According to FAO, about 40 percent of the world's irrigated land is currently subject to secondary salinization. The total area of salinized soils has reached almost 1 billion hectares at the beginning of the 21st century. The phenomena of soil salinization are spread mainly in Europe, Northern Asia, North America. Secondary salinization plays a leading role in Central and South Asia, Africa, Australia and South America [1,2].

In Russia, traditionally since the times of the USSR, the problems of secondary salinization of soils have been given considerable attention, taking into account the scale of irrigation construction in the second half of XX century. The innovative approach to the problem at that time, made it possible to develop a very convincing idea of the essence of the mechanism of salt migration and accumulation in soil, to develop recommendations for preventing and combating secondary salinization [3].



The soil map of Russia (scale 1: 2.5 million) published in 1988 contained a certain set of data on saline soils [4]. Through the efforts of the staff of the V.V. Dokuchaev Soil Institute at the turn of the 80's was prepared the "Map of the types of chemical salinization of soils of the USSR" (scale 1: 2.5 million) [5], which managed to identify the regularities of the combination of saline processes and reflect the geographical aspects of the distribution of salinization in USSR. Despite the obvious achievements, the map sinned by schematism, lack of information about the properties of soils in Siberia and the Far East, the imperfection of the original cartographic sources [6].

As time has shown, the social and economic problems facing the post-Soviet Russia did not allow the state to fully concentrate efforts on the development of the scientific base of agriculture, which entailed a growing shortage of primary data on the soils and significantly slowed down the development of ideas about the changing characteristics of natural and anthropogenic landscapes. As a matter of fact, soil-cartographic works were suspended.

Rapidly introduced into practice of scientific researches the advanced computer technologies have cardinaly transformed a spectrum of possibilities and speed of reception of the necessary information. However, the peak of their development, came in a period characterized by a very financially difficult and limited in organizational terms situation, concerning the obtaining of primary information on the peculiarities of soil formation in such a vast and heterogeneous territory, which occupies the Russian Federation. As a result, to this day the main soil-cartographic matrix for assessment studies remains the soil map edited by V.M. Fridland [4].

We have made an attempt to update information on secondary salinization of soils in Russia.

2. Object and Methods

According to available published materials, at the turn of the 90s the area of secondary saline arable land in Russia was on average about 1.5%. The processes of secondary salinization, in turn, covered the territory of arable lands with the size of about 9.5 million hectares. As can be seen from the above information (and this is confirmed by our data) the ratio between secondary salinized and secondary sodified soils in Russia is in the range of 1:5. And although secondary salinization processes are absolutely dominant on the planet, in Russia secondary sodic soils are much more common. Moreover, in the European part of the country secondary sodic soils covers first of all the south of the chernozemic zone with highly fertile soils [7].

The ploughing zone, which has decreased dramatically after the collapse of USSR, gradually recovered partially in the 2000s, while irrigated lands continued to decrease. At the same time, according to available data, areas of previously irrigated land that had been degraded and lost their fertility due to salinization and depletion of fertility were primarily abandoned [8,9].

According to E.I. Pankova, soil areas affected by secondary salinization make up less than 11% of all saline soils in the Russian Federation, while secondary sodification occupies more than 40% of the total area affected by this type of degradation [6].

In our analysis we have based on the geometric part of the Unified State Register of Soil Resources of Russia (scale 1: 2500000) in vector format [10]. The same map is a part of the European Soil-Geographical Database [11]. This predefines the compatibility of our map with the European Soil-Geographical Database.

At the first stage, information on secondary soil salinity was extracted from the geoinformation database "Soil degradation of Russia" [12]. Then this information was expertly analysed and updated on the basis of information about the properties of the soil in each specific soil mapping unit. After that, the information on secondary soil salinity was corrected taking into account the soil ploughing map of Russia [13]. Additional information from archive soil maps and scientific publications accumulated over the past thirty years was entered into the attribute database of the updated secondary soil salinity map. The updated map was created using the GIS ILWIS and then converted into a shapefile format. As attributes, the map contains information on soils secondary salinization, and sodification processes. The map was validated against a number of test sites throughout Russia, where the large-scale soil maps were available.

3. Results and Discussion

3.1. Secondary Salinization of Soils

The distribution of secondary saline soils on the European part of the country is the following (Figure 1).

The Volgograd Region (12% of soils are secondary salinized), the Stavropol Kray (8% of soils are secondary salinized), the Rostov Region (5%) and the Republic of Dagestan (5%) are distinguished here first of all. According to the obtained data, the most affected are soils of the spurs of the Volga Upland adjacent to the Tsimlyanskoye reservoir with automorphic solonetz and saline-chestnut soils.

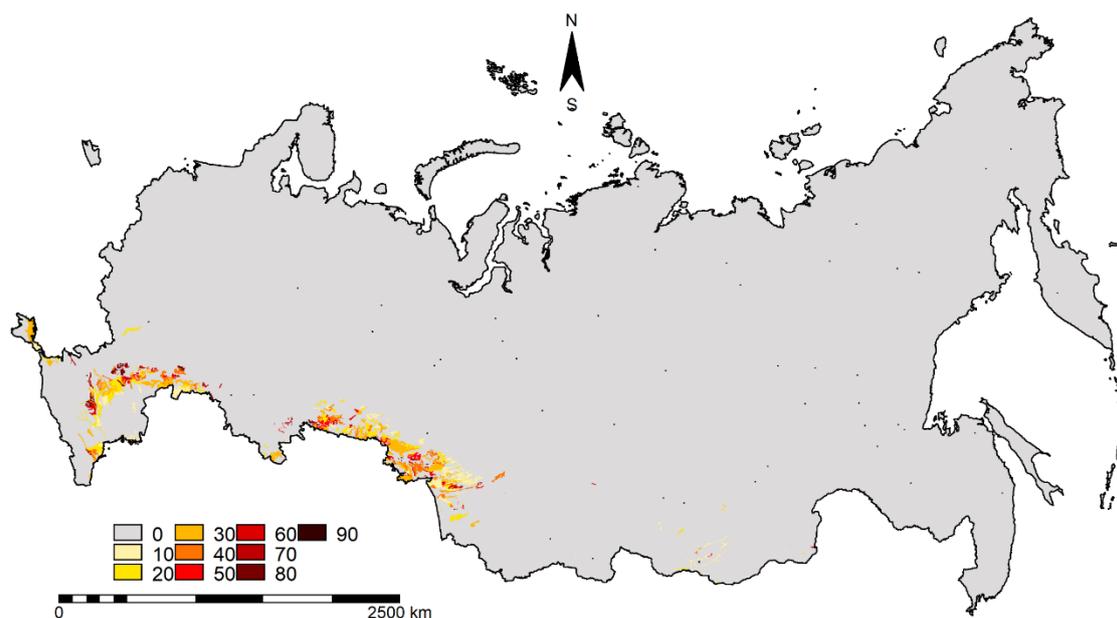


Figure 1. Map of secondary salinization of soils in Russia (percent from soil mapping unit).

Our data in general coincide with the published materials [14], and are well illustrated by the results of studies of A.F. Novikova, and E.I. Pankova, according to which the greatest damage to irrigated areas with respect to secondary salinization was caused in the 60-70s, when drainage was poorly used, and construction and commissioning of irrigation systems were not supported by sufficient information on soil properties and landscape features of territories. As a result, when the irrigated areas were abandoned (the irrigated area fell from 4.6 (1989) to 3.2% (2001)), desalinization on heavy loamy soils was almost not observed. Moreover, secondary salinization continues to develop even in rainfed conditions [15].

In the Stavropol Krai, the primacy in secondary salinization can be naturally given to arable lands of the Kuma-Manych depression with dark chestnut solonchaks, and solonetz soils, where the territory of salinization in the bend of the Kalaus River reaches 90%. The northern slope of the Stavropol Upland with saline chestnut-saline soils and automorphic solonetz is also characterized by higher salinity levels. In addition, relatively high salinity of light chestnut soils in the southwest of the region should be noted (Nogai steppe - up to 30%).

Speaking about secondary salinization in the Rostov region, we emphasize that the irrigated massifs, mainly confined to the terraces of the Don, Sal, Manych, Kuban rivers, gradually put into operation since the late 50's of the twentieth century, have similar types of agricultural lands as in the Volgograd region. Exactly during this period main massifs (up to 40%) of irrigated lands were secondary salinized. Efforts made by ameliorators in the period from the end of the 70s to the second half of the 80s allowed to stabilize the situation to some extent and create relatively favourable

conditions for irrigation on new lands. However, in the following years, some irrigation systems went into disrepair, land reclamation construction was stopped and research activities became fragmented. As the authors stress, “over the last 10-15 years, no systematic study of the irrigated lands has been conducted” [16].

According to our estimates, the situation is extremely unfavourable in the vicinity of the Proletarian Reservoir (70% of the dark-chestnut soils is secondary salinized). Large areas of secondary salinized soils are situated in the floodplain of the Yeya River, and on the left bank of the Chir River (south-east of the region).

In Dagestan, near 20-40% of soils in the Terek valley are secondary salinized. Secondary salinization is also observed in the south-east in the zone of dominance of meadow saline soils on the Caspian coast and in the north-west of the republic, in the Nogai Steppe, with light chestnut saline soils. Our estimates coincide with the results of many years of research expedition of the Faculty of Soil Science of Moscow State University in this region [17]. High level (1-3 m) of mineralized (25-80 g/l) ground waters is considered by the authors as a fundamental cause of secondary salinization under conditions of high capillary rise capacity of soils in the irrigation zone [18].

The limited irrigation lands results in moderate coverage of secondary salinization of the territory of Kalmykia. At the same time in the eastern part of the Republic, in the area of Yergeny, 10-20% of the land is secondary salinized, and in the Manych valley are isolated areas, within which soils with secondary salinity occupy near 70% of the land.

The Krasnodar Krai (only 2% of lands with secondary salinization) and the Astrakhan Region (1% of lands with secondary salinization) show relative prosperity in salinization of irrigated lands.

In the Lower Volga Basin, the processes of secondary salinization cover to a great extent the territory of the Saratov Region (6%). Our results correlate with the data available in the literature on the scale of secondary salinization of the region [19].

Secondary salinization of soils in Voronezh oblast, which occupies about 1% of the territory, is characterized by expressed localization. This phenomenon is widespread in the interfluvium Bitug - Kholov in the south of the Oka-Don Plain.

The problem of secondary salinization of soils on the Crimean Peninsula is notable. At present, the greatest concern is the north-eastern region of Crimea with meadow-chestnut saline soils in combination with solonchaks and dark-chestnut saline soils (30% of them is secondary salinized).

In the Urals and Siberia in contrast to European part of the country, object of salinization are chernozems. At the same time, according to our analysis, secondary salinization gets the greatest scale in Kurgan (12%) and Omsk (10%) regions. Secondary saline soils also occupy significant areas in the Novosibirsk Region (7%). Soil patterns with increased salinity due to anthropogenic factors are a characteristic element of the soils in the irrigated areas of the south of the Chelyabinsk Region (4%) and the Tyumen Region (3%). Among intensively used irrigated agricultural lands, saline lands in Orenburg Oblast and Altai Krai account for a certain share (near 1% in each of these regions).

Another distinctive feature of the conditions for salt migration in the Trans-Urals and Siberia is the pronounced natural overlogging of the lowland landscapes of Baraba and the Ishim plain. It is the western part of the Ishim Plain, occupying a vast territory in the east of the Kurgan region with a motley saline chernozems, that is the main source of secondary saline accumulation. The western districts of the Kurgan oblast are also characterized by a high share of secondary saline soils (10-40%).

Secondary salinity of soils is also common in the Novosibirsk, and Omsk oblasts, manifesting itself to some extent in fact on 2/3 of its territory (except for the north). Landscapes of Barabinsk lowland here, in the western and central parts of the region are favourable for the development of secondary salinization of soils (10-30% of soils are affected).

The Chelyabinsk Oblast, in its turn, is characterized by secondary salinization spots in the southern (upper Tobol River) and central (Ural River basin) parts. Moreover, in both the first and second cases, chernozem soils are adjacent to meadow saline soils, forming long enough zones of salt accumulation.

Focal secondary salinization, according to our estimates, is common in the Altai Kray. In the western tip of this region near 10% of soils are secondary salinized, as well as in the interfluvium of the Kulunda - Alei (Priobskoye plateau) and Charysh-Alei near 20-30% of soils are secondary salinized.

3.2. Secondary Sodification of Soils

Turning to the characteristic of secondary sodification of soils in Russia, we emphasize once again that this group of processes has a much higher prevalence here than secondary salinization, in contrast to the global trend, and also has the features of a pronounced latitudinal zonality, corresponding with the geochemical differentiation of sediments within the European part of the country (Figure 2).

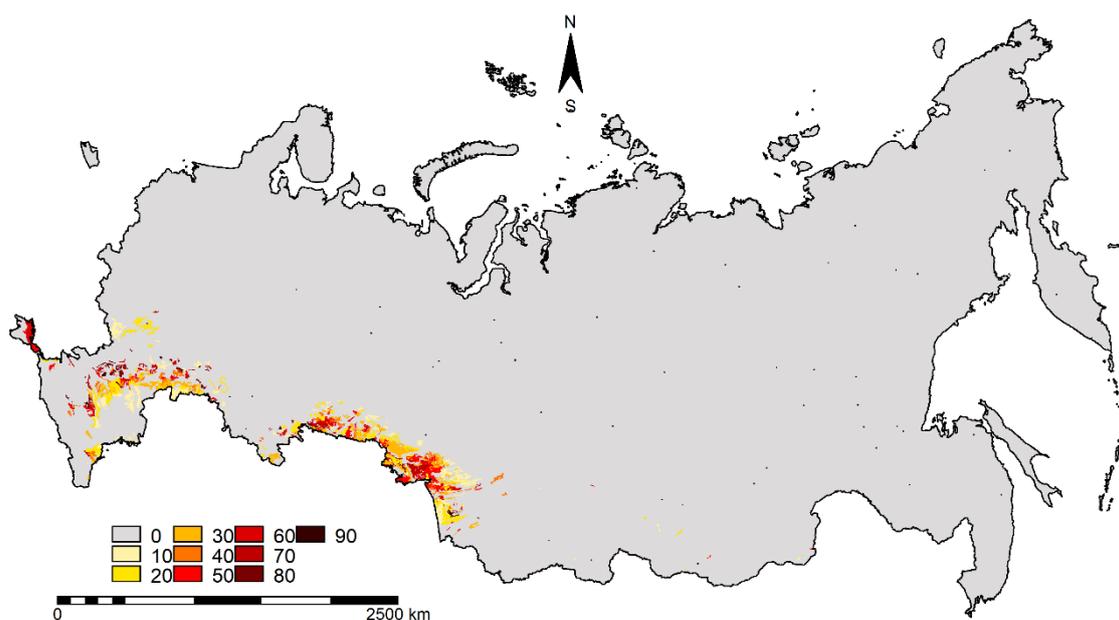


Figure 2. Map of secondary sodification of soils in Russia (percent from soil mapping unit).

Our results show that the greatest development of secondary sodification of soils reaches Volgograd (14% of soils) and Saratov (10% of soils) regions. These degradation phenomena are slightly inferior in terms of spatial coverage in the Stavropol Kray (9%) and Rostov oblast (8%). The role of the process of sodification is significantly less important in the Voronezh (3%) and Tambov (3%) oblasts, as well as within Krasnodar Kray (2%), Astrakhan (2%) and Samara (2%) oblasts. Some areas of secondary sodification are also observed in the Lipetsk (1%) and Belgorod (1%) oblasts.

However, an unprecedented scale, according to our results, the soil sodification process is acquired in the Crimea (26%), where on the Kerch Peninsula they occupy near 50% of irrigated land, and in Sivash region - up to 60% of the territory.

In the Volgograd region, the main areas of secondary sodified soils are concentrated in the Volga region (30% secondary sodified soils). In contrast to the dry-steppe landscapes of the Volgograd Region, large areas of irrigated chernozem soils are subject to secondary sodification in the Saratov region, often without signs of secondary salinization.

When considering the development of secondary sodification in the Stavropol Kray draws attention to a combination of this phenomenon with secondary salinization. In the upper reaches of the Kalous River and in the south-west of the Stavropol Upland, the process of secondary sodification covers a large area of irrigated lands.

In the Rostov region, in turn, its eastern part in the valley of the Gnilaya River and along the Don River with sodic chernozems is subject of secondary sodification. The northern bank of the Tsimlyanskoye reservoir is also characterized by secondary sodification.

For the Tambov region, the area of secondary sodification spread to the southern margin of the region, occupying the centre of the Oka-Don lowland. The Voronezh region, by our estimates, is characterized by moderate total secondary sodification. Here, massifs of sodic soils are mainly confined to the Don River valley.

Within the Krasnodar Kray, secondary salinization occurs in the south-east of the Kuban lowland, which occupy a limited area in the region. Alluvial soils are not subject to such processes.

Speaking about the Lipetsk and Belgorod Oblasts, it is necessary to emphasize the fragmented and extremely limited area of secondary sodification of soils.

Studies have shown that the Trans-Urals and southern Siberia with respect to secondary sodification demonstrate a significant degree of this phenomenon. The Kurgan (17% of soils are secondary sodified), Omsk (14% of soils are secondary sodified) and Novosibirsk (12% of soils are secondary sodified) oblasts hold leading positions here. Secondary sodification is also widespread in the Chelyabinsk Region (8%). Secondary sodified soils are found in the Altai Kray (4%), Tyumen (3%) and Orenburg (2%) oblasts.

According to our estimates, the main wedge of soils subject to secondary sodification within the Kurgan oblast is located in the interfluvium Tobol – Miass, north of the secondary salinization zone (30% of soils are secondary sodified). Besides, the western part of the oblast is also characterized by very high secondary soil sodification.

In the Omsk oblast the main centres of soil sodification are Barabinsk lowland in the east, Ishim plain in the west and regions in the south.

In the Novosibirsk Region, the main centres of soil sodification are in the west part of the region, where near 50% of soils are secondary sodified.

For the Chelyabinsk Region, in turn, a large area of secondary sodified soils is identified in the south (along the border with Kazakhstan) and south-west (the Ural River basin). The soils forming in the south-eastern spurs of the southern Urals, is characterized by pronounced sodification too.

In the Altai Kray, secondary sodified soils are mainly distributed in the west of the region, in Kulunda.

In the Tyumen region sodic soils are confined to the valley of the Vagai River, and in the Orenburg region they are localized in the basins of the Ural River (southern chernozems and automorphous solonetz's) and in the extreme south-west of the region.

4. Conclusion

The analysis of distribution of secondary salinization and sodification of soils in Russia made it possible to draw the following conclusions.

In Russia (contrary to the world trend) the primary role among the degraded saline processes is played by secondary sodification, widely distributed in regions with arid and subarid climate.

Salinity manifestations in irrigated soils of the European part of the country have elements of latitudinal differentiation. At the same time, secondary sodification prevails in the northern sector of the regular irrigation zone, while secondary salinization is more typical for southern regions with acute deficit of moisture. The main object of salt degradation development under irrigation conditions are chestnut and dark-chestnut soils with inclusion of solonetz's.

In the Trans-Urals and Southern Siberia, both secondary salinization and secondary sodification are reported to cover mainly the chernozem zone, where they are often accompanied by waterlogging and even swamping. The general low drainage of the Siberian chernozemic zone, combined with the heavy texture of soils, contributes to the "conservation" of salts in soil profiles, preventing desalinization even after irrigation has stopped.

The problems of secondary salinization and secondary sodification can be characterized for Russia as very relevant and require constant monitoring.

We assess the overall saline condition of soils in Russia as moderately destabilized [20], taking into account the specifics of land use, the diversity of salt manifestation in the landscapes of subarid and arid regions and changing climate in the northern hemisphere.

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