Soil Degradation in the Republic of Adygea Under Exogenous Geological Processes

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Abstract The geographical position of the Republic of Adygea determines the development of a wide class of exogenous geological processes (wind and water erosion; flooding, salinization and excessive water saturation, etc.), which may have a destructive effect on the soil cover. About 185.7 thousand ha (55.7% of the total area of 333.4 thousand ha) of agricultural land in the region are subject to weak wind erosion. Of these, 65.3 thousand ha (19.6%) are considered deflationary. 32.8 thousand ha (9.8%) of agricultural land in the Republic of Adygea are subject to water erosion. Lands saturated with water (including waterlogged) account for 64 thousand ha (19.2%). A total of 13.7 thousand ha or 4.1% of the total agricultural land in the Republic of Adygea is occupied by saline soils and solonetzes. Apart from wind erosion, exogenous processes have no significant effect on the state of the soil cover of the Republic of Adygea.

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1 Introduction

The soil cover is an independent complex natural shell of the globe – the pedosphere, the part of the biosphere which is the most saturated with life, where the processes of weathering and soil formation occur. The patterns of formation and diversity of soil cover, regimes, various properties, and characteristics of soils are determined by the pronounced heterogeneity of bioclimatic and lithological and geomorphological conditions. The specificity of the soil cover of certain regions is manifested in the composition of the soil cover, its structure, as well as in the features of the use of land funds.

Soil degradation in most cases occurs under the combined influence of natural and anthropogenic factors, while the anthropogenic influence creates the prerequisites for a sharp activation of natural influences. It is often difficult to distinguish between the effects of natural and anthropogenic degradation factors [1].

2 Soil Cover of the Republic of Adygea

Land resources occupy a leading place in the natural and economic potential of the Republic of Adygea [2]. Besides the fact that land is the main and irreplaceable means of production in agriculture, acting as a spatial basis, it is actually a connecting link for other natural resources. The state of land in varying degrees affects the condition of the animal and plant worlds, water sources, and other natural objects.

The soil cover of the republic experiences a significant load under the influence of exogenous geological processes [3]. Unique pre-Caucasian chernozems are degrading, almost all arable lands are affected by erosion, and processes of excessive water saturation and salinization are developing [4, 5].

3 Soil Degradation Due to Exogenous Geological Processes

The geographic location of the Republic of Adygea determines the development of a wide class of exogenous geological processes [6] (wind and water erosion; flooding, salinization and excessive water saturation, etc.), which have a destructive effect on the soil cover.

3.1 Wind Erosion

Wind erosion of soils on the territory of the Republic of Adygea is manifested in the form of deflation (from late Lat. *deflatio* – deflation) and accumulation (from Latin *akkumulatio* – accumulation) [7]. In open spaces, especially in the fields, deflation predominates; in places of natural deceleration of the wind flow, favorable conditions are created for the predominant development of accumulation processes.

The territory of the Republic of Adygea belongs to the zone of weak wind erosion, where aeolian processes are practically absent due to the fact that floodplain soils covered with vegetation do not undergo erosion and there are only prerequisites for weak aeolian accumulation. About 185.7 thousand ha of agricultural land in the region are subject to weak wind erosion, which is 55.7% of the total area (333.4 thousand ha) [8].

Wind erosion is manifested in the form of dusty (black) storms. During such storms, the wind picks up small particles of soil and carries them over great distances. Larger particles are displaced by the wind by leaps or dragging, destroying soil aggregates in the surface soil layer, causing an avalanche type of erosion. Black storms can cover large areas. Most often they are repeated in vast open spaces. In the case of black storms, the soil undergoes great damage in a short time. For example, within 3 days a soil layer of up to 25 cm can be demolished [9].

The largest source of dust storms in the steppes of the North Caucasus is the so-called Armavir wind corridor, covering the territory of the eastern parts of Krasnodar Region, the southern part of Stavropol Region, and southeastern parts of Rostov Region with a total area of about three million ha [10].

Eyewitnesses will long remember the dust storms of 1928, 1960, and 1969, when an east wind was blowing at more than 15 m/s for several days in a row, sometimes reaching 24–28 m/s with gusts of up to 30–35 m/s. The wind blew off the upper, chernozem soil layer to a depth of 15–25 cm, lifting it to a height of 1–3 km and moving it over great distances [11].

For example, the dust of the April storms of 1928 got into Romania and Poland. In February 1969, small particles of soil from the North Caucasus settled on white snow in Sweden, Finland, and Norway and fell together with snow in Belarus and St. Petersburg Region. In the southeast of the European part of Russia, fields with winter crops were almost completely destroyed, a fertile layer 10 cm thick was demolished, and irrigation canals were covered with dust. Sandy snowdrifts of 2–3 m height were formed at fences, walls of houses, and field shelterbelts. Roads, trees, and roofs of houses had a layer of sand and dust [12].

The horizontal extent of the areas covered by dusty storms is very different – from several hundred meters to thousands of kilometers or more. The dustiness of the atmosphere in the vertical dimension can vary from 1–2 m (dusty or sandy snow drifts) to 6–7 km.

Dust storms are observed, as a rule, in the summer. In the southern regions, they can also develop in winter, since the snow cover here is very unstable, and, in the absence of precipitation, the soil surface dries quickly. In winter, in these areas, development of peculiar snow and sand drifts is also possible, where dust and sand are transported together with dry snow.

The main reason for the formation of dust storms is turbulence due to the structure of the wind, contributing to the rise of dust and sand particles from the earth's surface. In this case, the degree of vertical instability of the air mass, in which a dust storm develops, is very important. Strong daily heating of the lower layers of air in the summer leads to a significant increase in temperature gradients to an altitude of 1–1.5 km above steppes and to 2–2.5 km above deserts. Convective mixing, extending to these heights, seeks to distribute particles of sand and dust raised from the earth's surface throughout the entire captured layer. Small particles forming a mist can rise very high; heavier particles have a lower height of rise and quickly fall to the earth's surface.

With stable air stratification, which is observed, for example, in the early spring in tropical Iranian air in the warm sectors of the Murghab and South Caspian cyclones, the layer of surface air overheating is limited to several hundred meters. Strong dust storms are often observed here, spreading to a height of only 200–300 m; at high altitudes, the air remains completely clean. If dusty, air can additionally warm up due to the Voeikov-Durst effect due to the intense absorption of solar radiation by dust particles suspended in the atmosphere [13].

Dust storms begin at some critical values of wind speed, which depend on the topography and soil structure and therefore are not the same for different areas. In most areas, dust storms begin at a wind speed of 10–12 m/s. However, on the loessial soil, weak dust storms can occur in summer even at a wind speed of 8 m/s and sometimes even at 5 m/s.

When the causes directly causing the dust storm disappear, the dust raised from the earth's surface remains in the air for several hours or even days. Large masses of dust are carried in these cases by airflows for hundreds and thousands of kilometers, forming the phenomenon of advective mist. Unlike dust storms, advective mist is usually observed in light winds and even in calm. Both vertical and horizontal visibility in mist can gradually decrease to several tens of meters. The duration of dust storms varies widely – from several seconds to several days. For example, a continuous dust storm lasting 80 h was recorded on the southern coast of the Aral Sea. Depending on the condition of the soil and the circulation conditions, dust storms are distributed very unevenly in terms of the number of phenomena and the total duration.

Within one relatively small territory, a detailed study can reveal places in which dust storms develop 4–5 times more often than in nearby areas. The repeatability of dust storms shows large differences at the borders between the cultivated irrigated zone and the natural semidesert territory.

The daily course of dust storms (maximum at midday and in the afternoon, minimum in the second half of the night, and early in the morning) corresponds to the summer diurnal variation of the wind speed and the course of the instability of the stratification of the lower layers of the troposphere. During quite long nights, especially in spring and autumn, the underlying surface cools down (often to frost), which leads to condensation of water vapor and moistening of the soil surface, while the flowability of small soil particles decreases. At low temperatures, light frost sometimes forms on the soil surface, which also reduces the mobility of dust and sand particles. During the day, on the contrary, there is an intensive drying of the soil. Nevertheless, with a proper soil structure and certain synoptic processes, dust storms are possible at any time of the day; however, the intensity of night dust storms is much weaker than during daytime.

Depending on the duration of the dust storm and visibility, the following main types of dust storms can be distinguished.

Short-term dust storms with a relatively slight decrease in visibility. These are caused by purely local fluctuations in wind speed and direction, their duration does not exceed 30 min, and visibility remains within 3–4 km, increasing at times up to 6–10 km. Dust storms of this type often alternate with drifting dusts.

Short-term dust storms with severe deterioration in visibility. In duration, they are similar to the storms of the first type but cause a more significant deterioration in visibility (up to several hundred meters and sometimes up to 10–20 m). They start almost suddenly – in relatively calm weather, the wind speed increases sharply, and at the same time, dust clouds of various vertical thicknesses sweep. After the first sudden deterioration in visibility, it gradually increases to 1–2 km or more, although the wind speed often continues to increase. These storms are usually generated by gusts associated with the passage of thunderstorm centers or sharp cold fronts. A sign of the approach of such a dust storm is a gray dust curtain under cumulonimbus clouds, when they are still at the horizon, within sight.

Long and pulsating dust storms with a predominance of a relatively small decrease in visibility (2–4 km). Short-term improvements and deterioration in visibility are observed periodically. Fluctuations in visibility occur over a wide area, in various places, and at different times. The duration of dust storms of this type reaches several hours and even days. These storms occur in a stable baric field with large pressure gradients (southeastern, southern, and southwestern periphery of powerful quasi-stationary anticyclones).

Long and severe dust storms with a decrease in visibility up to 500–1,000 m, in the initial stage – up to several tens of meters. Dust storms of this type, as a rule, have a large horizontal and vertical extent and are characterized in all directions by a uniform, usually dark gray background. Fluctuations in visibility occur in the range of low visibility values. The duration of such a storm is at least 2–4 h.

Drifting dust or sand is the transfer of dust or sand in the layer of no more than 2 m above the surface of the soil. Drifting dust, as a rule, is short-lived and is observed relatively rarely as an independent phenomenon; most often it arises at the beginning of a dust storm or at the end of it. Drifting sand is a very frequent occurrence in deserts, especially when there is coarse, well-screened sand on the surface of the soil. In some deserts, in summer, drifting sand is observed almost daily, and its height is mainly limited to the lower half-meter layer.

Such drifting causes significant sand drifts of roads, fields, canals, etc. In the cold half of the year, drifting sand can be combined with dust and sand storms of the third type, usually on the southern periphery of quasi-stationary extensive anticyclones at wind speeds of about 15 m/s and above. They are characterized by a more even structure of the wind field and often stable stratification of air masses.

The likelihood of dust storms in the Republic of Adygea is not high, since it lies south of the Armavir wind corridor. In 97% of the territory of the Republic, dust storms can happen once every 10 years, and in the remaining 3% of the territory – once every 20 years [14].

About 65.3 thousand ha of agricultural land (333.4 thousand ha) of the Republic of Adygea are considered deflationary. The maximum level of deflation is observed in Giaginsky District, where 22.4 thousand ha are exposed to it.

Distribution of deflationary lands (thousand ha) by administrative regions of the Republic of Adygea is presented in Fig. 1.

3.2 Water Erosion

Water erosion [16] is one of the most dangerous types of agricultural land degradation, causing soil destruction and loss of soil fertility. The danger of water soil erosion lies in the destruction and removal of the upper, most fertile soil layer, which entails a decrease in the humus layer of the soil and a decrease in land productivity.

On eroded lands, the water-holding capacity of each hectare decreases by 500–600 m^3, which is equivalent to a decrease in the potential yield of grain crops by 1.0–1.2 t/ha [17].

A necessary condition for the occurrence of water erosion of the soil is the runoff of surface water or surface runoff. There are three main types of surface runoff: rain runoff, snowmelt runoff, and irrigation water runoff. Three types of soil erosion correspond to them: rain erosion (or storm erosion – in heavy rains); snowmelt erosion; and irrigation erosion [18]. These types of erosion differ not only in the source of runoff but also in the mechanism of the process, as well as in the amount of damage they cause.

The duration of the process of rain erosion of the soil is measured in minutes and hours. In this case, the amount of soil washed off depends not only on the parameters of the water flow but also on the parameters of raindrops. The greater the mass and speed of a raindrop, the greater its kinetic energy and the greater the damage it causes to the soil. When a drop hits the soil, the drop itself and some very small amount of soil with which the drop interacts are destroyed. The products of destruction fly apart in the form of splashes. Part of the splashes do not fall onto the soil surface but into temporary water courses (streams, runlets) and are carried away by them. Thus, rain contributes to the “loading” of streams with solid material. In addition, raindrops, falling into the flow, turbulize it and increase the erosion and transporting ability.

Erosion during snowmelt is less pronounced but is longer than rain erosion.

Irrigation erosion, i.e., soil erosion during irrigation, is divided into subtypes depending on the method of irrigation: furrow irrigation erosion, strip irrigation erosion, border-check irrigation erosion, and sprinkling irrigation erosion [18].

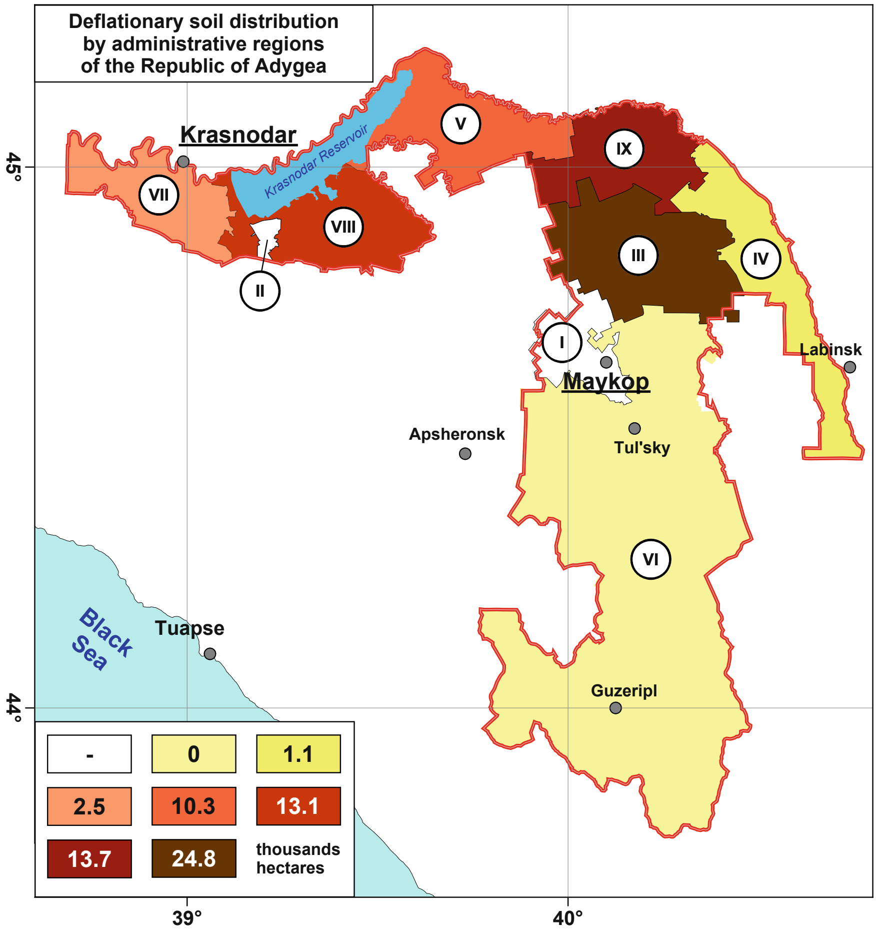

Fig. 1 Deflationary soil distribution (thousand ha) by administrative regions of the Republic of Adygea according to [15]. I, Maykop Republican Urban District; II, Adygeysk Republican Urban District; III, Giaginsky District; IV, Koshekhabl'sky District; V, Krasnogvardeysky District; VI, Maykopsky District; VII, Takhtamukaysky District; VIII, Teuchezhsky District; IX, Shovgenovsky District. Hyphen indicates data absence

Furrow irrigation is used for irrigation of cotton, corn, tomatoes, and sugar beet. Row widths for these crops are 0.6–0.9 m, and the width of the water flow in the irrigation furrow is up to 0.2 m. Soil losses during single irrigation can reach 100 t/ha. In terms of time unit, this is much higher than in the case of rain erosion or snowmelt erosion. This is explained by the fact that when irrigating along furrows, the amount of water interacting with the soil per time unit is much larger than during rains or during snowmelt.

Strip irrigation is used for irrigation of grass and grain crops. The width of the strips is measured in several meters. The width of the water stream during strip irrigation is equal to the width of the strips themselves. Therefore, the speed of such flows is low, and irrigation erosion is less pronounced than in furrow irrigation.

In border-check irrigation, erosion is even less pronounced. This is explained by the fact that the slope of the checks (usually rice checks) is very small and the speed of the water flow and the amount of soil washout associated with it are small.

Sprinkling is one of the most promising types of irrigation. It is used for irrigation of almost all agricultural crops. This type of irrigation is currently becoming increasingly common. Surface runoff and soil erosion during sprinkling occur when the irrigation rate begins to exceed the intensity of water absorption by the soil. Soil erosion in sprinkling is the least studied subtype of irrigation erosion.

By the morphological characteristics of erosion forms, there are two types of erosion: surface erosion (or soil washaway) and linear erosion (or soil washout). Each of the listed types of erosion can be accompanied by soil washaway or washout, but most often, by both, depending on the location of the studied area on the slope. Surface erosion, or washaway, in turn is divided into sheet erosion and rill erosion. The difference between them is rather arbitrary. It is believed that sheet erosion is caused by the movement of a continuous drain sheet. In reality, conditions for its formation are rarely created. Soil washout happens mainly due to rill streams.

The boundary of the transition of surface erosion to linear erosion is also quite formal. It is believed that if traces of erosion in the field disappear as a result of conventional soil treatment, then this is surface erosion; if not, then it is linear.

The damage from water erosion in the Republic of Adygea is annually expressed in significant quantities. Over the past 40 years, 33.2 thousand tons of soil have been washed away, while 16 thousand tons of humus have been irretrievably lost. In 1914, the humus content was in leached chernozems, 7.9%; in meadow and meadow chernozem soils, 6.5%; and in gray forest soils, 5.9% [19]. Medium-humic and fertile chernozems almost disappeared in agricultural lands; the areas of low-humic chernozems decreased, which accordingly led to an increase in the areas of weak-humic chernozems [20]. As of January 1, 2019, 32.8 thousand ha of agricultural land of the Republic of Adygea are subject to water erosion, which is about 9.8% of the total agricultural land (333.4 thousand ha) [17]. These processes are especially strong in Giaginsky District, where 12.1 thousand ha are considered washed away [15].

Distribution of lands subject to water erosion (thousand ha) by administrative regions of the Republic of Adygea is shown in Fig. 2.

3.3 Flooding and Excessive Water Saturation

Flooding and excessive water saturation of lands [21] in the Republic of Adygea are the most important factors determining the decline in the fertility of agricultural land and causing soil degradation. The causes of flooding and excessive water saturation are associated both with natural climatic changes and with various types of human economic activity (irrigation, hydraulic engineering, industrial and municipal water

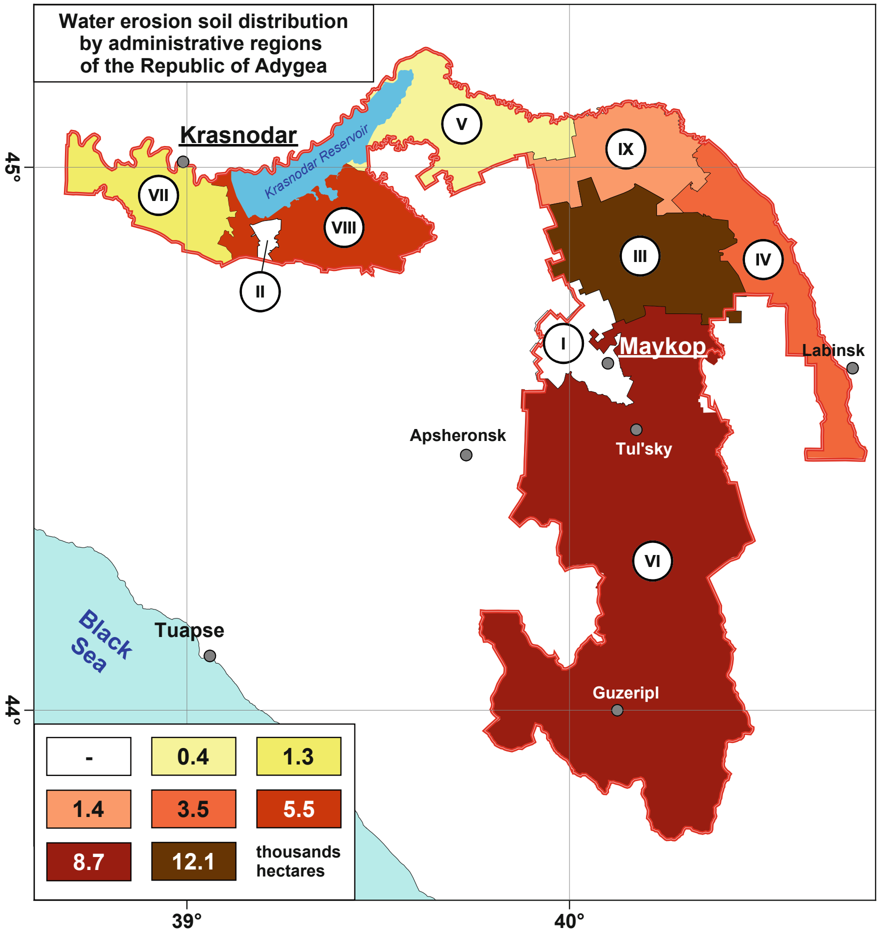

Fig. 2 Water erosion soil distribution (thousand ha) by administrative region of the Republic of Adygea according to [15]. I, Maykop Republican Urban District; II, Adygeysk Republican Urban District, III, Giaginsky District; IV, Koshekhabl'sky District; V, Krasnogvardeysky District; VI, Maykopsky District; VII, Takhtamukaysky District; VIII, Teuchezhsky District; IX, Shovgenovsky District. Hyphen indicates data absence

consumption, agrotechnical methods of moisture accumulation in soils, land management). These types of activities lead to excessive water saturation of lands, which, depending on the reasons that cause it, and the stage of the process, can be both reversible and practically irreversible.

Land with excessive water saturation is formed under excessive moisture at a close groundwater level; as a result of surface stagnation of precipitation or irrigation water in drainless depressions; as a result of periodic or constant flooding by flood waters in floodplains and river deltas; and a result of periodic prolonged flooding of the soil surface during rice cultivation. Excess moisture in soils (even short-term stagnation in the upper layer) leads to a sharp deterioration in their water-physical properties and air regime. Flooding and excessive water saturation lead to a change in the hydrological regime of the soil and its dehumidification, compaction, and destruction of the structure.

With increasing speed, calcium leaching occurs both from the soil solution and from the soil absorption complex, and soil gleying develops [22]. The mentioned processes cause deep restructuring of the soil components as a dispersed multiphase system. Due to changes in the specific surface and hydrophilization, the amplitudes of volumetric deformations increase. There is a decrease in porosity and a change in the ratio of pores in size and function (moisture-retaining and moisture-conducting). The range of moisture available to plants is reduced. These changes contribute to soil compaction, deterioration of their structure, and a decrease in water permeability, which leads to a further increase in the area of lands with excessive water saturation [23].

Depending on the duration and intensity of excess moisture, several groups of soils with excessive water saturation are identified that require implementation of various complexes of reclamation measures [21].

A group of *short-term excessively moistened lands* – soils with excessive water saturation for 2–3 weeks, but not more than one month, with a depth of groundwater of 3–7 m. The source of excessive water saturation is precipitation, diluvial-flooded, and, in the case of alluvial soils – floodplain (floodwater) water.

Temporarily excessively moistened soils, with excessive water saturation during a smaller part of the vegetative period, is due to groundwater at a depth of 1.5–3.0 m.

Long-term excessively moistened soils – soils with excessive water saturation during most of the vegetative period due to closely occurring groundwater (1.0–2.0 m) and floodplain waters.

The group of *permanently excessively moistened soils* includes soils with excessive water saturation during the entire vegetative period with a depth of groundwater of less than 1 m. The source of excessive water saturation is groundwater and floodplain waters. Such conditions are formed as a result of the construction of canals, reservoirs, and irrigation systems. In most cases, this leads to an increase in the level of groundwater, which, when linked with irrigation water, can cause excessive water saturation of soils.

In the Republic of Adygea, 19.2% of soils have a low degree of excessive water saturation, and the remaining 80.8% have a below average degree of excessive water saturation [24]. An increase in the intensity of soil flooding almost everywhere led to the abandonment of the use of flooded lands and the switch from arable land to grassland and deposits. Recent surveys of the distribution of lands with excessive water saturation in the Republic of Adygea showed that 80% of them are gray forest-steppe soils, chernozems compact, meadow-chernozemics compact, and sod gleys [23].

In the Republic of Adygea, flooding occurs mainly in the lowlands and in the valleys of the following rivers: Kuban, Laba, Belaya, Khodz, and Pshish. The floodplain terraces of the Kuban River (Yablonovsky Village of Takhtamukaysky

District) and the left bank of the Krasnodar Reservoir (Teuchezhsky and partially Krasnogvardeysky Districts) are constantly flooded.

The total area of flooded land according to the survey 1975–1978 amounted to 32.5 thousand ha. It mainly consisted of the lands of agricultural landscapes of rice fields and individual sections of floodplains of rivers of the low part of the Republic. Over the past 35 years, in addition to these lands, over the territory of 17,5 thousand ha, floodplain lands were flooded in the lower reaches of the rivers flowing into the Krasnodar Reservoir, such as River Pshish, River Psekups, River Dysh, River Marta, River Apchas, and River Shunduk [23]. On average, within 1 year, the total area of flooding in the deltas of these rivers would increase by 500 ha. Flooded land areas vary from year to year depending on the amount of precipitation and the water level in the Krasnodar Reservoir [25].

Since the beginning of the filling of the Krasnodar Reservoir (1975) and the commissioning of rice systems (1977), a steady regime of flooding of the adjacent territories has been established, associated with a seasonal increase in the level of groundwater. The maximum water level in the Krasnodar Reservoir is reached at the end of winter and is maintained in spring and early summer, due to the need to supply water to rice checks. This period is characterized by the high level of groundwater and by the most considerable impact of the reservoir on the mouth sections of the floodplain landscapes of the rivers flowing into the reservoir. Around the reservoir a strip with a width of 0.5–3 km gets flooded. The prevalence of flooding here is from 30 to 100%. The most flooded parts of the Kuban River valley are the floodplain and the first supra-floodplain upper quaternary terraces. The floodplain of the Kuban River, which has a significant width of the edge, is flooded along the entire length by 80–100%.

The valleys of the Laba and Belaya rivers, with a width of 1–8 km, are prone to flooding up to 70%. Flooding in their floodplains is completely dependent on the hydrological regime of the rivers and is manifested in the phase of seasonal flood and flash floods season. The rest of the Republic's territory is flooded within the floodplains of the small rivers, such as River Giaga, River Psenafa, River Fars, River Pshish, River Psekups, River Afips, and other smaller rivers [26].

The prevalence of flooding in these rivers is about 30%, with an increase in the prevalence of flooding in the downstream area. In total, 12.2 thousand ha of lands on the left bank of the Krasnodar Reservoir and the Kuban River in its lower reaches are subject to flooding in the Republic [26]. On the rest of the lowland territory of the Republic, land flooding occurs in the winter-spring period in the valleys of small rivers and on flat watersheds as a result of winter-spring precipitation. Floodplain lands of river valleys are almost completely flooded; flooding covers all the large areas of land of river terraces. In the mountainous regions of the Republic of Adygea, flooding is fragmentary in separate sections of high floodplains and low parts of the first supra-floodplain terraces.

Lands with excessive water saturation in the Republic of Adygea occupy more than 64 thousand ha of agricultural land. The largest number of lands with excessive water saturation (18.6 thousand ha) is located in Teuchezhsky District [15].

Distribution of lands with excessive water saturation (thousand ha) by administrative regions of the Republic of Adygea is presented in Fig. 3.

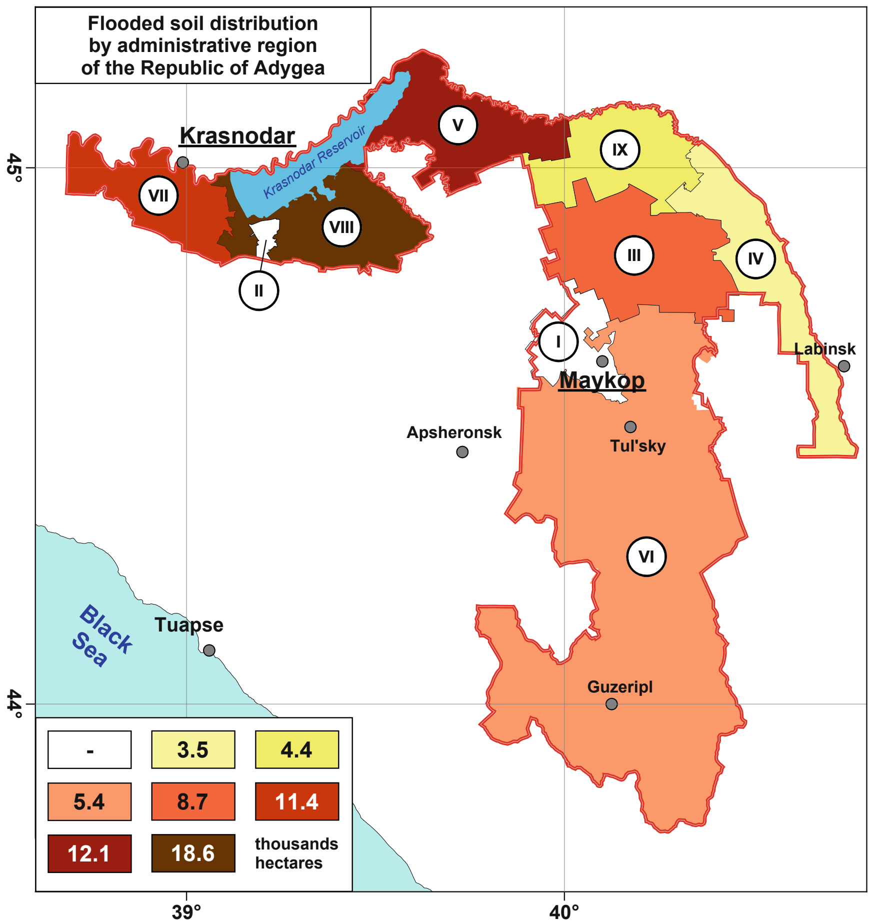

Fig. 3 Flooded soil distribution (thousand ha) by administrative region of the Republic of Adygea according to [15]. I, Maykop Republican Urban District; II, Adygeysk Republican Urban District; III, Giaginsky District; IV, Koshekhabl'sky District; V, Krasnogvardeysky District; VI, Maykopsky District; VII, Takhtamukaysky District; VIII, Teuchezhsky District; IX, Shovgenovsky District. Hyphen indicates data absence

3.4 Waterlogging

Waterlogging of the territory begins when the groundwater level reaches the surface of the earth [16]. Upland, transitional, and lowland swamps are distinguished. The swamped areas of the Republic of Adygea are distinguished by the fact that they are not swamps in the generally accepted sense of the word. These are mainly low-lying swamped areas in the floodplains of river valleys, flooded by flash floods periodically for a more or less long time, unsuitable for field cultivation, and belonging to the category of “inconvenient land.” Waterlogging in the Republic of Adygea is not widespread.

In the interfluve of the Laba and Psenafa rivers, there lies a strip of development of waterlogged lands in the Transcaucasian northwest direction, which is apparently explained by the common bend in the relief during the transition from the mountain zone to the submontane terraced plain [2]. Excessively wet areas are located mainly in the floodplains of the rivers, in the bottoms of small U-shaped valleys, and also in drainage-free depressions. Excessively moistened areas are overgrown with swamp vegetation. Many of these sites are located on regulated river floodplains, such as River Giaga and River Psenafa. Swampiness of the floodplains of rivers increases downstream and reaches 100% in some places (River Laba and River Gryaznukha) [27].

3.5 Salinization

Salinization is an increase in the content of readily soluble salts in the soil due to the addition of them by ground and surface waters (primary salinization) or due to irrational irrigation (secondary salinization) [3]. Salinization of soils is one of the reasons limiting the development of irrigated agriculture. Saline soils vary in the occurrence depth of the salt horizon, chemical parameters, and degree of salinization. By the occurrence depth of the upper salt horizon (its upper boundary), saline soils are divided into solonchak soils (salts in the layer of 0–30 cm), solonchak-like soils (30–80 cm), deep solonchak-like soils (80–150 cm), and deep saline soils (deeper than 150 cm).

Due to the fact that different salts are not equally toxic to plants, saline soils are distinguished by the composition of salts: chloride and sulfate-chloride, chloride-sulfate, sulfate, soda-chloride, soda-sulfate, chloride-soda, sulfate-soda, and sulfate- or chloride-hydrocarbonate. The name of the type of salinization contains those anions whose content exceeds 20% of the sum of mEq of anions; the predominant anion in the name is put in the last place [28].

Soils of different types of formation can be saline, distinguished in the genetic classification taxonomy as special genera of subtypes of chernozems, chestnut and brown semidesert soils, meadow and meadow-boggy soils, etc. Solonetzes are also considered saline soils (in USDA soil taxonomy, solonetz corresponds to sodium-rich alfisols). However, among the variety of saline soils, solonchaks are distinguished as an independent type. Solonchaks include soils containing a large amount of water-soluble salts in the surface and in the profile. Depending on the chemistry of salinization, salts in the upper horizon of solonchaks range from 0.6–0.7 to 2–3% or more.

In the environmental assessment of saline soils, the terms “biological salt tolerance” and “agronomic salt tolerance” are used. Biological salt tolerance is the ability of a plant to carry out a full cycle of individual development on a saline soil, often with a reduced rate of accumulation of organic matter while maintaining offspring

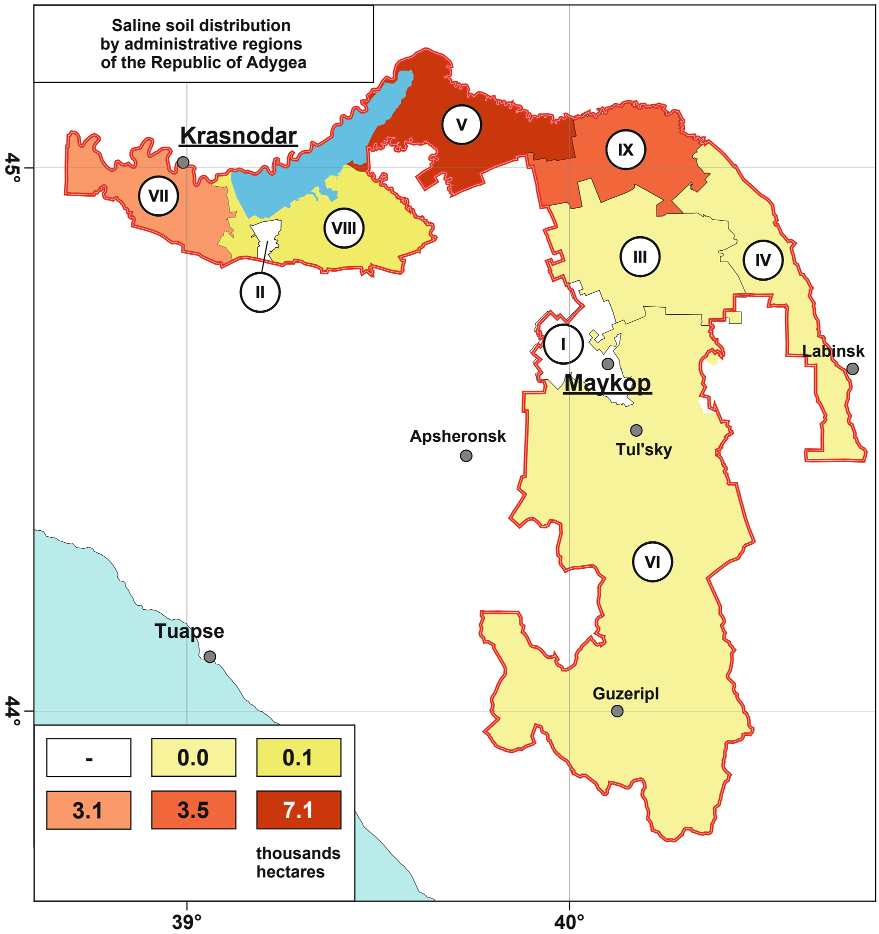

Fig. 4 Saline soil distribution (thousand ha) by administrative regions of the Republic of Adygea [27]. I, Maykop Republican Urban District; II, Adygeysk Republican Urban District; III, Giaginsky District; IV, Koshekhabl'sky District; V, Krasnogvardeysky District; VI, Maykopsky District; VII, Takhtamukaysky District; VIII, Teuchezhsky District; IX, Shovgenovsky District. Hyphen indicates data absence

reproduction. Agronomic salt tolerance is the organism's ability to carry out a full development cycle on a saline soil and produce products that meet agricultural practices under these conditions. Recently, biological salt tolerance has been called "salt endurance," and agronomic salt tolerance is now actually called "salt tolerance" [28].

The main saline soils and solonetzes are located in Krasnogvardeysky District (7.0 thousand ha), in Shovgenovsky District (3.5 thousand ha), in Takhtamukaysky District (3.1 thousand ha), and in Teuchezhsky District (0.1 thousand ha) (Fig. 4). In total, in the Republic of Adygea, about 13.7 thousand ha, or 4.1% of the total agricultural land area, is occupied by saline soils and solonetzes, which are mainly located on the left bank of the Krasnodar Reservoir (Krasnogvardeysky, Takhtamukaysky, and Teuchezhsky districts) between the rivers Fars and Ulka (Shovgenovsky District) [27].

In Krasnogvardeysky and Shovgenovsky districts, meadow solonetzes are prevalent. They are confined to closed depressions of supra-floodplain terraces and are formed on alluvial clays with a close (on average 1.15 m) location of groundwater.

The area of salinization still tends to expand, which is a consequence of a disordered water regime, improper exploitation of irrigated land, and low agricultural technology in farms.

4 Conclusions

The geographical position of the Republic of Adygea determines the development of a wide class of exogenous geological processes (wind and water erosion; flooding, salinization and excessive water saturation, etc.), which have a destructive effect on the soil cover.

The territory of the Republic of Adygea belongs to the zone of weak wind erosion (deflation). About 185.7 thousand ha (55.7% of the total area of 333.4 thousand ha) of agricultural land in the region are subject to weak wind erosion. Of these, 65.3 thousand ha (19.6%) are considered deflationary. The maximum level of deflation is observed in Shovgenovsky District, where 13.7 thousand ha (37%) are affected.

32.8 thousand ha of agricultural land of the Republic of Adygea are subject to water erosion. These processes are especially strong in Giaginsky District, where 12 thousand ha are considered washed away. Lands with excessive water saturation (including waterlogged lands) in the Republic account for 64 thousand ha. The maximum part of such soils is located in Teuchezhsky District – 18.6 thousand ha.

In total, 13.7 thousand ha in the Republic of Adygea are occupied by saline soils and solonetzes, which are mainly located on the left bank of the Krasnodar Reservoir in Krasnogvardeysky District.

In general, exogenous processes have no significant effect on the state of the soil cover in the Republic of Adygea.

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