Current state of the soil cover of the Don River delta and coastal zone under the conditions of intensified anthropogenic activity

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Abstract. The soil cover of the Don River delta is characterized by heterogeneity and complexity due to local differences in the intensity of alluvial sedimentation and hydrological regimes and to diverse forms of microlrelief. Currently, there is an increase in anthropogenic load on the delta soils. Based on long-term field research using GIS technologies, three key ecological and geographical areas of soil formation in the northern, central, and southern parts of the delta were identified. In the ecological and geographical distribution of soilscapes in the Don River delta, five main types of anthropogenically transformed soil complexes with different degrees of degradation were according to the degree of degradation. These complexes were formed during the development of the predominant soil-forming processes-potable, alluvial, sod and gley formation under the influence of anthropogenic impact.

1. Introduction
The Don River delta is a unique natural ecosystem, which is characterized by the presence of almost untouched by anthropogenic impact natural landscapes, high biological diversity, and unique habitats. The studied territory consists of riverbed, floodplain, deltaic and estuarine deposits. The soil cover of the Don River delta and the northern Azov region is characterized by complexity associated with both natural factors and diverse forms of anthropogenic impact on soils.

The Don River delta participates in the formation of the bioresource potential of the Sea of Azov and the Taganrog Bay, and is also an important land reserve for the socio-economic development of the region. It also serves as a transport hub for sea cargo transportation, an important agricultural area, and a center for recreation and tourism.

Anthropogenic soil degradation in the delta is caused both by the direct impact on the soil (recreational construction, pollution, waterlogging, coastal abrasion, etc.) and by the consequences of river flow regulation since the second half of the twentieth century (an increase in the area occupied by thin silty sediments and a reduction in the area of accumulation of sandy sediments).

Currently, the conservation of biodiversity of water and land ecosystems of the delta is one of the most important areas of scientific work of the Southern scientific center of the Russian Academy of...
Sciences. To conduct multiple studies, the Kagalnik scientific expedition base was organized on the coast of one of the channels in the southwestern part of the delta [1, 2].

The purpose of this study is to assess the current state of the soil cover on islands and in coastal zone of the Don River delta under the influence of anthropogenic loads.

2. Objects of monitoring; research plan and methods
The object of the study was the soil cover of the island and coastal parts of the Don River delta (figure 1).

![Figure 1](image.png)

Figure 1. Areas of research of soils of the Don River delta (A – northern part; B – southern part).

When studying the soil cover, standard field and laboratory methods were used: comparative geographical, ecological and landscape profiling, as well as physical and chemical methods [2].

A schematic map of anthropogenic transformation of the soil cover of the delta and coastal area was compiled using GIS technologies and integrated assessment of soil factors. To rank the territory by the degree of soil degradation, the Harrington scale was used [3], based on which five zones of soil degradation under the influence of economic activity were identified with different indicator weights: very high, high, medium, below average, low. Ranking of indicators was performed by linear interpolation using the following formula in the equation (1):

$$P = \frac{(A_{\text{max}} - A_{\text{min}})}{n},$$

where:

- $P$ rank,
- $A_{\text{max}}$ the maximum value of the indicator;
- $A_{\text{min}}$ the minimum value of the indicator;
- $n$ the number of ranks.

3. Results and discussion
As a result of the expedition works in 2014–2020, it was found that the soils of in the northern part of the delta are represented by five types and subtypes: alluvial, alluvial-meadow, meadow-alluvial, meadow, and layered sandy soils.

Soil-forming deposits in the island part of the delta are unevenly distributed. Riverbed sands are deposited on the islands washed by large branches of the river, such as the Wide, Commotion, Merinova distributaries. As you move away from the water courses, these sands are replaced by floodplain
sediments and ancient sands. They occupy a significant part of the delta islands and compose massifs of the Svinoy, Donskoy, Kuterma, and other islands. Delta sands are found in the western part of the delta and, also, on small islands in the southern part. An increase in the area of thin alluvial soils composed with a low resistance to wind blowing, especially during the dry period, and a reduction in the soil organic matter content lead to changes in the natural delta complexes. Delta sands are mainly fine-grained sands formed under the active influence of sea water. They are distributed along the periphery of the delta, along the Mertvyi Donets and Kalancha distributaries. Gray-yellow delta sands are enriched in silty and clayey material and often contain mollusk shells [3, 4].

As a result of many years of research, three ecological and geographical zones in the Don River delta were identified.

The northern part of the delta (delta islands between the Mertvyi Donets and Kuterma distributaries) and occupies the area of 12.256 km². It is characterized by a predominance of shallow alluvial soils on layered sandy alluvium and meadow-alluvial layered gleyed soils on floodplain sediments and on ancient sands. The main forms of anthropogenic degradation are a decrease in the thickness of the upper soil horizons, waterlogging, and secondary salinization of alluvial soils [5].

The soil cover of the central part of the delta is characterized by the greatest variety of soil types (between the Kuterma and Church distributaries; the area of the studied Islands is 32.81 km².

In the soil cover of the central part of the delta, alluvial-meadow carbonate soils in combination with meadow-alluvial saline, as well as meadow-marsh, and swampy soils are widespread. As key anthropogenic processes, it is necessary to identify coastal abrasion, activation of surface runoff, and salinization [6].

The southern part of the delta lies between the Tserkovny and Kamenik distributaries to the confluence of the Kagalnik River in the Taganrog Bay; the areas the studied islands is 13.48 km². It is characterized by the formation of soil complexes, including thin alluvial soils on layered sandy alluvium, alluvial-meadow carbonate soils, meadow-alluvial saline, and alluvial layered gleyed soils on sand loamy alluvial sediments. The development of these complexes is related to alluviation processes. The southern part of the Don River delta Islands is subjected to the most intense anthropogenic load. This is due to the high population density, the development of sea and river cargo transportation, wear and breakdown of hydraulic structures (ponds), chemical and physical water pollution.

Assessment of the degree of degradation of the soil cover under the influence of economic activity. Spatial analysis of the distribution of soils according to the degree of degradation showed that non-degraded soils are found in areas removed from agricultural use and assigned to the specially protected natural areas, tourism development, and Donskoy Nature park. Nondegraded soils do not form continuous areas; overall, they occupy 18% of the studied territory (1078 ha) (figure 2).
Slightly degraded soils are characterized by insignificant manifestations of dehumification, deflation, as well as salinization and water erosion and cover 21% of the studied area, or 1266 ha.

Areas of moderately degraded soils are concentrated in the central part of the delta and occupy 35% of the studied area (2049.6 ha). They are used for grazing, as residential areas, places adjacent to navigable channels that are subjected to abrasion and washing away of the fertile soil layer by waves («anthropogenic tsunami»). The intensification of abrasion in the delta is confined to the areas with intensified transportation.

Highly degraded soils are confined to places of intense anthropogenic load and are subjected to deflation, salinization and dehumification (these include washed-out soils of riverine watersheds, takyr surfaces and inclusions). Very heavily degraded soils occupy a significant area in the southeastern coastal part of the delta. These soils are subjected to very strong losses of humus, over-compaction, and a decrease in the thickness of the fertile layer by 2.1–2.3 times compared to the soils of the protected areas of the Don Delta Natural Park.

Highly degraded soils make up 26% of the territory (1546.46 ha), these are areas of discharge from ponds, valleys of dried rivers, streams, degraded and polluted landscapes (figure 3).

Figure 3. Map of anthropogenic transformation of the soil cover of the island and coastal parts of the Don River delta: 1. Complexes of alluvial, meadow-alluvial soils on sandy loam deposits. 2. Meadow-alluvial layered bare soils on deposits of floodplain and ancient sands. 3. Alluvial-meadow carbonate soils in combination with meadow-alluvial saline soils. 4. Alluvial-meadow layered bare soils on alluvial loamy and sandy deposits subject to sheet erosion.

It is revealed that the soil cover has undergone changes under the impact of both natural and anthropogenic factors. This is due to increased anthropogenic load on the ecosystems in the lower reaches of the Don River, hydrotechnical constructions, washing away of beaches and soils as a result of «anthropogenic tsunamis» from large-tonnage vessels, increased recreational load, and agricultural activities.
4. Conclusions
It is established that since the middle part of the 20th century, changes have occurred in the soil cover of the Don River delta. In the modern period, the banks of large watercourses are occupied by thin soils formed on floodplain and ancient sands, which replace meadow and meadow-alluvial soils along large watercourses. Soil degradation is due to the increasing anthropogenic load on ecosystems in the lower reaches of the Don River, hydrotechnical constructions, agriculture, and an increase in the population density of the Northeastern Azov region. According to the degree of degradation, five main types of anthropogenically transformed soil complexes were identified in the studied territory. Under the current conditions, under intense anthropogenic load, the area of degraded delta soils will increase, which negatively affects their fertility.

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