Monitoring of the Agricultural Landscape and Long-Term Forecasting of Soil Fertility in the Kuban River Delta

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Abstract. The article considers the issues of soil fertility forecasting monitoring and substantiates the methods applied to the agricultural landscape of the Kuban river Delta on the example of assessing the initial state of arable land fertility. There was conducted the analysis of the properties of the Delta geosystems: openness, integrity, functioning, dynamics, evolution and structure of the geosystem. Environmental factors are indicated when considering the Delta geosystems. The dependence of the surface radiation balance on the terrain features is considered on the example of the Kuban river Delta. The need for a comprehensive assessment of agro-resource potential is justified due to the development of degradation processes in the soil. The criteria for long-term forecasting as a single integrated approach to the methodology of assessing agricultural resource potential are substantiated. An integral indicator of soil fertility was used to assess fertility. The specific natural-technogenic complexes of separate parts of the Delta geosystems in relation to the Kuban river are identified. The impact of human anthropogenic activity has led to a noticeable decrease in soil fertility, reduced reserves of biomass, humus and basic nutrients in the soil, a single comprehensive monitoring of the assessment of agro-resource potential of its availability and use is necessary as a result of the development of degradation processes. Assessment of land resources to determine the trend of soil formation processes and soil fertility dynamics of a specific territory is very relevant. It is necessary to justify the identification of the main factors that affect the process of changing soil fertility, biomass, humus and basic nutrients.

1. Introduction

At present, the term "Delta" refers to a multi-arm estuarine section of the river, composed of thick alluvial deposits. In the geomorphological approach, the Delta is a system of sediment deposits of river origin, i.e. the place of the most active sedimentation [1]. Due to the fact that the structure and formation of rivers are closely related to hydrologic-morphological, geological, hydrogeological, geochemical, Aeolian and other processes, there are various concepts of "Delta" in the literature, depending on the tasks and the accepted approach to its study [2, 3].

Currently, the natural flow of the Kuban river is significantly distorted by the existing water management system for regulating and using the flow on the Upper, Middle and Lower Kuban. After commissioning of the Krasnodar reservoir the water regime of the Lower Kuban is determined by economic necessity of releases from it [4, 5, 6, 7]. To obtain a homogeneous range of runoff characteristics, the natural runoff was restored in monthly calculation intervals for the water management year by summing the hydrometric runoff and irrevocable water intake above the
calculated target, taking into account water regulation by the reservoir [8]. To assess the representativeness of this series, a difference integral curve of modular coefficients [9, 10] (Figure 1) is constructed.

![Integral curve of the annual flow of the Kuban river into the Krasnodar reservoir for the period 1911-2021.](image)

**Figure 1.** Integral curve of the annual flow of the Kuban river into the Krasnodar reservoir for the period 1911-2021.

The analysis of the curve shows that, starting from the 1918-1919 water management year to 1938-39, that is, for 20 years, there was little water. Currently, since 1987-88, the Kuban river has been in a multi-water phase in terms of water flow.

The variety of natural conditions in the Kuban river basin also affects the distribution of runoff within the year along the length of the river. In the upper part of the Kuban river, where the rivers with the largest areas of glaciation on the slope of the Greater Caucasus range, the melting of which causes the highest summer flow – 65-75% of the annual flow [11]. Downstream, due to a decrease in the share of glacial nutrition, the share of spring and summer flooding in the annual volume decreases and it is 45-60% in different water years near the city of Krasnodar. The most low-water period is autumn-winter (November-February), during which about 20-30% of the annual runoff passes. The calculation of the maximum flow of the Kuban river in the lower reaches of the Krasnodar reservoir, the mode of which was changed under the influence of water management measures, was made by statistical processing of restored natural water flows [12].

River deltas are transitional zones from land to sea. They have a high bioclimatic potential and are extremely responsive to any changes caused by economic activity, both in river basins and in the coastal part of the sea.

2. Materials and methods

The main feature of a geosystem, of course, is openness. The sediment transported by the river is deposited within the Delta due to a decrease in the flow rate. They form a relief, a characteristic feature of which is the general "bump" of the delta, the formation of river shafts and depressions between the channels [13] (Figure 2).

![Section from West to East through the right bank Delta of the Lower Kuban.](image)

**Figure 2.** Section from West to East through the right bank Delta of the Lower Kuban.
A consequence of the deltas' topography features is a natural decrease in depth and an increase in ground water mineralization from the center to the periphery. The discharge of the underground stream is usually due to evaporation, which in many cases, especially in arid regions, is accompanied by salinization of the land [14, 15]. In the steppe zone, salinization of land under natural conditions is poorly expressed as a result of significant intensity of natural moisture (precipitation). There is no underground inflow and outflow due to poorly expressed drainage of root deposits.

River (liquid and solid) runoff at the top and mass exchange with the sea at the lower border of the Delta, as well as the receipt of solar energy and precipitation determine the general nature of the terrain, the features of hydrogeological, geochemical and soil-biological conditions of the deltas [16].

The high bioclimatic potential of deltas at south-moderate latitudes is due to the influx of solar energy and favorable conditions of natural moisture, it contributes to the formation of highly productive biocenoses (coastal estuaries, marshes).

Changing the degree of openness is accompanied by a violation of the basic properties and leads to the evolution of the Delta geosystems, i.e. to irreversible changes. These include: erosion of riverbeds, drying of the Delta territory, deterioration of hydrogeological, geochemical and soil-biological conditions, and increased influence of the sea on the hydrological and hydrochemical regimes of estuaries and lakes.

All other properties of the Delta geosystems (integrity, functioning, structure, dynamics), they are determined by the interaction and interdependence of individual components, which include the atmosphere, biota, soil, and water resources.

When considering the Delta geosystems, it is necessary to identify the main environmental factors (solar radiation, precipitation, soil temperature), and establish a relationship between the environmental factors and the components of the geosystem.

One of the main environmental factors that determine the relationship of climate indicators with the components of the natural system is the hydrothermal regime characterized by the "dryness index". The analysis of numerous data shows that the values of the "dryness index" within the large river deltas (rivers Kuban, Volga, Terek, etc.) vary in a very wide range [17, 18, 19].

The high value of the radiation balance is confined to elevated non-flooded places with a deep occurrence of the ground water level. A lower value of the radiation balance is associated with interstitial depressions that are subject to periodic or permanent flooding.

A wide range of changes in the hydrological regime contributes to the formation of different landscapes.

An important advantage of the "dryness index" is that it determines the main properties of components of geosystems, in particular soils and biota [20]. Thus, the "dryness index" should be understood not only as a complex characteristic of the hydrothermal regime of the territory, but also as a controlled value that allows you to change the structure and properties of geosystems. Changing the value of the "dryness index" in one direction or another due to changes in the water regime (landfall, changes in the volume of river flow and flooding, irrigation) is accompanied by changes in the properties of individual components and the geosystem as a whole. These changes concern, first of all, such components of the Delta geosystems as biota and soils [21].

Given the significant differences in individual parts of the Delta geosystems, it is advisable to distinguish three characteristic natural-territorial (man-made) complexes.

The first complex is riverine ramparts and the top of the Delta. These landscape elements are associated with elevated terrain elements and the top of the Delta. They are not subject to flooding by river waters and are mainly represented by zonal soils peculiar to this climate zone [22].

The second complex consists of estuaries and marshes that are not directly connected to the sea. These formations are confined to interfluvial depressions and are represented by azonal soils.

The third complex is the seaside estuaries directly connected to the sea [23]. These natural features occupy the coastal part of the Delta and are mostly open water.

In different natural zones, the structure of the Delta geosystems has its own features and differences, but the general scheme of their formation is more or less the same [24].
For the first and second complexes, the main changes are associated with a violation of the natural and hydrothermal regime and soil formation conditions. Violation of the hydrothermal regime occurs due to plowing and agricultural production (including land irrigation). Violation of conditions of soil formation is associated with changes in flooding regime caused by the embankment of the channel, i.e. the change in volume flow in the top of Delta.

For the third complex, changes are caused by a violation of water exchange with the sea and the hydrochemical regime of estuaries as a result of a decrease in the volume of runoff (the leveled regime of coastal estuaries does not change at a constant sea horizon) [25].

Thus, the change in the properties of components of the Delta geosystems are mainly associated with changes in hydrothermal and hydrochemical regimes.

The influence of human anthropogenic activity has led to a noticeable decrease in soil fertility, a decrease in the reserves of biomass, humus and basic nutrients in the soil, as a result of the development of degradation processes [26]. A single integrated approach to the methodology of assessing the agro-resource potential of its availability and use in a particular region is needed. A set of reclamation measures aimed at improving soil formation processes will have a high degree of effectiveness in addressing the issue of industrial safety of agricultural products within the borders of the Kuban river Delta [27]. Assessment of land resources, to determine the trend of soil formation processes and soil fertility dynamics of a specific territory, becomes vital and very relevant.

Based on the above statement, it becomes necessary to identify the main factors that affect the process of changing soil fertility, biomass, humus and basic nutrients, as well as hydrolytic acidity.

Based on the analysis of data from soil surveys of leached Chernozem fields in the coastal zone of the Kuban river Delta, the initial state of the agricultural landscape (layer 0-100cm) was estimated.

We considered a seven-field feed crop rotation with equal-sized fields located on the right bank Delta zone of the Kuban river to assess the fertility.

The values of factors necessary for calculating the fertility index are determined: hydrolytic acidity; the ratio of humates to fulvates and the relative content of N, P, K.

Based on the obtained mathematical model of assessing the state of the agricultural landscape with built-in crop rotation, the forecast of the initial state of the entire life of the project was "lost". This time before the reconstruction of the technogenic complex, which is carried out due to changes in technologies and technical means, is about 25 years. For our case, this is the end time of the third rotation, i.e. 21 years old. As can be seen from the research results, the scientifically based crop rotation provides an increase in the integral indicator of the provision of SG humus for the projected period (21 years) by 0.14 units, (humus reserves increase by 27 t/ha), and the fertility index by 0.43 units. In the forecast period, there is a positive balance of humus 1.29 t/ha per year, nitrogen 64.9, phosphorus 46.5 and potassium 62.4 kg/ha per year. At the same time, we assume that the acid-base factor does not change (ΔSНyear = 0) (Table 1).

| Years | S_G | S_NP_K | S | G, t/ha | N, kg/ha | P_2O_5, kg/ha | K_2O, kg/ha |
|-------|-----|--------|---|--------|---------|---------------|-------------|
| 0     | 3.76| 5.44   | 13.78| 357    | 17847   | 325           | 3979        |
| 7     | 3.81| 5.54   | 13.92| 366    | 18302   | 651           | 4416        |
| 14    | 3.86| 5.63   | 14.07| 375    | 18756   | 976           | 4853        |
| 21    | 3.9 | 5.73   | 14.21| 384    | 19210   | 1301          | 5289        |
| Δ     | 0.14| 0.29   | 0.43| 27     | 1363    | 976           | 1310        |
| % from max | 60.9 | 67.4 | 71.1 |

Figure 3 shows the relationship between the biota of the Delta geosystems and the hydrothermal regime.
Fig. 3. Obtained graphs of biota productivity values (N) from the dryness index (R) at different boundary parameters of the radiation balance values (R) (kJ/cm$^2$ per year): 1 - minimum radiation balance (R= 167); 2 - average radiation balance (R = 209); 3 - maximum radiation balance (R = 251).

The soil index, which characterizes natural fertility, affects the yield of specific crops in the conditions of specific agricultural equipment, it should be characterized by as few parameters as possible. The following factors were selected, mainly determining soil fertility: humus reserves and quality, reserves of the main elements of mineral nutrition (nitrogen, phosphorus and potassium), which are in accessible and semi-accessible forms for plants, as well as hydrolytic acidity. They determine the fertility of the soil with a certain degree of accuracy limited by reasonable limits.

The soil can not be fertile in conditions of deficiency of main elements of mineral nutrition (nitrogen, phosphorus and potassium) or with high hydrolytic acidity.

The selected characteristics have a certain zonal conditionality, and each formed zonal type of soil can be considered a certain quasi-stationary state of it, corresponding to these external conditions.

It is necessary to understand that the influence of human economic activity will lead to a change in the natural "natural" course of the processes of formation of qualitative and qualitative humus reserves, basic soil minerals, hydrolytic acidity, changes in the parameters of the soil radioactivity balance, and as a result, changes in the hydrothermal and hydrochemical regimes for the Delta geosystems of the Kuban river.

3. Conclusion

The generalizations made are not comprehensive, of course; they only give a general idea of the features of formation and functioning of the Delta geosystems. When considering the specific features of the Delta geosystems in various natural zones it is necessary to note the following:

1. Deltas of large rivers are specific geosystems, a characteristic feature of which is a large variety of hydrothermal regime, mainly associated with the hydrological conditions of deltas. The main factors determining the variety of hydrothermal regimes along with climate, hence the structure and functioning of the Delta geosystems, are river (liquid and solid) runoff and water exchange with the sea (water intake). The structure of the Delta geosystems includes zonal and azonal elements — first, second and third complexes.

2. Delta geosystems, especially in the southern regions, are characterized by high bioclimatic potential and are important objects for the development of agriculture and fisheries.

3. Delta geosystems are transition zones from land to sea. They, like all border systems, are very responsive to any changes in the degree of openness: changes in the volume of river (liquid and solid) runoff at the top of the Delta, hydrological and hydrochemical regimes of the sea (the basis of erosion), development of the Delta territory (the collapse of the riverbed, agricultural land use, including irrigation and drainage).
4. All economic activities within river deltas should be based not only on the management of natural resources or even on the preservation of the Delta geosystems in their original form, but on the further development and increase of ecological and socio-economic potentials in accordance with the requirement of sustainable development.

4. References

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