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RIVER BASINS OF THE CRIMEAN PENINSULA: SPATIAL DIFFERENTIATION IN AGROECOLOGICAL STATE AND RISKS OF SOIL DEGRADATION

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Abstract. The article is devoted to the study of the agroecological state of the river basins of the Crimean Peninsula's agricultural zone and their typification by the occurrence of soil degradation processes and the degree of the anthropogenic impact using the basin approach. The basins of fourth order (according to the Straler-Filosofov system) were used as the basic assessment units (with the exception of the territory of Mountainous Crimea and the Southern Coast basins). Using geoinformation systems and remote sensing data, an analysis of the spatial distribution of eight indicators was carried out: forest cover, pressure coefficient, erodedness coefficient, the share of saline soils, karst cavities areas density, LS-factor, elevation difference, and drainage density. For an objective identification of basin types, the kernel K-means clustering method was chosen implemented in the ArcGIS software. It has been found out that two key attributes of soil degradation, including erodedness and salinity levels, have a strong influence on distinction of groups from each other. Forest cover and geomorphological factors (LS-factor and elevation difference) have a noticeable influence. Pressure coefficient and karst cavities areas density does not have a significant impact on the identification of types.

As a result, four spatially homogeneous basin groups were identified. Basins with soil salinization (34 % of the study area) are located east of the Bakal Peninsula along the northern border of Crimea, including the Syvash region and the entire Kerch Peninsula. It is characterized by the biggest share of saline soils (92,2 %) with a minimum erodedness coefficient (0,02) in the soil cover structure and low forest cover (0,6 %). Basins with maximum agricultural load (38 %) are located in the central part of the Crimean Plain. These territories are more involved in crop production than the other areas due to favorable geomorphological and soil and climatic conditions. It has been found that 77 % of the territory of this type is plowed up or allocated to gardening and viticulture. Basins with water erosion risk (21 %) are located predominantly along the foot of the northwestern macroslope of the Crimean Mountains and in northwestern Crimea. It is most eroded one compared with the (0,25), and geomorphological conditions create increased risks of water erosion processes, as evidenced by high values of the LS-factor (0,9) and elevation difference (75,3 m). For basins with an increased risk of exogenous geomorphological processes (7 %) characterized by the greatest distribution of karst. Specific land use problems have been identified for each type of basin, and ways to address them have been proposed. In terms of the land management, the identified territorial groups of basins can serve as primary differentiation units for priority soil protection measures.

Keywords: *river basin, Crimea, typification, soil degradation, land use, GIS*

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РЕЧНЫЕ БАССЕЙНЫ КРЫМСКОГО ПОЛУОСТРОВА: ПРОСТРАНСТВЕННАЯ ДИФФЕРЕНЦИАЦИЯ ПО АГРОЭКОЛОГИЧЕСКОМУ СОСТОЯНИЮ И РИСКАМ ПОЧВЕННОЙ ДЕГРАДАЦИИ

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Аннотация. Исследовано агроэкологическое состояние речных бассейнов земледельческой зоны Крыма и их типизации по проявлению почвенно-деградационных процессов и степени антропогенной нагрузки с использованием бассейнового подхода. Выполнен анализ пространственного распределения почвенных, геоморфологических и эколого-хозяйственных показателей. Проведена группировка бассейнов, которая может быть использована для планирования по эколого-реабилитационного землепользования.

Ключевые слова: *речные бассейны, Крым, типизация, деградация почв, землепользование, ГИС*

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Introduction

Over the past decade, the state of the Crimean agricultural sector has undergone significant transformations under conditions of the changing socio-economic situation. The high agro-climatic potential of the peninsula brings about favorable conditions for development of crop production, which has resulted a high degree of the agricultural development: a third of Crimea's land is allocated for the cultivation of field crops, orchards, and vineyards. Even the closure of the North-Crimean Canal which provided up to 85 % of the Crimean Peninsula's water demand did not lead to the crop production area reduction. This is connected with the overall economic growth and the absorption of unused lands: there was an increase in the farmland area by 14 % from 2015 to 2020.

Alongside the intensive development of the agricultural sector in the peninsula, conditions are brought about for risky farming associated with the strengthening of soil degradation processes [Ergina et al., 2023], including those which have intensified during the period of the fresh water shortage [Tabunshchik et al., 2021]. Negative changes in the Crimean soil resources are caused by intensive plowing, leaving the surface without vegetation, irritation without drainage systems, non-compliance with the balance of nutrients, and the use of heavy cultivating equipment. Meanwhile, there are also problems in the spatial land use management in: the system of land use is disrupted, all the previously used lands are not absorbed, stripped farming, curvedness, complex configuration, wedging, outland, and interspersion have been found.

Soil degradation is included in the list of key threats in the Strategy for Environmental Security of the Russian Federation until 2025. This is also reflected in the Strategy of Social and Economic Development of the Republic of Crimea until 2030, which states that the soil fertility decline and reforestation work extent reduction impedes the formation of a sustainable natural environment. However, soil management practice often underestimates the significance of the declared threats. Thus, according to Rosstat, environment protection costs in the agricultural sector of the Republic of Crimea have decreased 5 times since 2015, and in 2021 they constituted less than 0,1 % of the total costs of environmental protection activities in the region.

With the rapid development of the agricultural sector in the region, a balanced approach is required to solving soil and water protection problems and forming a sustainable land use. Various methods of rational territorial organization and its assessment were previously proposed for the Crimean territory, such as land zoning according to agro-ecological characteristics [Badenko et al., 2020;

Melnichuck, Zackalichnaya, 2021], landscape planning within the boundaries of administrative-territorial entities [Kalinchuk, Kudrian, 2019], as well as the basin approach [Ivankova, 2020; Buryak, 2021; Tabunshchik et al., 2022].

We see the basin approach as the most optimal way to solve the problems of preserving the soil and water resources of the territory. The basin concept of nature use combines the principles of landscape planning with keeping track of the hydrological features of the catchment basin [Lisetskii, 2021; Dmitrieva, Zhigulina, 2020]. This approach provides the implementation of comprehensive solutions to protect soils and water in entire river basins, including through regulation of surface water drainage, the water flow through soils, and soil erosion in agricultural landscapes [Lisetskii, Buryak, 2023].

When carrying out land management activities, the zoning of the territory is especially important. Fundamental zoning units include ecological and economic zones, similar areas in terms of ecological and economic characteristics, and homogeneous areas [Komarov et al., 2019; Nabati et al., 2020]. An important feature of identifying agroecological areas of the same type is that their boundaries are brought to light not by random or statistical, but by genetically predetermined features of the territory, which bring about the natural and historical interconnection of individual parts of the same type of area and their interdependence in the chain of economic ties. A river basin can be such a unit.

The river basin as an integral natural formation, which is a meeting point for flows of substances and energy, is to be considered from the perspective of operational territorial units of integrated environmental monitoring. In recent years, sustainable land use has been justified not for individual economic areas but within the boundaries of complete basins that integrate separate subsystems of landscape architecture according to common features of hydrofunctioning [Mukharamova et al., 2020; Yermolaev et al., 2022; Buryak et al., 2022].

When zoning, agroecological resources should be reviewed in close connection with forest, water, recreational, managerial and business resources to reflect the set of all conditions for the development of the agroindustrial complex [Novikov, Novikov, 2021]. The objective of environmental zoning is to identify the compliance of the proposed land use options with their natural potential. Zoning should establish the environmental priorities and constraints that should be followed when using them in order to prevent the occurrence of environmental problems.

The purpose of the study was an integral assessment of the environmental and resource condition of the Crimean Peninsula using the basin approach, typification of river basins by the agroecological state and development of degradation processes to substantiate soil and water protection measures.

Materials and methods

The study area. Provide The Crimean Peninsula in the south of the East European Plain with a relatively small area (about 27,000 square kilometers) is characterized by a high natural and landscape diversity (Fig. 1). The barrier effect of the Crimean Mountains in the south of the peninsula forms a sort of "reverse" zonality of the Plain Crimea: in the north of the peninsula, there are semi-desert steppe locations: further to the south, typical steppe, then forest-steppe and forest locations are found landscapes [Pozachenyuk, 2019]. The history of agrarian development of Crimea lands is as long as several thousand years. There was a significant change, especially in the natural landscapes on the peninsula during the Great Greek Colonization of Northern Black Sea coast, when several major agricultural zones emerged in Crimea and the subsequent agricultural impacts on the soils continued for a millennium [Lisetskii, 2019].

The study covered the basins where land use was dominated by the arable farming sector: the Plain Crimea (including North Crimean Lowland steppe, Tarkhankut Upland, Central Crimean Plain steppe and Kerch hilly-ridged steppe) and Foothill forest-steppe. The Crimean Mountains and South Coast of Crimea were not analyzed in this study since they have more tourist and recreational specificity of land use.

The authors analyzed Crimea's basin structure [Lisetskii, et al., 2020] by using GIS based on the processing of *SRTM* (Shuttle radar topographic mission) data with a resolution of 3 arc seconds with detailing by using topographic maps at a scale of 1 : 100,000. *SRTM* resolution is suitable for studies of this scale, and its spatial analysis provides the necessary details and helps to define accurately the boundaries of the basins [Esin et al., 2021] and its morphometric characteristics.

The automatic analysis of the digital elevation model (*DEM*) identified 6 000 erosional forms of various hierarchies. Their watersheds were grouped at the level of 4th order basins (according to the Straler-Filosofov system) (Fig. 2).

For the Crimean Plain, permanent watercourses function, starting mainly from the 4th basin order, which occupy 52 % of the territory of the peninsula. In addition to the 4th basin order, individual basins of 1st-3rd order (if the mouth of the main erosional form was adjacent to the coastline) and the 5th and 6th order territories situated near the riverbed were identified. The coastline also has areas with runoff towards the sea without a pronounced main erosion form, which were not involved in the analysis.

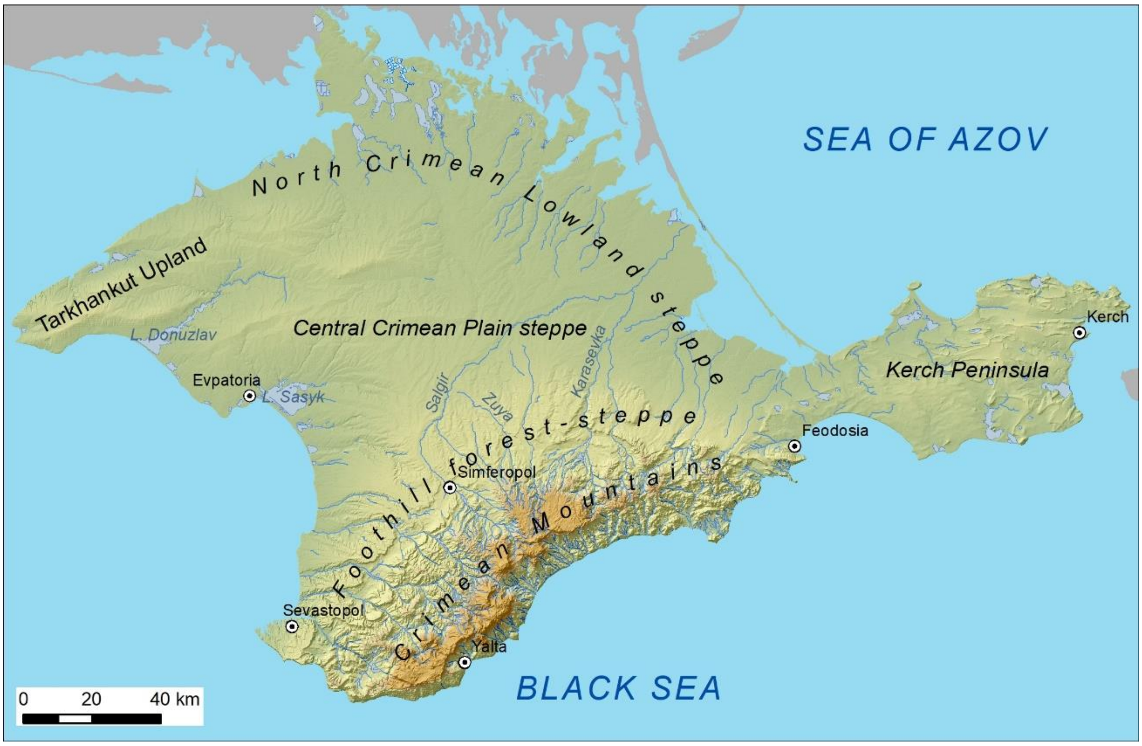

Fig. 1. Physical map of the Crimean Peninsula

Рис. 1. Физическая карта полуострова Крым

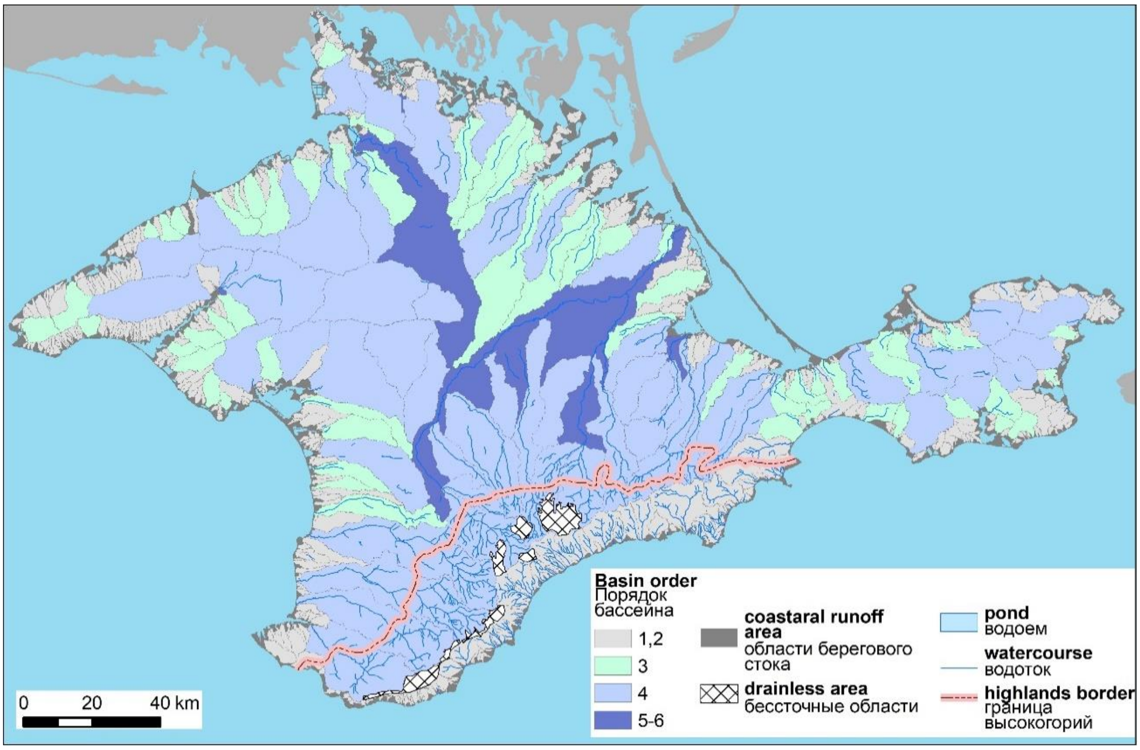

Fig. 2. The river basins structure of the Crimean Peninsula

Рис. 2. Структура речных бассейнов полуострова Крым

Note that the basins of the northwestern macroslope of the Crimean Mountains have very different land use specifics depending on the landscape zone. In such cases, averaging of the evaluation parameters across the entire territory of the basin may decrease the accuracy of the typification results. Therefore, such basins were divided into a piedmont-plain part, where the main areas of anthropogenically transformed lands are concentrated, and a mountain part, which was not included in the analysis.

Typification methodology. A geodata base was generated for Crimea territory based on remote sensing data and the global digital elevation model [Buryak, 2021]. Using the spatial analysis, a component-by-component assessment of the natural and economic conditions in the Crimean river basins was carried out. The general scheme of the study is presented in figure 3.

To identify the main groups of basins with similar specific features of degradation processes, geomorphological conditions, and the degree of anthropogenic transformation of landscapes, eight indicators were selected, including forest cover, pressure coefficient, erodedness coefficient, the share of saline soils, karst cavities areas density, LS-factor, elevation difference, and drainage density.

High-resolution satellite images from the Google Earth resource were used to analyze the agricultural land structure.

After interpretation and vectorization, the land cover types were identified: arable farming (farmland, former paddy fields, orchards and vineyards), buildings (settlements, garden areas with buildings, industrial facilities, roads, individual complexes of structures, and other facilities), natural agricultural areas (herbaceous vegetation, trees and shrubs), water bodies, disturbed lands (quarries, dumps and cemeteries).

The forest cover indicator is expressed as a share of the area covered with trees and shrubs (including forest belts) of the total basin area. The pressure coefficient К [Kochurov, 1999; Chibilyov et al., 2022], expresses the ratios of farmland types, i.e. anthropogenically transformed territories, to the ecological fund lands, affecting the stability of the natural environment (1):

$$К = S_1/S_2, \quad (1)$$

where S_1 – area of destabilizing land (building land, disturbed land, farmland, orchards and vineyards); S_2 – area of stabilizing lands (forests, shrubs, herbaceous vegetation, swamps, and water bodies).

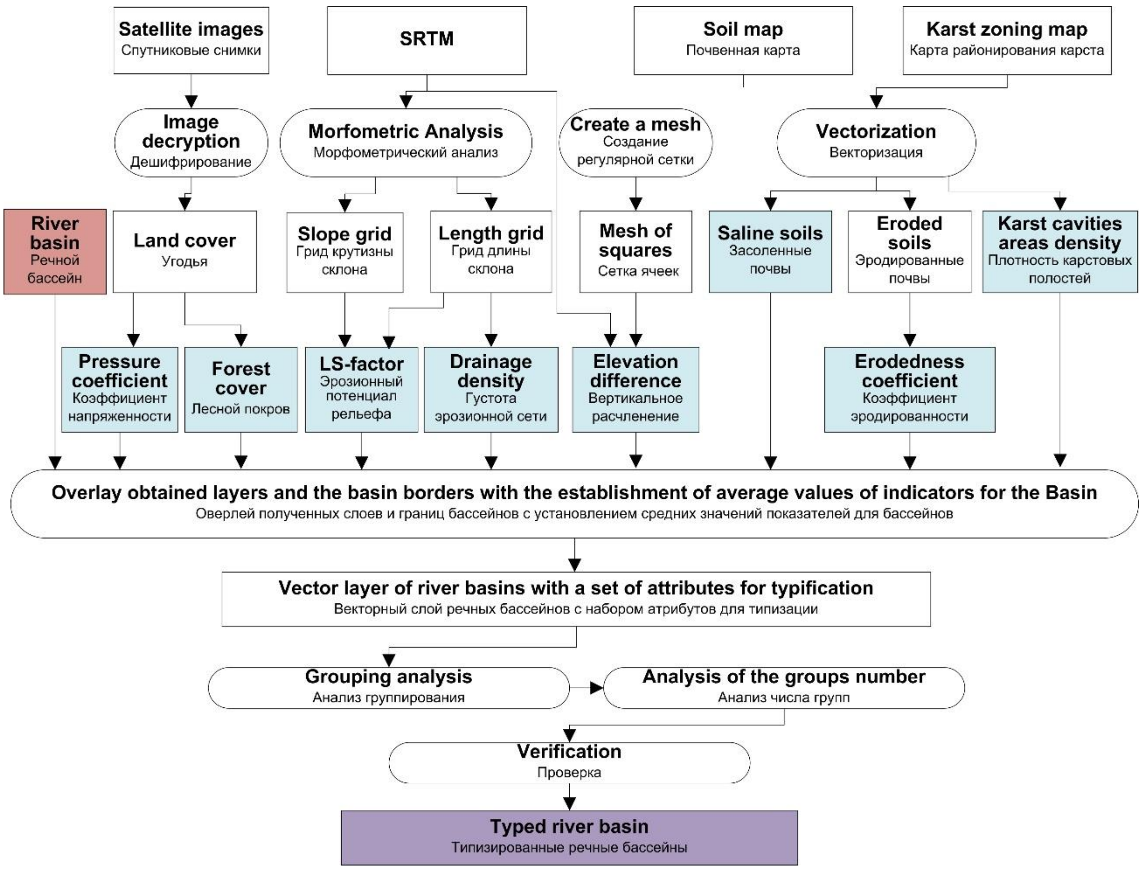

Fig. 3. The GIS-analysis scheme for river basins typification

Рис. 3. Схема ГИС-анализа для типизации речных бассейнов

To determine the share of saline soils and degree of erosion, a vector soil map [Soil map…, 2023] of the Ukrainian SSR in 1967 at a scale of 1:200,000 was used. The nomenclature of the map makes it possible to determine the share of erosion in each soil contour and the presence of salinization processes. The total areas of soils subject to salinization of different intensity were calculated for each basin. To demonstrate the degree of erosion, a more differentiated approach was used, which took into account the contribution of soils with different degrees of erosion to the decrease in the potential fertility level. The calculation is based on summarizing the results of more than twenty studies of changes in soil properties and crop yields under the impact of erosion [Lisetskii et al., 2012]. According to them, the decrease in the grain crop yields on soils with a weak, medium and strong degree of erosion is on average 19, 36 and 54 %, respectively. For each basin, the shares of soils corresponding to the erosion degree were calculated and the weighted average erodedness coefficient was also calculated, which shows the yield decrease percentage depending on the soil erosion.

The distribution of karstic phenomena was estimated based on the previously conducted regional zoning and the inventory of karst cavities [Vakhrushev et al., 2022]. For 1604 areas of karst process occurrence with a total length of 118,3 km, the density of karst cavities was estimated for each basin (in km per sq km).

SRTM data with a resolution of 3 arc seconds were selected as the initial elevation data. The LS-factor is a relief potential for water erosion, it combines slope length and slope angle influence on soil loss in the *USLEM* empirical model [Morgan, 2005] according to the formula (2):

$$LS = \frac{\sqrt{L}}{100}(1.38 + 0.965 \cdot S + 0.138 \cdot S^2), \quad (2)$$

where LS – relief erosion potential; L – slope length, m; S – slope steepness, degrees.

The value of elevation difference was calculated as the weighted average difference between the maximum and minimum values of the absolute height across the basin. For this purpose, a grid of 3 × 3 km squares was built. The choice of the cells size is substantiated by the minimum mean normalized error compared with other square sizes. The elevations for each square were calculated using *SRTM*. Next, we took the kriging interpolation method as a basis to construct a vertical terrain dissection map based on elevation difference within a cell.

The analysis of the drainage density was carried out according to the runoff accumulation model, which shows the number of cells up the slope from which the runoff can flow into each subsequent lower cell. Cells with a total runoff of 200 or more cells (126 ha of the overlying catchment area for SRTM resolution) were identified as erosion network elements. The results were updated by using topographic maps on a scale of 1 : 100,000, with special attention to the Syvash area basin. The drainage density for each basin was calculated as the ratio of the total length of its erosion network to the basin area.

Among many methods of clustering algorithms [Ezugwu et al., 2022], the clustering algorithm based on partition, in particular, the K-means algorithm, is most suitable for the purposes of typification in this study. The basic idea of kernel K-means is to take advantage of the kernel method and the original clustering algorithm, transforming the original data into a high dimensional feature space by nonlinear kernel function in order to carry out the original clustering algorithm. The work [Różycka, Migoń, 2021] describes the stages of using the method for river basins, including the selection and assessment of indicators, correlation analysis, re-selection of indicators, the grouping procedure, and grouping verification and evaluation. Using this approach helped qualitatively identify significantly different groups.

This clustering model was implemented in *ArcGIS* 10.5, software package, which was used in the study. *Grouping Analysis* tool of *Clustering Calculation* subset of the *Spatial Statistics* toolbox was used. The vector layer of river basins with the entered parameters for each indicator was used as input data. No spatial constraints were applied for the objects when setting the parameters. It means that the basins do not have to be located next to each other to be included in the same group. When grouping, the calculation algorithm standardizes the values in the analysis fields, since variables with a high degree of variability have a greater impact on clustering than variables with less variability. Standardization involves a z-transformation, where each value is subtracted from the mean of all values and divided by the standard deviation of all values. Standardization allows using different types of input data, such as coefficients, shares, and absolute indicators. The optimal number of groups to classify best the similarities and differences of objects was measured using Calinski-Harabasz pseudo F-statistics, which also reflects the similarity of objects within a group and the difference between groups.

Results and discussion

Analysis of typification indicators. The total forest cover of Crimea, including woodlands, trees and shrubs and man-made forests, is about 12 %. The forest cover of the basins decreases naturally from the foothills to the plain. If the high-mountainous areas and the southern coast of Crimea are excluded from the total forest cover analysis, the indicator for the agrarian developed territory will be 3,3 %.

In terms of the land cover ratios, most of the peninsula (62 %) is characterized by the high pressure ($K > 2{,}4$) (Fig. 4, *d*). It is represented by the agricultural basins in the central part of the peninsula, where the anthropogenic load is formed by plowed areas. The pressure close to the optimal one ($K = 0{,}7$–$1{,}3$) is typical for the Kerch Peninsula and Tarkhankut, which is explained by the extensive areas of natural herbaceous vegetation and fallow lands not used in agriculture. The basins of the mountainous zone have the highest environmental stability, since the share of anthropogenically transformed lands here is reduced to a minimum.

In total, 35 % of the Crimean territory (9,000 sq km of soils) are exposed to salinization processes of different intensity (Fig. 4, *b*). These soils are represented by chernozems, kastanozems and fluvisols of varying degree of salinity. In addition, 5,4 % of the soil cover is represented by solonetz and solonchak soils. Basins with a high share of salinated soils form a belt from the Bakal Peninsula along the northern border of Crimea, including the Syvash region and the entire Kerch Peninsula.

Eroded agricultural landscapes occupy 13,200 sq km, which amounts to 52 % of the peninsula area (Fig. 4, *a*). The agricultural lands in Crimea are prone predominantly to wind deflation; their area is 5,6 times larger than that of lands with water erosion degradation [Ergina et al., 2023]. Deflation processes are typical of areas with insufficient moistening and low relative air humidity (southern and dry steppe). The most eroded basins are at Foothill forest-steppe and Tarkhankut elevated Plain.

The combination of insignificant elevations and flat surfaces in the plain part forms low values of the LS-factor averaging 0,61 (Fig. 4, *c*). The basins of western Tarkhankut have a higher *LS* of 0,7. In the Foothills, the relief function is the highest one (2,2), but does not reach the critical values (4,3–5,2) set in [Malyshev, Goleusov, 2019].

On average, the drainage density of the territory is 0,61 ± 0,19 km/sq km. In the plain part of Crimea, the erosion network consists of hollows, shallow ravines and gullies, and rivers. The northern part of the peninsula has a lower erosion network density and, therefore, a higher probability of replenishment or of a potential groundwater zone existence. The insignificant the erosion network density leads to a coarse texture of the basin with highly permeable soil and relatively better vegetation cover and low relief. In the central and western part of the Crimean Plain there is a developed ravine-beam network with low values of the river network density, i.e. a large amount of precipitation does not stop in this area. When designing basin natural resource management, it is important to prevent the development of ravine and gully networks and to preserve as much soil moisture as possible for agricultural production.

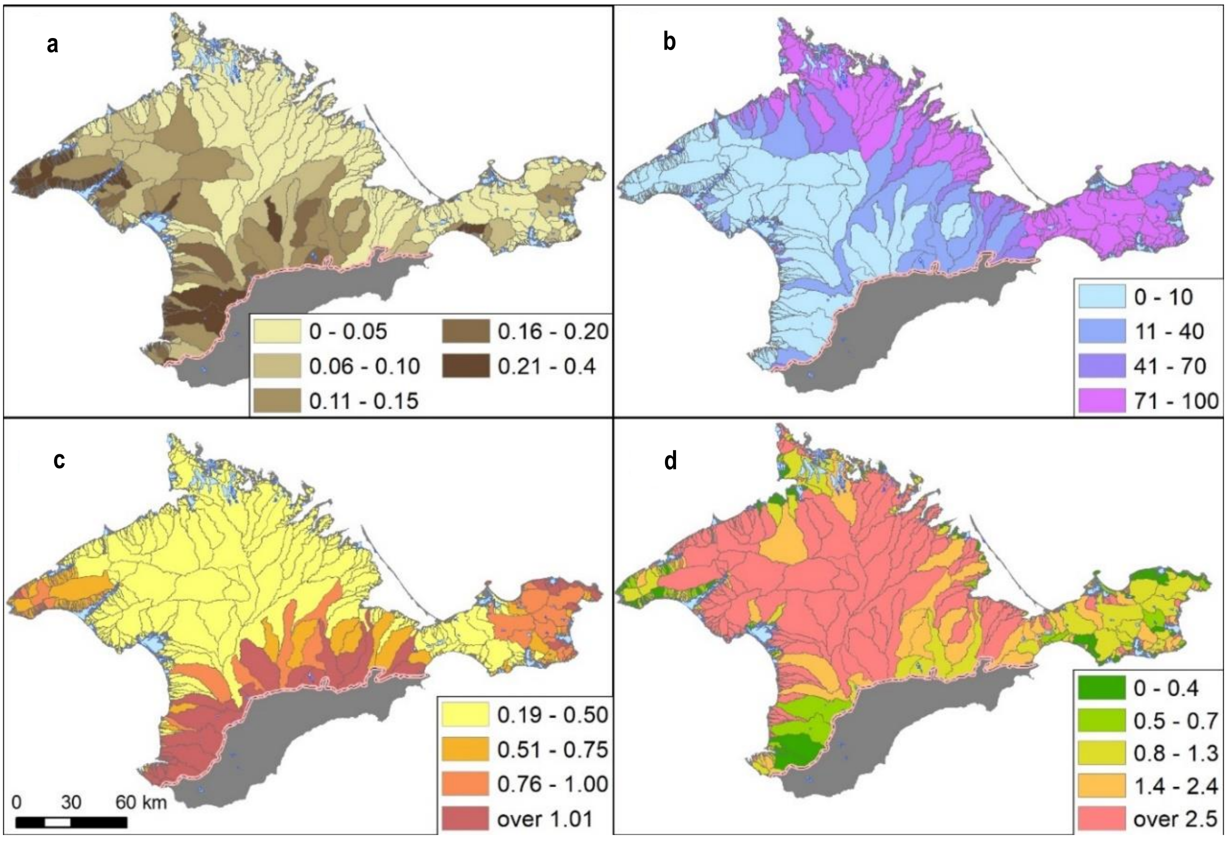

Fig. 4. Distribution of the key typification indicators within the boundaries of the Crimean river basins
Legend: a – erodedness coefficient; b – the share of saline soils, %; c – LS-factor; d – pressure coefficient

Рис. 4. Распределение ключевых показателей типизации в границах речных бассейнов Крыма
Условные обозначения: a – коэффициент эродированности; b – доля засоленных почв; c – эрозионный потенциал рельефа; d – коэффициент напряженности

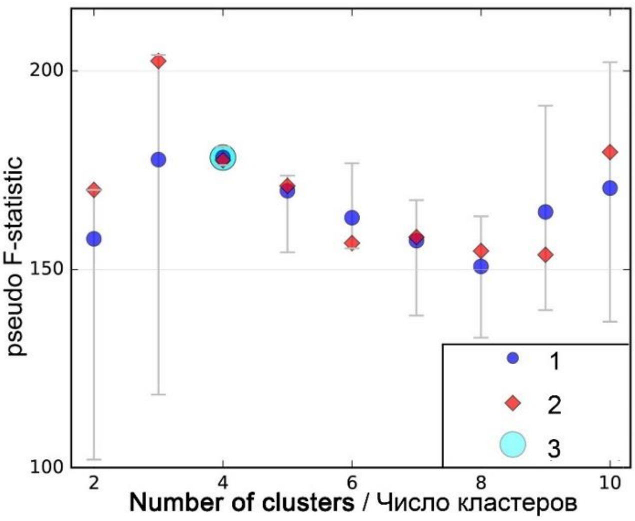

Fig. 5. Calinski–Harabasz pseudo F-statistics plot

Legend: 1 is mean; 2 is median; 3 is max mean

Рис. 5. График псевдо-F-статистики Калински–Харабаза

Условные обозначения: 1 – среднее; 2 – медиана; 3 – максимальное среднее

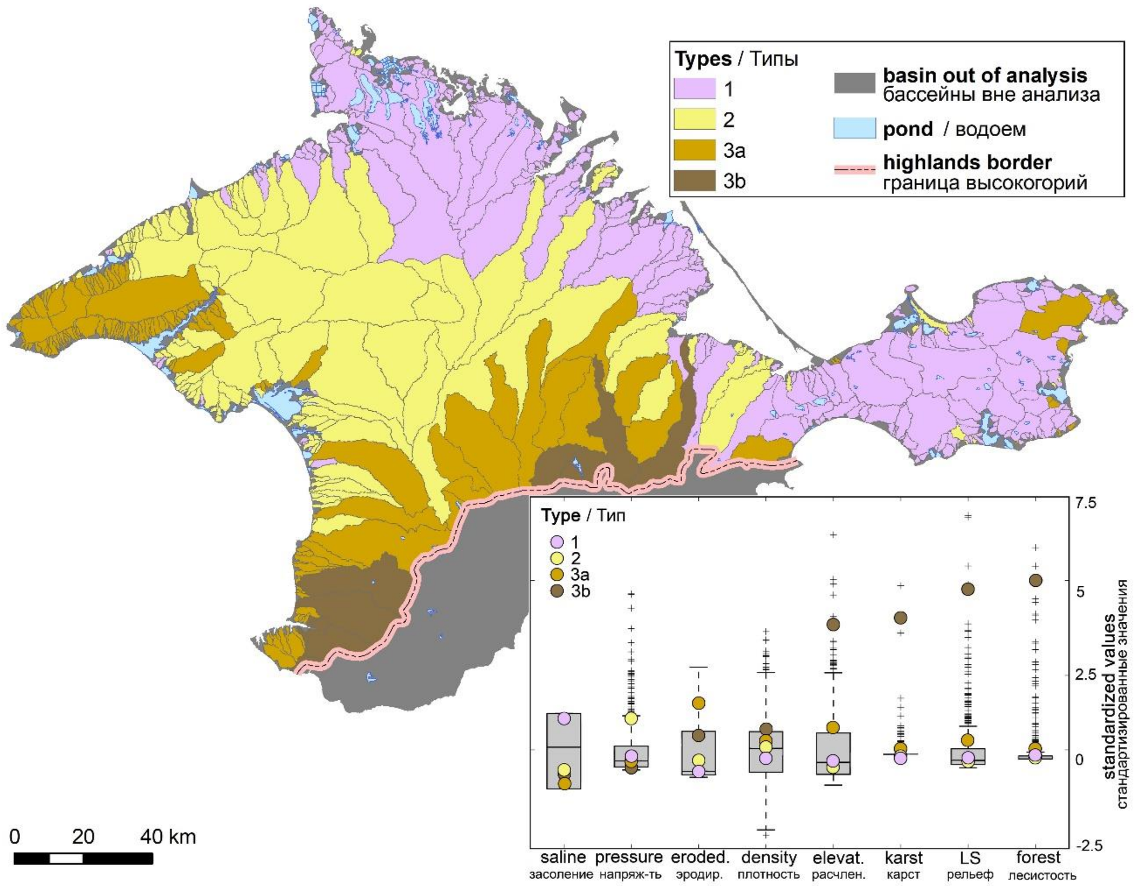

Fig. 6. Typed basins of Crimea by agroecological condition and development of soil degradation processes

Рис. 6. Типизация бассейнов Крыма по агроэкологическому состоянию и развитию почвенно-деградационных процессов

Values of the typification parameters for the selected basin types

Значения параметров типизации для выделенных типов бассейнов

Typification parameters	R^2	Types			
		1	2	3a	3b
Forest cover, %	0,59	0,6±2,4	0,7±2,7	1,9±4,8	35.6±18,7
Pressure coefficient	0,27	2,6±2,9	10,7±11,7	1,6±2,0	0,5±0,4
Erodedness coefficient	0,75	0,02±0,03	0,06±0,05	0,25±0,08	0,14±0,09
Saline soils, %	0,78	92,2±15.1	23,0±33,6	5,7±15,3	19,7±28,0
Karst cavity density, km/sq km	0,36	0,12±0,04	0,12±0,03	0,30±0,43	5,7±7,2
LS-factor	0,58	0,5±0,4	0,4±0,1	0,9±0,6	4,9±2,4
Elevation difference, m	0,54	33,7±31,8	27,7±11,1	75,3±28,9	201,2±45,6
Drainage density, km/sq km	0,06	0,55±0,19	0,62±0,20	0,66±0,26	0,74±0,16
Area, thou sq km	–	7,0	7,7	4,4	1,4
Number of basins	–	272	130	152	13

Note. The color highlight of cells shows parameters that define the features of each identified group.

Примечание. Цветное выделение ячеек указывает на главные параметры, определяющие особенности каждой выделенной группы.

Five stages of elevation difference have been identified for plain zone. The maximum values are on the Tarkhankut and Kerch peninsulas, while the minimum values are in the eastern and northern parts of the North Crimean lowland.

The overwhelming majority of karst cavities are located within Ai-Petrinskaya, Yaltinskaya, Nikitskaya Yailas, Babugan-yaila, Chatyr-Dag Yaila, Demerdzhi-yaila, Dolgorukovskaya Yaila and Karabi-yaila. In agriculturally developed basins, karst processes are found only in the Foothills area; the average karst cavity density ranges from 1 to 4 km/sq km. In the Plain Crimea, karst cavities also exist; their average density is 0,12 km/sq km.

Typification results. The results of calculating Calinski-Harabasz pseudo F-statistics show that pseudo F-statistics reach the highest values for 4 groups (see Fig. 5). Therefore, clustering was carried out for this number of types.

The results of the basin type spatial distribution and the analysis of their values of the indicators are given in figure 6 and table.

The analysis shows that the strongest effect ($0,7 < R^2 < 0,9$) on the difference of groups from each other is provided by two key signs of soil degradation, i.e. soil erodedness and salinization. Slightly less, but noticeable ($0,5 < R^2 < 0,7$) influence has the forest cover and geomorphological factors, i.e. LS-factor and elevation difference. The intensity coefficient and karst cavity density do not significantly affect the group identification. And the drainage density parameter can be excluded from the analysis.

The types of basins shaped spatially rather homogeneous groups, despite the fact that this criterion was deliberately not set in the analysis. In some cases, the basins are isolated from the main massif of their type; the reason for this is the wide variety of soil and geomorphological conditions of the peninsula. We will consider below the features of the identified types of basins.

Type 1 – Basins with soil salinization. This type is located east of the Bakal Peninsula along the northern border of Crimea, including the Syvash region and the entire Kerch Peninsula (34 % of the study area). It is characterized by the biggest share of saline soils (92,2 %) with a minimum erodedness coefficient (0,02) in the soil cover structure and low forest cover (0,6 %). When developing soil and water protection facilities in the territory, it is necessary to pay attention to reclamation and agro-engineering measures aimed at combating salinization, especially with an increasing share of irrigation in these areas. Efficiency is increased by the combined implementation of various actions. Comparison of ameliorative effects and duration of after effects showed their increase in the following order: chemical reclamation of irrigation water, chemical land reclamation and ameliorative plowing.

Type 2 – Basins with the maximum agricultural pressure. This largest group of basins occupies 38 % of the study area and is located in the central part of the Crimean Plain. These territories are more involved in crop production than the other areas due to favorable geomorphological and soil and climatic conditions. It has been found that 77 % of the territory of this type is plowed up or allocated to gardening and viticulture. As a consequence, the highest pressure coefficient of 10,7 is set for this type. The share of afforestation is 0,7 %, including field protective forests, which is insufficient to preserve soil fertility. The priority task for these basins should be to reduce the anthropogenic load through the use of soil-protective crop rotations on degraded arable lands or their conservation, reclamative afforestation, including planting windbreaking forest belts and increasing the water protection forest cover along the banks of rivers and water bodies. In some basins of this type, it is would be also necessary to take reclamation measures to prevent salinization, including the secondary one (23 % of soils are exposed to salinization).

Type 3 – Basins with water erosion risk. Basins of this type occupy 28 % of the study area and form two clusters: along the foot of the northwestern macroslope of the Crimean Mountains and in northwestern Crimea (west of the Tarkhankut Peninsula and the southern shore of Lake Donuzlav). There are also separate basins in the east of the Kerch Peninsula.

Subtype 3a is the most eroded one compared with the (0,25), and geomorphological conditions create increased risks of water erosion processes, as evidenced by high values of the LS-factor (0,9) and elevation difference (75,3 m). The territories are used quite actively in agricultural production (32 %) and require widespread anti-erosion actions. They include the contour organization of the ploughland, the surface runoff control, anti-erosion forest belt planting, the grassing of hollows on the ploughland.

Subtype 3b – Basins with increased risk of exogenous geomorphological processes. This is the smallest group of basins occupying 7 % of the territory and has only 13 facilities. In terms of all manifestations of negative processes taken together, it is very similar to subtype *3a*. However, it has its own distinctive features: the basins of this subtype are located on elongated forested (35,6 %) mountain spurs, so extremely high average indicators of LS-factor (4,9) and elevation difference (201,2 m) are set here. This particular subtype is characterized by the greatest ocurrence of karst processes. Therefore, special attention should be paid to combating water erosion and karst formation on the few lands used for agriculture (25 % of the territory).

Conclusions

Data on soil degradation processes and land use features of the Crimean river basins are summarized. The advantage of the study is using the clustering algorithm kernel K-means method, which allows to identify in a balanced manner groups of objects that are homogeneous in terms of the totality of indicators. This helped identify four types of basins with a common specific characteristics of degradation processes and the degree of anthropogenic transformation of landscapes based on the ratio of geomorphological, soil, and environmental conditions. Specific land use problems have been identified for each type of basin, and ways to address them have been proposed. In terms of the land management, the identified territorial groups of basins can serve as primary differentiation units for priority soil protection measures. The results of the study can serve as the basis for developing standard scenarios of soil and water protection arrangement of the Crimean agricultural territory.

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