Assessment of the geomorphological basis of landscapes of the Crimean Peninsula using geoinformation technologies

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Abstract. The goal is, based on modern methods of geoinformatics and geomatics, to assess the landscapes of the Crimean Peninsula for tourism using a set of indicators characterizing the expressiveness of the geomorphological basis: the absolute height, steepness of the slopes, the depth of the relief and the density of the dissection of the relief. Organization and research methods: assessment of the landscapes of the Crimean Peninsula by a set of indicators characterizing the expressiveness of the geomorphological basis was carried out using the Quantum GIS (QGIS) software package by creating a series of maps reflecting the geomorphological characteristics of the relief and their subsequent overlay analysis for each of the landscapes of the Crimean Peninsula. To create maps and obtain indicator values, geoinformation, cartographic, and cartometric research methods were used. The data obtained for each landscape were further processed by statistical methods using the statistical calculation environment R and the Statistica 10 program. Results: the values of the absolute height, slope steepness, depth of the dismemberment of the relief and the density of the dissection of the relief were calculated for each landscape of the Crimean Peninsula. In addition, by implementing statistical methods, zoning of landscapes of the Crimean Peninsula was carried out using a set of indicators characterizing the expressiveness of the geomorphological basis.

1. Introduction

The Crimean Peninsula is a unique natural area that combines various combinations of geological and geomorphological conditions, climatic conditions, hydrological characteristics, soil cover, flora and fauna and, as a consequence, a variety of landscapes.

The first work on the allocation of natural landscapes on the Crimean Peninsula began at the beginning of the twentieth century. As noted by Vasily Ena [1], the first work on the allocation of natural landscapes on the Crimean Peninsula is associated with the name of Boris Dobrynin. He subdivided the Crimean Peninsula into Mountain Crimea, the steppe plain Crimea and the Kerch Peninsula and distinguished a number of smaller units.
Later, zoning issues were developed by the authors of the Council for the Study of the Productive Forces of the USSR Academy of Sciences. According to this zoning experience, the southern mountainous part of the peninsula forms the province of the Crimean-Caucasian mountainous country, and the steppe part of the peninsula forms the North Crimean province, which is part of the dry-steppe zone of the East European lowland country.

Landscape studies and zoning of certain parts of the peninsula were carried out by: Nina Dzens-Litovskaya, who identified 18 landscapes within the plain-steppe Crimea; Grigory Grishankov, indicating 5 types of localities for eastern Crimean Yail; Nina Pavlova, dividing the Steppe Crimea, including the Kerch Peninsula, into 5 landscapes and several "groups of tracts"; Zinaida Kryukova, proposing for the Crimean mountains a complex “sectoral” landscape separation scheme (12 natural districts with “landscape sectors” included in their composition). Landscape research on the Tarkhankut Peninsula was conducted by Peter Podgorodetskiy and others [1].

According to V.G. Ena [2], who proposed his scheme of zoning of the Crimean peninsula, 47 landscapes are distinguished: the landscape region of the Crimean forest middle mountains (Main Crimean ridge: landscapes 1–14); the region of the Crimean forest-sibljak sub-Mediterranean (Southern coast of Crimea: landscapes 15–27); the area of the Crimean forest-steppe foothills (Inner and Outer cuesta ridges, Southern and Northern inter-ridge depressions: landscapes 28–37); region of steppe hills (Kerch peninsula: landscapes 38–39); landscape region of the Plain-Steppe Crimea (landscapes 40–47).

In the Atlas of Natural Conditions and Natural Resources of the Ukrainian SSR, on the territory of the Crimean Peninsula, 21 categories of types and types of landscapes are distinguished, including 10 plain-steppe types of landscapes and 11 mountain forests [3]. However, the most complete is the characteristic landscape of the Crimean Peninsula made out by Grigory Grishankov [4, 5]. Natural zones, according to Grigory Grishankov, are considered as three-dimensional formations, on the one hand, and on the other, zoning as a multifactorial phenomenon. Within each landscape level stands out its own system of natural zones. “Landscape levels are planetary geomorphological formations that are relatively uniform in the nature of the relief and soil moisture, but differing in their peculiar manifestations of geographical zonality” [4]. On the territory of the Crimean Peninsula G.E. Grishankov identifies 4 landscape levels: hydromorphic, upland, low-mountain and mid-mountain [5].

2. Methods and materials
A large number of works have been devoted to the study of various landscape components [6–10]. Recently, the number of publications considering landscapes as the basis for tourism and recreational activities – the so-called landscape resources – and the number of publications where geoinformation technologies act as the leading research method, has been growing [11–22]. The study of the expressiveness of the geomorphological basis of landscapes of the Crimean Peninsula using geoinformation technologies is actively used in tourism activities to assess the aesthetic characteristics of the landscape, landscape planning of territories and water areas, making active management decisions by authorities. The basis of the study of the expressiveness of the geomorphological basis of the landscapes of the Crimean Peninsula were works [23–25].

The study includes three stages, is performed using geographic information systems (GIS) and is based on modern geographic information, cartographic, cartometric and statistical research methods. Among the old research methods, the literary and analytical method of research was actively used.

At the first stage, an analysis and selection of all available information on the research topic is performed. At the second stage, source materials are processed in geographic information systems (GIS) and statistical indicators characterizing the objects of research are obtained. At the third stage, the analysis of the obtained data is carried out, the final conclusions are constructed and conclusions are drawn.

The first stage traditionally included an analysis of all available information on the research topic. As a source of data for the analysis of the expressiveness of the geomorphological basis of landscapes
of the Crimean Peninsula, a landscape map of the Crimean Peninsula was compiled by Professor Ekaterina Pozachenyuk and published in [26], which is based on a map of Grigory Grishankov. According to [26], 13 landscapes stand out on the territory of the Crimean Peninsula (Figure 1), which occupy different geographical locations and have different landscape potentials. To analyze the expressiveness of the geomorphological basis of landscapes of the Crimean Peninsula, we used the Shuttle radar topographic mission (SRTM) data [24] based on which, at the second stage of the work, maps are constructed that reflect the absolute height, steepness of the slopes, the depth of the terrain and the density of the terrain for landscapes of the Crimean Peninsula.

The second stage included the use of the Quantum GIS (QGIS) software package in the environment of which map building and calculations were performed. To build a map of landscapes of the Crimean peninsula, the paper version of the map [26] was scanned and converted to a vector format by digitizing the boundaries of landscapes using the “Layer” menu and the “Create Vector Layer” submenu.

A map of the absolute height of the territory of the Crimean peninsula was constructed by classifying the previously downloaded digital terrain model Shuttle radar topographic mission (SRTM). The construction of maps of the depth of the fragmentation of the relief and the density of the fragmentation of the relief was carried out according to the technique described in [24, 27–30]. As a result, the maps shown in Figures 3 and 4 were obtained.

The slope steepness map was constructed in the Quantum GIS (QGIS) software package using the Slope Angle tool of the Morphometric Analysis submenu of the Raster menu (Fig. 5).

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**Figure 1.** Landscape of the Crimean Peninsula

**Figure 2.** Absolute altitudes of the Crimean Peninsula, m
Figure 3. Density of the relief dissection of the Crimean Peninsula, km/sq. km

To obtain spatial information about the absolute height, steepness of the slopes, the depth of the topography and the density of the topography within the landscapes of the Crimean peninsula, we used the Zonal Statistics tool of the Raster menu of the Quantum GIS (QGIS) software package, which allows getting for each indicator a set of the following statistics: the minimum indicator value within the landscape, the maximum indicator value within the landscape, the amplitude of the indicator values within the landscape and the average indicator value within the landscape. Additionally, with the help of the “$.area” command, the areas of each landscape on the territory of the Crimean Peninsula were calculated.

Figure 4. Depth of dissection of the relief of the Crimean Peninsula, m/sq. km

Figure 5. Slope gradient of the Crimean Peninsula, degree
3. Results
As a result of the study, it was found that the largest area within the Crimean Peninsula is occupied by the landscapes of accumulative-denudational elevated plains, while the smallest area is occupied by the landscapes of South Coastal middle mountainous forests (Table 1).

For each of the considered indicators for the landscapes of the Crimean Peninsula, maximum, minimum and average values along with amplitude values were obtained that are presented in Tables 2–4.

| Landscape                                      | Area. sq. km | Perimeter. km |
|------------------------------------------------|--------------|---------------|
| Landscapes of depositional lowlands undrained and poorly drained | 4829.5       | 2680.0        |
| Landscapes of moderately drained depositional lowlands         | 2795.1       | 1286.3        |
| Landscapes of accumulative-denudational elevated plains        | 5554.0       | 2892.2        |
| Landscapes of structural-denudation elevated plains            | 3438.6       | 2066.2        |
| Landscapes of piedmont steppes                                | 1658.1       | 699.1         |
| Landscapes of piedmont forest steppes                          | 1800.3       | 835.8         |
| Landscapes of low mountainous broad-leaved forests             | 919.1        | 554.3         |
| Landscapes of middle mountainous forests                       | 522.1        | 420.4         |
| Landscapes of Yayla mountain meadows                          | 427.1        | 256.4         |
| Landscapes of mountain forest of middle heights southern slopes | 562.0        | 327.2         |
| Landscapes of South Coastal middle mountainous forests         | 290.7        | 275.4         |
| Sub-Mediterranean landscapes of South Coastal low mountains    | 501.4        | 481.6         |
| Azonic landscape complexes                                    | 2066.4       | 2882.1        |

| Landscape                                      | Absolute altitudes. m | Min | Max | Range | Mean |
|------------------------------------------------|-----------------------|-----|-----|-------|------|
| Landscapes of depositional lowlands undrained and poorly drained | -6.0 | 178.0 | 184.0 | 19.7 |
| Landscapes of moderately drained depositional lowlands             | -4.0 | 144.0 | 148.0 | 21.5 |
| Landscapes of accumulative-denudational elevated plains            | -14.0 | 206.0 | 220.0 | 62.0 |
| Landscapes of structural-denudation elevated plains                | -10.0 | 183.0 | 193.0 | 72.1 |
| Landscapes of piedmont steppes                                    | 12.0  | 386.0 | 374.0 | 178.1 |
| Landscapes of piedmont forest steppes                             | -8.0 | 771.0 | 779.0 | 285.3 |
| Landscapes of low mountainous broad-leaved forests                 | 1.0   | 949.0 | 948.0 | 455.2 |
| Landscapes of middle mountainous forests                           | 251.0 | 1442.0 | 1191.0 | 696.6 |
| Landscapes of Yayla mountain meadows                              | 318.0 | 1531.0 | 1213.0 | 960.5 |
| Landscapes of mountain forest of middle heights southern slopes    | 43.0  | 1500.0 | 1457.0 | 556.6 |
| Landscapes of South Coastal middle mountainous forests             | 12.0  | 1150.0 | 1138.0 | 291.9 |
| Sub-Mediterranean landscapes of South Coastal low mountains        | -4.0  | 676.0 | 680.0 | 150.9 |
| Azonic landscape complexes                                         | -5.0  | 1443.0 | 1448.0 | 127.9 |

The resulting set of values of the considered indicators for each landscape is unique. However, given the fact that all the indicators in question have different dimensions in the classification, it is necessary to bring them to uniform series. To do this, in the Statistica 10 program, data were standardized (the "Data" menu, the "Standardize" window), as a result, comparable values were obtained.

Using the menu “Analysis – Multidimensional Exploration Analysis”, a hierarchical classification of the landscapes of the Crimean Peninsula was made according to the expressiveness of the geomorphological basis. The connection Ward method was used as a union rule, and the Euclidean distance was used as a measure of proximity. As a result, a vertical dendrogram was obtained and 3 classes of landscapes were identified (Figure 6).
The allocation of three classes of landscapes was confirmed by checking using the K-means method in Statistica 10 and using the statistical package R. So the first cluster was formed by the Sub-Mediterranean landscapes of South Coastal low mountains and Landscapes of depositional lowlands undrained and poorly drained; the second cluster was formed by the Landscapes of moderately drained depositional lowlands; Landscapes of accumulative-denudational elevated plains; Landscapes of structural-denudation elevated plains; Landscapes of piedmont steppes; Landscapes of piedmont forest steppes and Azonic landscape complexes; the third cluster was formed by the Landscapes of low mountainous broad-leaved forests; Landscapes of middle mountainous forests; Landscapes of Yayla mountain meadows; Landscapes of mountain forest of middle heights southern slopes; Landscapes of South Coastal middle mountainous forests (Table 5, Figure 7).

### Table 3. Density of the relief dissection (km/sq. km) of the Crimean Peninsula within the landscape

| Landscape                                                                 | Density of the relief dissection. km/sq. km | Min  | Max  | Range | Mean  |
|---------------------------------------------------------------------------|---------------------------------------------|------|------|-------|-------|
| Landscapes of depositional lowlands undrained and poorly drained          |                                             | 0.00 | 2.61 | 2.61  | 0.69  |
| Landscapes of moderately drained depositional lowlands                    |                                             | 0.01 | 2.55 | 2.54  | 1.00  |
| Landscapes of accumulative-denudational elevated plains                   |                                             | 0.02 | 2.56 | 2.54  | 0.99  |
| Landscapes of structural-denudation elevated plains                       |                                             | 0.00 | 2.78 | 2.78  | 0.86  |
| Landscapes of piedmont steppes                                           |                                             | 0.14 | 2.35 | 2.21  | 0.95  |
| Landscapes of piedmont forest steppes                                    |                                             | 0.05 | 2.41 | 2.36  | 0.88  |
| Landscapes of low mountainous broad-leaved forests                        |                                             | 0.08 | 2.47 | 2.39  | 0.88  |
| Landscapes of middle mountainous forests                                  |                                             | 0.10 | 1.94 | 1.83  | 0.82  |
| Landscapes of Yayla mountain meadows                                     |                                             | 0.18 | 2.11 | 1.93  | 0.81  |
| Landscapes of mountain forest of middle heights southern slopes           |                                             | 0.07 | 2.33 | 2.26  | 0.88  |
| Landscapes of South Coastal middle mountainous forests                    |                                             | 0.21 | 2.31 | 2.10  | 1.05  |
| Sub-Mediterranean landscapes of South Coastal low mountains              |                                             | 0.01 | 2.45 | 2.43  | 0.72  |
| Azonic landscape complexes                                               |                                             | 0.00 | 2.48 | 2.48  | 1.01  |

### Table 4. Depth of dissection of the relief (m/sq. km) of the Crimean Peninsula within the landscape

| Landscape                                                                 | Depth of dissection of the relief. m/sq. km | Min  | Max  | Range | Mean  |
|---------------------------------------------------------------------------|---------------------------------------------|------|------|-------|-------|
| Landscapes of depositional lowlands undrained and poorly drained          |                                             | 0.0  | 157.0| 157.0 | 13.3  |
| Landscapes of moderately drained depositional lowlands                    |                                             | 0.0  | 113.0| 113.0 | 9.9   |
| Landscapes of accumulative-denudational elevated plains                   |                                             | 0.0  | 99.0 | 99.0  | 16.2  |
| Landscapes of structural-denudation elevated plains                       |                                             | 0.0  | 121.0| 121.0 | 20.5  |
| Landscapes of piedmont steppes                                           |                                             | 6.0  | 173.0| 167.0 | 32.5  |
| Landscapes of piedmont forest steppes                                    |                                             | 9.0  | 389.0| 380.0 | 91.4  |
| Landscapes of low mountainous broad-leaved forests                        |                                             | 26.0 | 583.0| 557.0 | 219.1 |
| Landscapes of middle mountainous forests                                  |                                             | 24.0 | 510.0| 486.0 | 161.1 |
| Landscapes of Yayla mountain meadows                                     |                                             | 48.0 | 790.0| 742.0 | 274.8 |
| Landscapes of mountain forest of middle heights southern slopes           |                                             | 25.0 | 753.0| 728.0 | 208.0 |
| Landscapes of South Coastal middle mountainous forests                    |                                             | 0.0  | 535.0| 535.0 | 169.2 |
| Sub-Mediterranean landscapes of South Coastal low mountains              |                                             | 0.0  | 50.0 | 50.0  | 12.0  |
| Azonic landscape complexes                                               |                                             | 0.0  | 510  | 540   | 41.6  |

Obviously from Table 6 and Figure 7, the clusters under consideration represent rather independent formations, however, the inclusion of Sub-Mediterranean landscapes of South Coastal low mountains and Landscapes of depositional lowlands undrained and poorly drained into cluster 1 is very controversial and requires additional refinement, since only 4 indicators were taken into account in the analysis. Most likely this is due to the fact that the differentiation of these landscapes will manifest itself under the influence of other factors (climatic, hydrological, etc.).
Table 5. Slope gradient (degree) of the Crimean Peninsula within the landscape

| Landscape                                                   | Min  | Max  | Range | Mean |
|-------------------------------------------------------------|------|------|-------|------|
| Landscapes of depositional lowlands undrained and poorly drained | 0.0  | 14.3 | 14.3  | 0.8  |
| Landscapes of moderately drained depositional lowlands      | 0.0  | 17.0 | 17.0  | 0.5  |
| Landscapes of accumulative-denudational elevated plains     | 0.0  | 13.0 | 13.0  | 0.9  |
| Landscapes of structural-denudational elevated plains       | 0.0  | 15.7 | 15.7  | 1.1  |
| Landscapes of piedmont steppes                              | 0.0  | 23.4 | 23.4  | 1.8  |
| Landscapes of piedmont forest steppes                       | 0.0  | 37.0 | 37.0  | 5.3  |
| Landscapes of low mountainous broad-leaved forests          | 0.6  | 51.8 | 51.2  | 12.3 |
| Landscapes of middle mountainous forests                     | 0.0  | 42.1 | 42.1  | 9.7  |
| Landscapes of Yayla mountain meadows                       | 0.2  | 55.4 | 55.2  | 14.8 |
| Landscapes of mountain forest of middle heights southern slopes | 0.1  | 58.5 | 58.3  | 11.1 |
| Landscapes of South Coastal middle mountainous forests      | 0.0  | 61.8 | 61.8  | 9.9  |
| Sub-Mediterranean landscapes of South Coastal low mountains | 0.0  | 7.9  | 7.9   | 0.7  |
| Azonic landscape complexes                                  | 0.0  | 42.1 | 42.1  | 2.5  |

Figure 6. Clustering of the landscape of the Crimean Peninsula, m/sq. km
### Table 6. Average values within the selected clusters

| Criteria                                      | Cluster 1 | Cluster 2 | Cluster 3 |
|-----------------------------------------------|-----------|-----------|-----------|
| Absolute altitudes, m                         | 85.3      | 124.5     | 592.2     |
| Density of the relief dissection, km/sq. km   | 0.71      | 0.95      | 0.89      |
| Depth of dissection of the relief, m/sq. km   | 12.7      | 35.4      | 2.1       |
| Slope gradient, degree                        | 0.75      | 2.1       | 11.6      |

**Figure 7.** Clustering map of the landscape of the Crimean Peninsula

### 4. Conclusion

The paper shows the possibility of applying geographic information technologies in the study of the geomorphological basis of landscapes of the Crimean Peninsula. Using the methods of geoinformatics and statistics among the landscapes of the Crimean Peninsula, three relatively uniform indicators were identified that characterize the expressiveness of the geomorphological basis: the absolute height, steepness of the slopes, the depth of the dissection of the relief and the density of the dissection of the relief. The first cluster was formed by Sub-Mediterranean landscapes of South Coastal low mountains and Landscapes of depositional lowlands undrained and poorly drained; the second cluster was formed by the Landscapes of moderately drained depositional lowlands; Landscapes of accumulative-denudational elevated plains; Landscapes of structural-denudation elevated plains; Landscapes of piedmont steppes; Landscapes of piedmont forest steppes and Azonic landscape complexes; the third cluster was formed by the Landscapes of low mountainous broad-leaved forests; Landscapes of middle mountainous forests; Landscapes of Yayla mountain meadows; Landscapes of mountain forest of middle heights southern slopes; Landscapes of South Coastal middle mountainous forests.

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References

[1] Ena V 1969 Results and prospects of landscape and geographical research in Crimea In Natural conditions and natural resources of Crimea (Simferopol: Tavria) pp 52–5
[2] Ena V 1960 Physico-geographical zoning of the Crimean Peninsula Bull. of Moscow Univer. Ser. 5 Geogr. 2 33–43
[3] Ena V 2007 Discoverers of the Crimean land. Essays of 2500-year history of Taurida nature study (Simferopol: Business-Inform) 520 p
[4] Grishankov G 1972 Landscape levels of continents and geographical zoning Izv. Akad. nauk SSSR. Ser. Geograf. 4 3–18
[5] Pozachenyuk Е 2009 Modern Landscapes of the Crimea and Adjacent Water Areas (Simferopol: Business-Inform) 672 p
[6] Pozachenyuk E, Lisetskii F, Kalinuchk I et al 2019 Modern landscapes of the Kerch peninsula Int. Multidisciplinary Sci. GeoConf. Survey. Geol. and Mining Ecol. Manag. SGEM vol 19 no 5.1 pp 477–84
[7] Silva R, Pereira J and Alves S 2019 The landscapes from Ouro Preto, Minas Gerais State: Decoding in space and time Ornamental Horticult. 25(1) 9–17
[8] Prince S 2019 Dwelling and tourism: embracing the non-representational in the tourist landscape Landscape Res. 44(6) 731–42 DOI: 10.1080/01426397.2018.1518520
[9] Aspinall R and Pearson D 2000 Integrated geographical assessment of environmental condition in water catchments: Linking landscape ecology, environmental modelling and GIS J. of environ. Manag. 59(4) 299–319
[10] Bender O, Boehmer H, Jens D and Schumacher K 2005 Using GIS to analyse long-term cultural landscape change in Southern Germany Landscape and Urban Plann. 70(1-2) 111–25
[11] Kalinichenko A 2014 Spatial model of ecotourism development in South-Western Crimea Vest. Moskovskogo univer. Ser. 5 Geograf. 5 62–6
[12] Los M 2017 Assessment of the Relief of the Tyumen and Tobolsk Tourist and Recreational Framework for Tourism Development Geograf. Vest. 4 161–9 DOI: 10.17072/2079-7877-2017-4-161-169
[13] Sarancha M 2008 Recreational potential of the Udmurt Republic: an integrated estimation on the basis of GIS-technologies Izv. Vyssh. Ucheb. Zaved. Severo-Kavkazskii reg. Ser. Estestv. Nauki 4 122–3
[14] Mu Y, Nepal S and Lai P 2019 Tourism and sacred landscape in Sagarmatha (Mt. Everest) National Park, Nepal Tourism Geogr. 21(3) 442–59
[15] Kreisel W and Reeh T 2011 Tourism and landscape in South Tyrol Central Europ. J. of Geosci. 3(4) 410–23
[16] Drazic D, Veselinovic M, Rakonjac L et al 2014 Geographic, landscape and other natural characteristics of belgrade as the basis for development of tourism Europ. J. of Geogr. 5(3) 96–122
[17] Mikulec J and Antoušková M 2011 Landscape and tourism potential in the protected landscape areas Agricult. Econ. 57(6) 272–8
[18] Murphy P 1986 Tourism as an agent for landscape conservation: an assessment Sci. of the Total Environ. 55 387–95
[19] Bibaeva A and Makarov A 2018 Application of Information Systems for Calculations of Indicators of Aesthetic Assessment of Landscapes Izv. Irkutskogo gosud. univer. Ser. Nauki o Zemle 24 17–33 DOI: 10.26516/2073-3402.2018,24.1
[20] Khosseini S, Rubtsov V, Gabdrakhmanov N and Bulatova G 2016 Determination of Priority Zones of the Desert Tourism Development by Using Geoinformational Systems: a Case Study of Iran, Isfahan Province Izv. Ross. Akad. nauk. Ser. Geograf. 5 109–18
[21] Jiang Y, Wang Y, Cheng S and Ye M 2008 The theory research on tourism landscape ecosystem Shengtai Xuebao Acta Ecol. Sinica 28(4) 1786–93
[22] Pignatti S 1993 Impact of tourism on the mountain landscape of central Italy Landscape and Urban Plann. 24(1-4) 49–53
[23] Kurlovich D 2013 Morphometric GIS analysis of the relief of Belarus Zemlya Belarusi 4 42–8
[24] Tabunshchik V and Petlukova E 2019 Density of the Relief Dissection on the Territory of the Crimean Peninsula Izv. Vyssh. Ucheb. Zaved. Severo-Kavkazskii reg. Ser. Estestv. Nauki. 1 95–100
[25] Kurlovich D, Fedorako S and Ylanchik E 2012 Assessment of suitability of landscapes of Volozhin district for tourist activity and development of ecotourism routes Hieahrafija: probl. vykladannia 2 3–14
[26] Pozachenyuk E 2003 Landscape, Atlas. The Autonomous Republic of Crimea (Simferopol: TNU) pp 38–9
[27] Florinsky I 2016 Digital Terrain Analysis in Soil Science and Geology (Amsterdam: Elsevier/Academic Press) 486 p
[28] Piriyev R 1983 Metody morfometricheskogo analiza rel’yefa (na primere territorii Azerbaydzhana) (Baku: Elm) 119 p
[29] Pogorelov A and Dumit J 2009 Rel’yef basseyna r. Kubani (morphologicheskiy analiz) (Moscow: GEOS) 220 p
[30] Orekhova G and Novykh L 2017 Natural diversity of the springs of the upper reaches of the Seversky Donets and Vorskla river basins Nauchn. vedomosti Belgorodskogo gosudarst. univer. Yestestv. Nauki 40(18(267)) 131–9