Geoinformation modeling of anthropization extent in the Zakhidnoukrainskyi physic-geographic region

V. Samoilenko, L. Bilous, O. Havrylenko, I. Dibrova (Taras Shevchenko National University of Kyiv)

SUMMARY

Geoinformation modeling of the anthropization extent in the Zakhidnoukrainskyi physic-geographic region with the use of modern spatial data bases, formed from remote sensing data, showed an essential anthropogenic impact on the regional landscapes. All physic-geographic sub-regions of the region are greatly anthropized. Most physic-geographic districts also fell under great anthropization, and in two districts very great anthropization was simulated. Cause-effect analysis of simulated high anthropogenic impact level in the region demonstrated the objectivity of the achieved results. Thus, only about 18% of the regional area is under environmental favorable land use and/or land cover (LULC) systems. However very geo-negative LULC systems predominate, among which broad-leaved forest tilled, village built-up, recreational and geo-negative hydromelioration systems are the most widespread. The obtained results affirm the validity of the applied geoinformation-model approaches. They can be directly implemented, together with the created spatial data bases, in regional schemes and projects of environmental management for its optimization and realization of effective environmental protection measures.

Introduction. A model study of landscapes' and physic-geographic taxons' anthropization on the basis of modern geoinformation technologies is currently the most pressing problem of geography and geoinformatics. In addition, the European Landscape Convention (Samoilenko et al., 2018a) envisages that the urgent tasks of European states are not only to monitor changes and factors in the transformation of their landscapes, but also the international communication of relevant spatial data bases, especially for trans-boundary regions. Under such conditions, the purpose of this study was to model by geoinformation tools the extent of anthropization in the trans-boundary Zakhidnoukrainskyi physic-geographic region and to realize a cause-effect analysis of this extent conditionality by the peculiarities of regional land use.

Methods of investigations and initial data. To achieve the set purpose, we used, on the one hand, modern model analytic tools proposed in our previous publications (Samoilenko et al., 2018a, 2018b, 2019; Bilous et al., 2020). They contain a scheme and scale of the landscape and/or physic-geographic taxons' anthropization extent, caused by the different level land use and/or land cover (LULC) systems as systems of land use and/or its effects. This scheme / scale distinguish nine categories and subcategories: from very slight to excessive anthropization (see the legend of Figure 1). Geo-positive (nature-accentuated) and geo-negative LULC systems are also classified according to the mentioned categories. In addition to the categories, the anthropization scale is realized through the use of anthropization indexes, average-weighted by the areas of LULC systems for given physic-geographic taxons.

On the other hand, we adapted the spatial data bases (DB) on land use and land cover created in our work (Samoilenko et al., 2018a) to the investigating region. They were formed on the basis of geoinformation processing of modern open sources for digital spatial data. These sources contained raster maps of the European Space Agency (ESA, 2015) and the National Geomatics Center of China (NGCC, 2011), initially obtained from remote sensing data concerning a number of satellite programs, as well as data from the geoinformation web-service *OpenStreetMap*, thematic raster maps from electronic version of National Atlas of Ukraine (National Atlas, 2007) and other representative sources. These spatial DB were further used to obtain by spatial queries for the region the so-called quasi-spectra of LULC systems' areas in a certain taxon. They allowed realizing the cause-effect analysis of anthropization extent conditionality for regional structures.

Results of investigations. In the first step, regional anthropization fields were generated using MapInfo Pro 2019 GIS tools (Figure 1a). These fields were simulated by anthropization categories, averaged- weighted for 1 km^2 raster cells. Then anthropization fields were averaged by modeling for 6 physic-geographic sub-regions of the region (Figure 1b) and for their 33 districts (Figure 1c) with additional calculation of the corresponding anthropization indexes. The results of geoinformation modeling demonstrated the following.

All sub-areas of the investigating region are greatly anthropized (Figure 1b), with four of them by the low and two by the high grade of such category. The best condition is in the Zakhidnopodilska vysochynna, and the worst – in the Volynska vysochynna sub-regions. Only one of the 33 physic-geographic districts in the region is characterized by low-categorical moderate-great anthropization (Figure 1c). But most districts fell under great anthropization, both low-categorical (46%) and high-categorical (33%), and in two districts at all very great anthropization was simulated. A concise cause-effect analysis of such anthropogenic impact effects in the sub-regions can be summarized as follows.

The LULC system areas quasi-spectrum for the *Volynska vysochynna sub-region* of high-categorical great anthropization, obtained on query to spatial DB in (Samoilenko et al., 2018a), shows that among the very small by area geo-positive LULC systems predominate broad-leaved forest (5.1% of sub-regional area) and wetland (1.2%). Instead, the sub-region is dominated by the village built-up system (over 20% of the sub-regional area) and slightly, moderately and middling sloping broad-leaved forest tilled systems (together almost 31%), as well as geo-negative hydromelioration system (about 7%). The area fraction of all just listed LULC systems in the sub-region is over 58%. There are also moderately and middling sloping non-forest tilled systems (20% of the sub-regional area).

As a result, 5 districts of the Volynska vysochynna sub-region (see Figure 1c) are marked by great anthropization. In this case, only in one of them the anthropization is low-categorical, and in the others – high-categorical. But the Ostrozko-Goshchanskyi district is very greatly anthroped and in general one of the worst in the "anthropization" rating for the plain landscapes of Ukraine.
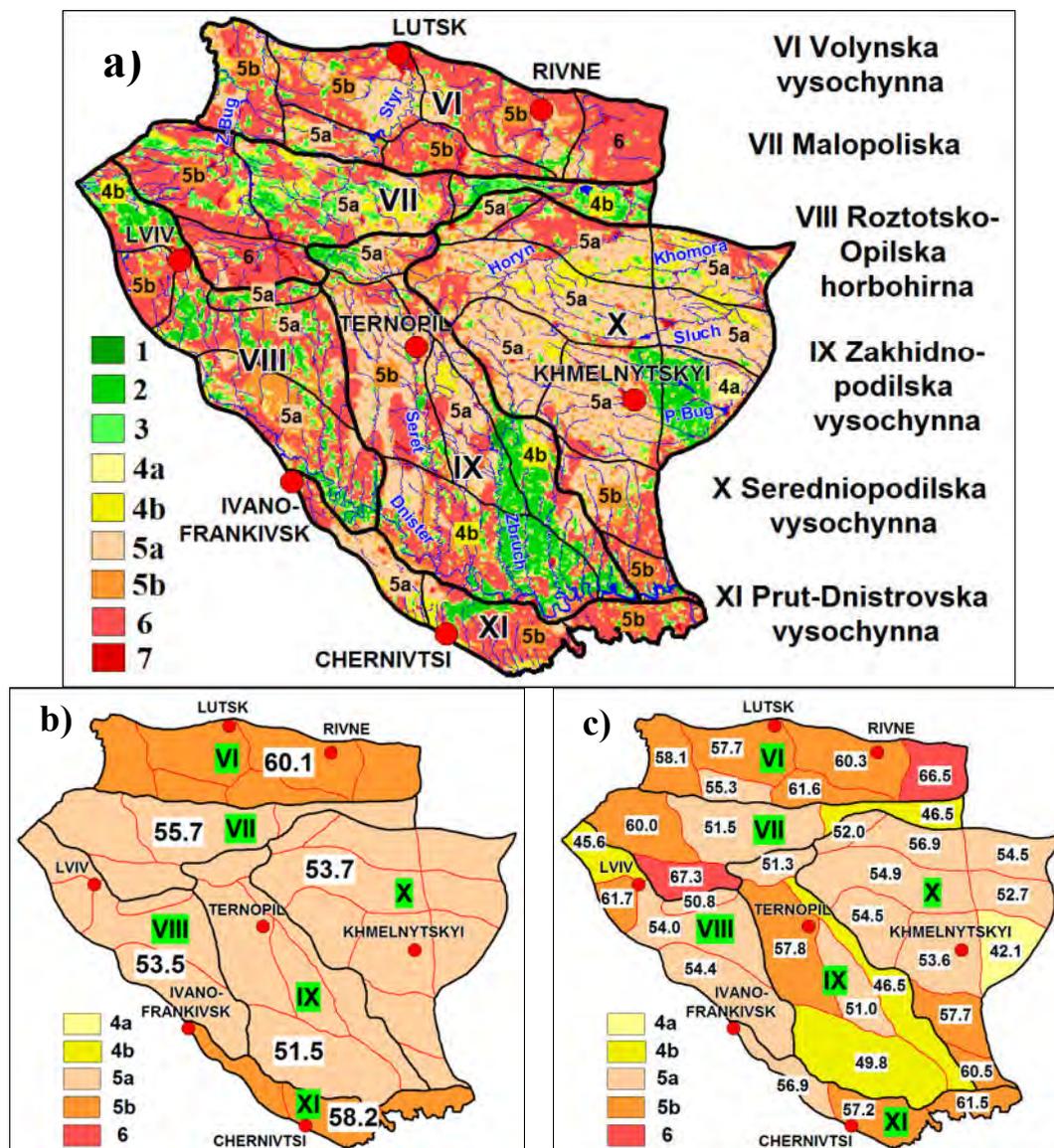

Figure 1 Simulated fields of anthropization extent (a) and average-weighted anthropization extent categories and indexes of physic-geographic sub-regions (b) and districts (c) in the Zakhidno-ukrainskyi region. Legend: boundaries of the physic-geographic taxons: xx – sub-regions, ▬ and ▬ – districts; **VI…XI** – codes of the physic-geographic sub-regions; **1…7** – anthropization extent categories and subcategories, namely anthropization: **1** – very slight, **2** – slight, **3** – moderate, **4a** – low-categorical moderate-great, **4b** – high-categorical moderate-great, **5a** – low-categorical great, **5b** – high-categorical great, **6** – very great, **7** – excessive; **42.1…66.5** – average-weighted anthropization indexes

The LULC system areas quasi-spectrum for the *Malopoliska sub-region* of low-categorical great anthropization, obtained on request, testifies that forest systems essentially predominate in area among the geo-positive land use systems. These are coniferous, broad-leaved and mixed-forest systems with a total area of 22.5% in the sub-region, taking into account, for comparison, 25.5% of such area for the main geo-positive LULC systems. The largest percentage of the sub-regional area is

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occupied by very geo-negative LULC systems. They include, in particular, the geo-negative hydromelioration system with 17.3% of the sub-regional area and the systems of village built-up with 9.3% and recreational with 7.8%. The total territory of these systems is over 34% of the sub-regional area. In addition, moderately geo-negative LULC systems differ in the sub-region. These are, first of all, a slightly sloping non-forest tilled system, which occupies more than 11% of the sub-regional area, and a moderately sloping non-forest tilled system, which covers almost 4% of this area.

Under such conditions, the integrated anthropization degree of 4 districts in the Malopoliska sub-region is very diverse in values (see Figure 1c). It ranges from moderate-great to very great anthropization in the Kulykivsko-Buzkyi district. This district is generally the worst for forest and forest-steppe districts of Ukraine according to its average-weighted anthropization index (63.7%).

Peculiarities of the LULC system areas quasi-spectrum for the *Roztotsko-Opilska horbohirna sub-region* of low-categorical great anthropization are that, firstly, broad-leaved forest system "alone" predominates in geo-positive LULC systems with more than 22% of the sub-region area. Relatively significant for the conditions of the region is the total area of nature-protection systems, which reaches about 3% of the sub-regional area. Secondly, among the environmentally unfavorable land use systems, on the one hand, very geo-negative LULC systems dominate. They include, first of all, essentially, middling, moderately and slightly sloping broad-leaved forest tilled systems. Each of them occupies, respectively, 12.8%, 8.3%, 3.1% and 2.3% of the sub-regional area, and together they cover more than 26% of such area. This is followed by a system of village built-up with almost 10% of the sub-regional territory and a recreational system with more than 8% of the sub-regional area. All the land use systems just listed together occupy almost 45% of the sub-regional model area.

Districts of the Roztotsko-Opilska horbohirna sub-region (see Figure 1c) are characterized, firstly, by a moderate-great integrated extent of anthropization. It marks the Nemyrivsko-Bryukhovytsyi district due to the presence of a massive forest system, especially broad-leaved forest, with an area of about 45% of the district area. Great anthropization has been simulated in other districts of the sub-region. In particular, the Horodotsko-Shchyretskyi district is the worst by such condition. This is primarily due to the essential district area of various by the slope broad-leaved forest tilled systems (60%).

The *Zakhidnopodilska vysochynna sub-region* of low-categorical great anthropization is marked by the highest percentage of nature-protection systems' areas among forest and forest-steppe sub-regions of all Ukraine. Such LULC systems occupy more than 15% of the sub-regional territory. This is an effect, firstly, of the fact that the Podilski Tovtry National Natural Park and the Medobory Natural Reserve are located in this sub-region. The broad-leaved forest system situated here, with its more than 8% of the region's area, also has a positive impact on the sub-regional environment. However, a much stronger by contribution impact on the sub-regional conditions is exerted, firstly, by geo-negative LULC systems. Among them the middling, essentially and moderately sloping non-forest tilled systems prevail with the total 37.3% of sub-regional area. Secondly, very geo-negative land use systems are also marked by environmentally unfavorable effects of anthropization. Among them are, first of all, village built-up systems with more than 11% of the sub-regional area and the middling, essentially and moderately sloping broad-leaved forest tilled systems, which have a total of 12%, as well as recreational system with more than 8% and geo-negative hydromelioration system with almost 3%. The total area of all just mentioned LULC systems is over 34% of the sub-regional area.

Under such conditions, on the one hand, the two districts of the Zakhidnopodilska vysochynna sub-region with the highest percentage of nature-protection systems' areas are characterized by moderate-great anthropization (see Figure 1c). Great anthropization has been simulated in the other three districts. Moreover, the Zborivsko-Terebovlianskyi district differs here with its high-categorical great anthropization. This physic-geographic district has a middling sloping non-forest tilled system, which occupies more than 43% of the district area.

The areas quasi-spectrum for the *Seredniopodilska vysochynna sub-region* of low-categorical great anthropization shows that among the generally small by total area geo-positive LULC systems (11%), broad-leaved forest and nature-protection systems predominate with about 5% of the sub-regional area each. But among the geo-negative land use systems, on the one hand, very essential by areas are, first of all, middling and moderately sloping non-forest tilled systems. Their total model area is almost

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50% of the sub-regional area. On the other hand, the impact of very geo-negative LULC systems is also noticeable. The largest area among them is occupied by village built-up with 13% of this area.

Hence, only one district of the sub-region (see Figure 1c) is characterized by low-categorical moderate-great anthropization. This is due to the fact that large areas of this area belong to the nature-protection and broad-leaved forest systems. Other districts are marked by great anthropization, and two of them have high-categorical such extent. This is effect of the fact that both these areas include essential areas of forest and non-forest tilled systems, as well as system of village built-up.

The LULC system areas quasi-spectrum for the *Prut-Dnistrovska vysochynna sub-region* of high-categorical great anthropization shows that among geo-positive LULC systems the broad-leaved forest system sharply prevails in territory. It, however, occupies less than 10% of the sub-region area. But the "palette" for the impact of geo-negative land use systems on the sub-region looks, unfortunately, much more significant. Here very geo-negative LULC systems dominate. Almost 42% of the sub-regional area belongs to middling, slightly and essentially sloping broad-leaved forest tilled systems. All three physic-geographic districts of the Prut-Dnistrovska vysochynna sub-region (see Figure 1c) are marked by great anthropization, with one being low- and two being high-categorical.

Conclusions. Geoinformation modeling of the anthropization extent in the Zakhidnoukrainskyi physic-geographic region showed an essential anthropogenic impact on the landscapes and taxons of the region. All sub-areas of the region are greatly anthropized. Most physic-geographic districts also fell under great anthropization, and in two districts very great anthropization was simulated. Cause-effect analysis of the conditionality for level of such anthropogenic impact in the region demonstrated the objectivity of the achieved results. Thus, only about 18% of the regional area is under environmental favorable LULC systems. Among them, broad-leaved forest system with 8.8% of the sub-regional area, nature-protection system with 5%, coniferous forest and mixed forest systems with 1.3% each and wetland system predominate (all together – 17% of the area). Among the environmental unfavorable systems differ very geo-negative LULC systems. These are the middling, moderately, essentially and slightly sloping broad-leaved forest tilled systems with 18.8% of the regional area, village built-up system with 12.8%, recreational system with 4.6% and geo-negative hydromelioration system with 4.4%. All of them together occupy more than 41% of the regional area. The obtained results affirm the validity of the applied geoinformation-model approaches. They can be directly implemented, together with the created spatial data bases, in regional schemes and projects of environmental management for the purpose of its optimization and realization of effective environmental protection measures.

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