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Geoinformation model cause-effect analysis of anthropogenic impact in the Podilsko-Prydniprovskyi region

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SUMMARY

Geoinformation model cause-effect analysis of anthropogenic impact on physic-geographic taxons was performed in the Podilsko-Prydniprovskyi region. The analysis applied modern spatial data bases and a progressive model scheme for cumulative distribution of land use and/or land cover (LULC) systems in taxons. The scheme operates with 10 types of this distribution and the relevant 10 categories of anthropogenic impact intensity from weak to excessively strong. The geoinformation implementation of the scheme verified that 65% of the 31 regional districts fall under the high-categorical strong anthropogenic impact and only in one district such impact is moderate-strong. This is due to the fact that geo-negative LULC systems, primarily non-forest and broad-leaved forest tilled systems with various slope, form more than 90% of the regional area. Instead, environmentally favourable systems, first of all broad-leaved forests, cover only 9% of this area. The obtained methodological and applied results can be used in regional schemes and projects to optimize the environmental management and substantiate urgent environmental protection measures.

Introduction

The regional investigation of the landscape anthropization as the process of landscape transformation through human impact and the geoinformation modeling of the consequences of this anthropization for the environment are the most actual problem of geoecology and geomatics. So, the first task of this paper was to use modern geoinformation tools for modeling anthropogenic impact on the Podilsko-Prydniprovskyi physic-geographic region and its sub-regions and districts. The second task was to perform a cause-effect analysis of such impact conditionality by the peculiarities of regional land use and/or land cover (LULC) systems as systems of land use and/or its effects.

Methods and initial data

To solve the mentioned tasks, we used, on the one hand, modern geoinformation model analytic tools developed in our previous publications (Samoilenko et al., 2018a, 2018b, 2019, 2020; Bilous et al., 2020; Havrylenko et al., 2020a, 2020b). Among these tools, the scheme of the LULC system areas' cumulative distribution in physic-geographic taxons is the most progressive for modeling. The scheme is based on the concept that the types of the mentioned distribution in its shape are identical to a certain category and intensity of anthropogenic impact on taxons. The scheme operates with ten codes and types of distribution which reflect categories of different by intensity anthropogenic impacts on taxons, namely: 0 – excessively convex distribution – weak impact; 1 – very convex distribution – moderate impact: 2 – convex distribution – low-categorical moderate-strong impact; 3 – weakly convex distribution – high-categorical moderate-strong impact of the 1st level; 4 – close to rectilinear distribution – high-categorical moderate-strong impact of the 2nd level; 5 – weakly concave distribution – high-categorical moderate-strong impact of the 3^{d} level; 6 – concave distribution – low-categorical strong impact; 7 – essentially concave distribution – high-categorical strong impact; 8 – very concave distribution – very strong impact; 9 – excessively concave distribution – excessively strong impact.

On the other hand, we used the spatial data bases on land use and land cover developed in our publications (Samoilenko et al., 2018a, 2020). They were created by geoinformation processing of modern open digital sources. 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, as well as thematic raster maps from National Atlas of Ukraine (National Atlas, 2007) and other representative sources concerning investigating region. We obtained also the so-called quasi-spectra of LULC system areas in certain taxons as a result of the corresponding queries to mentioned data bases. Such quasi-spectra were the initial sources for the cause-effect analysis of anthropization impact conditionality at regional physic-geographic units.

Results

The anthropogenic impact on 8 physic-geographic sub-regions and their 31 districts in the Podilsko-Prydniprovskyi region was simulated using MapInfo Pro 2019 GIS tools (Figure 1). The results of geoinformation modeling and its analysis demonstrated the following.

The cumulative distribution of the LULC system areas in physic-geographic sub-regions of the region is characterized by parity of concave and essentially concave distributions, each in 4 sub-regions. This is identical to the low- and high-categorical strong anthropogenic impact on the sub-regions.

The Podilsko-Prydniprovskyi region is characterized by low variability of the LULC system areas' cumulative distributions in the physic-geographic districts of the region (see Figure 1). Only three types of cumulative distribution are simulated here. Among them an essentially concave distribution with code 7 is dominated. This distribution type applies to 65% of the districts and indicates the high-categorical strong anthropogenic impact on them. And only one physic-geographic district of the region is characterized by relatively lesser anthropization extent. This is the Cherkasko-Chyhyrynskyi district with close to rectilinear distribution, which is equal to the high-categorical moderate-strong anthropogenic impact of the 2nd level.

This situation in the region is caused by the fact that environmentally favourable land use systems form only 9% of the regional area. And the largest among them is the broad-leaved forest system with

6.6%. Environmentally unfavorable systems are represented, first of all, by non-forest tilled systems with all classified slope, the area of which reaches over 47% of the regional area. In addition, very geo-negative systems essentially affect the anthropization of the region. These are broad-leaved forest tilled systems with 23.7% of the regional area, the village built-up system with 12.6% and the recreational system with 5.4%. Together, these LULC systems cover 36.9% of the regional area.

Figure 1 *Digital choropleth of the anthropogenic impact on the physic-geographic districts of the Podilsko-Prydniprovskyi region. Legend: boundaries of the physic-geographic taxons:* ▬ *– region and sub-regions,* ▬ *– districts;* **XII…XIX** *– codes of the physic-geographic sub-regions;* 4…7 *– districts' anthropogenic impact category*

The *Pivnichno-Zakhidna Prydniprovska vysochynna sub-region* has a concave cumulative distribution of land use system areas with code 6, i.e. falls under the low-categorical strong anthropogenic impact. The quasi-spectrum of this region shows, on the one hand, the presence of very limited by area geo-positive systems, where the largest broad-leaved forest system covers only 3.7% of the sub-regional area. On the other hand, unsatisfactory geoecological conditions of the region are caused by geo-negative land use systems of three categories. Firstly, it is moderately, middling and slightly sloping non-forest tilled systems, the total area of which reaches more than 53% of the model sub-regional area. Secondly, these are very geo-negative systems, which together cover almost 35% of the sub-regional area. Here some systems dominate, such as the village built-up system with 13.3% of the sub-regional area and moderately, slightly and middling sloping broad-leaved forest tilled systems with 11.3%, as well as recreational system with 5.3% and moderately and slightly sloping coniferous forest tilled systems with 5.0%. As a result, the cumulative distribution of system areas in districts is concave in one district and essentially concave in two more (see Figure 1). Such situation is identical to low- and high-categorical strong anthropogenic impact on these physic-geographic taxons.

In the *Pivnichno-Skhidna Prydniprovska vysochynna sub-region* the concave cumulative distribution of land use system areas is also modeled. This marks a low-categorical strong anthropogenic impact on the sub-region. The quasi-spectrum of sub-regional areas corresponds to this. According to such spectrum, there is a small percentage of nature-protection systems' areas in 1.2%, which together with the territory of the broad-leaved forest system occupy only a little more than 7% of the sub-regional area. The anthropization extent of the sub-region is determined, first of all, by essentially and middling sloping non-forest tilled systems. The total area of such LULC systems is 60% of the sub-regional area. Similar contribution to the anthropization of the sub-region is made by very geo-negative land use systems. Among them, the recreational system predominates with 12.1% of the sub-regional area and the village built-up system with 10.3%. As a result, one physic-geographic district of the sub-region falls under the low-categorical strong anthropogenic impact and three districts fall under the high-categorical strong impact (see Figure 1).

The *Kyivska vysochynna sub-region* is also characterized by a negative for environment concave cumulative distribution of sub-regional land use system areas. The corresponding quasi-spectrum indicates a small area of geo-positive LULC systems. Various forest systems prevail among them with only 7.2% of the sub-regional area. The primary anthropization impact on the sub-region is caused by the system of arable land in non-forest territories. In the latter, non-forest tilled systems with different slope dominate, occupying together almost 50% of the sub-region area. The contribution of excessively geo-negative LULC systems is also noted because of the city-town built-up system. Its presence is caused by the location in the south-western part of Kyiv. Hence, both districts of the sub-region fall under the low-categorical strong anthropogenic impact.

Anthropogenic impact on the *Prydnistrovsko-Skhidnopodilska vysochynna sub-region* is modeled as high-categorical strong. What is decisive for this sub-region is that middling and essentially sloping broad-leaved forest tilled systems sharply dominate among very geo-negative land use systems. Their area is almost 44% of the sub-regional territory. In addition, the system of village built-up with 13.1% of the sub-regional area and the recreational system with 12.1% are widespread. These systems, together with the types of broad-leaved forest tilled system, cover almost 69% of area in this physic-geographic sub-region. A considerable share of the area belongs to geo-negative systems. Among them the middling and essentially sloping non-forest tilled systems prevail with 20% of the sub-regional area. Consequently the most characteristic type of system areas' cumulative distribution in districts is essentially concave. This type of distribution is an indicator of high-categorical strong anthropogenic impact on districts.

Anthropogenic impact on the *Serednobuzka vysochynna sub-region* is high-categorical strong because the cumulative distribution of land use system areas in the sub-region is essentially concave. A feature of the sub-regional quasi-spectrum is a small percentage of its area under the broad-leaved forest system, which is 11.2%. Very great anthropization of this taxon is caused by very geo-negative LULC systems. These are, firstly and again, the broad-leaved forest tilled system of all calculated types of its surface slope with almost 50% of the sub-regional area and the system of village built-up with 12.5%. Together, all just listed systems cover 62.0% of the sub-regional area. Middling and moderately sloping non-forested tilled territories are also spread. They occupy about 18% of the sub-regional area. Cumulative distributions in the districts coincide with the sub-regional distribution and indicate a high-categorical strong anthropogenic impact (see Figure 1).

In contrast to the previous two taxons, the *Tsentralnoprydniprovska vysochynna sub-region* is characterized by a concave distribution identical to the low-categorical strong anthropogenic impact. The structure of the relevant quasi-spectrum shows a low area share of dominant among geo-positive broad-leaved and coniferous forest systems, namely about 10% of the sub-regional area. Instead, firstly, geo-negative middling, essentially and moderately sloping non-forest tilled systems prevail with more than 42% of the sub-regional area. Secondly, very geo-negative systems are also important, because their total area is over 30% in the sub-region. Among them the village built-up system with 14.1% of the sub-regional area and middling and essentially sloping broad-leaved forest tilled systems with 16.5% dominate. Cumulative distributions in the districts are essentially concave and represent a strong anthropogenic impact. This does not apply, as already mentioned, only to the Cherkasko-Chyhyrynskyi district, which falls under the high-categorical moderate-strong anthropogenic impact of the 2nd level. This is due to the fact that geo-positive coniferous, broad-leaved and mixed forest and wetland systems occupy more than 35% of the district area.

The *Pivdennopodilska vysochynna sub-region* generally falls under the high-categorical strong anthropogenic impact. The area of geo-positive LULC systems is only about 8% of the sub-region. The broad-leaved forest system predominates here, covering about 6% of the sub-regional area. In contrast, geo-negative essentially and middling sloping non-forest tilled systems make the largest contribution to the anthropization of the sub-region, occupying 60% of its area. Very geo-negative systems also complement this contribution. Among them, the recreational system with 12.1% of the sub-regional area and the village built-up system with 10.3% were modeled. Under such conditions, cumulative distributions in districts mark low-categorical and high-categorical strong anthropogenic impacts on these districts (see Figure 1).

The cumulative area distribution of the *Pivdennoprydniprovska vysochynna sub-region* is essentially concave, which reflects the high-categorical strong anthropogenic impact on the sub-region. The quasi-spectrum of areas somewhat distinguishes this sub-region from other sub-regions of the

Podilsko-Prydniprovskyi region. This is due to the fact that geo-negative middling and essentially sloping non-forest tilled systems are extremely superior in area to all other land use systems. They occupy almost 72% of the model sub-regional area. Hence, the concave and essentially concave cumulative area distributions in the districts of the sub-region (see Figure 1) are expected to indicate low- and high-category strong anthropogenic impact on these physic-geographic districts.

Conclusions

Geoinformation model cause-effect analysis of anthropogenic impact on physic-geographic taxons was performed in the Podilsko-Prydniprovskyi region. The analysis applied modern spatial data bases and a progressive model scheme for cumulative distribution of land use and/or land cover (LULC) systems in taxons. The scheme operates with 10 types of this distribution and the relevant 10 categories of anthropogenic impact intensity from weak to excessively strong. In addition quasi-spectra of LULC system areas in taxons were used as a result of the thematic queries to spatial data bases. The geoinformation implementation of the scheme and quasi-spectra verified that 65% of the 31 regional districts fall under the high-categorical strong anthropogenic impact and only in one district this impact is moderate-strong. This is due to the fact that geo-negative LULC systems, primarily non-forest and broad-leaved forest tilled systems with various slope and village built-up and recreational systems, form more than 90% of the regional area. Instead, environmentally favourable systems, first of all broad-leaved forests, cover only 9% of this area. The obtained methodological and applied results can be used in regional schemes and projects to optimize the environmental management and substantiate urgent environmental protection measures.

References

Bilous, L.F., Shyshchenco, P., Samoilenko, V. and Havrylenko, O. [2020] Spatial morphometric analysis of digital elevation model in landscape research. *European Association of Geoscientists & Engineers. Conference Proceedings, Geoinformatics: Theoretical and Applied Aspects 2020,* May 2020, V.2020: 1-5. https://doi.org/10.3997/2214-4609.2020geo124

ESA [2015] European Space Agency. CCI Land Cover Map. Web source: http://maps.elie.ucl.ac.be/CCI/viewer

Havrylenko, O., Shyshchenko, P., Samoilenko, V. and Bilous, L. [2020a] Criteria for optimising air quality monitoring in Ukrainian cities (by example of Kyiv). *European Association of Geoscientists & Engineers. Conference Proceedings, XIV International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment"*, Nov. 2020, V.2020: 1-5. https://doi.org/10.3997/2214-4609.202056009

Havrylenko, O., Shyshchenko, P. and Tsyhanok, Ye. [2020b] Landscape functional zoning of urban protected areas. *Environmental Research, Engineering and Management*, **76**, 3: 121–136. http://dx.doi.org/10.5755/j01.erem.76.3.24258

National Atlas [2007] National Atlas of Ukraine (electronic version). Institute of Geography NASU, SRPE "Cartography" et al. [in Ukrainian].

NGCC [2011] National Geomatics Center of China. Globeland30 Land Cover Map. Web source: http://www.globallandcover.com/GLC30Download

Samoilenko, V.M., Dibrova I.O., Plaskalnyi V.V. [2018a] Anthropization of Landscapes. Monograph. Kyiv, Nika-Tsentr, 2018. 232. (in Ukrainian).

Samoilenko, V., Dibrova, I., Osadchyi, V., Vishnikina, L. [2018b] Procedure of Landscape Anthropization Extent Modeling: Implementation for Ukrainian Physic-Geographic Taxons. *Environmental Research, Engineering and Management*, **74**, 2: 67-81. http://dx.doi.org/10.5755/j01.erem.74.2.20646

Samoilenko, V. Dibrova, I. [2019] Geoecological Situation in Land Use. *Environmental Research, Engineering and Management*, **75**, 2: 36-46. http://dx.doi.org/10.5755/j01.erem.75.2.22253

Samoilenko, V., Bilous, L., Havrylenko, O. and Dibrova, I. [2020] Geoinformation modeling of anthropization extent in the Zakhidnoukrainskyi physic-geographic region. *European Association of Geoscientists & Engineers. Conference Proceedings, XIV International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment"*, Nov. 2020, V.2020: 1-5. https://doi.org/10.3997/2214-4609.202056010