ТЕОРЕТИЧНІ ОСНОВИ ЛАНДШАФТОЗНАВСТВА

THEORETICAL FOUNDATIONS OF LANDSCAPE SCIENCE

УДК 911.5
DOI: 10.31652/2786-5665-2025-8-71-81

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MICROSPATIAL PROCESSES AS INDICATORS OF ENVIRONMENTAL DEVELOPMENT: ESSENCE, RELEVANCE

Abstract. The current state of development of rural landscapes of Ukraine is unstable and requires a detailed study of the factors of this state and the development of recommendations for their development in the future. Applying the relevant principles (historicism, adaptability, complexity) and their appropriate methods (analysis, synthesis, field research and GIS technologies) of research, on the example of the model region of the plain part of Ukraine – Podillia, the natural and social factors of the formation of rural landscapes of the research region were considered. Among the natural factors: favorable spatial location and significant differentiation and variety of natural conditions and resources; among social groups – socio-economic, historical-political and ethno-demographic groups. It is noted that the modern structure of the rural landscapes of Podillia and Ukraine is determined mainly by the types of localities within which villages were built, and starting from the second half of the 20th century and socio-economic factors. The directions of the rational restoration of the rural landscapes of Podillia, which can be used in the development of the rural landscapes of Ukraine, are substantiated. Among them: a combination of «two cultures», partial or full museumization of villages, use of investment projects and reconstruction of villages by private individuals, development of green tourism, reorientation of economic activities of village residents. In the future, the research that has been started must be expanded and detailed, which will lead to the formation of a rational network of rural landscapes of Ukraine and its gradual unification with the Western European one.

Keywords: Ukraine, Podillia, rural landscapes, factors of formation, directions of reconstruction, rational use.

Канський В. С., Атаман Л. В., Чиж О. П. МІКРООСЕРЕДКОВІ ПРОЦЕСИ ЯК ІНДИКАТОРИ РОЗВИТКУ НАВКОЛИШНЬОГО СЕРЕДОВИЩА: СУТЬ, АКТУАЛЬНІСТЬ

Анотація. На початку XXI ст., коли навколишнє середовище є досить нестабільним, все більшого значення набувають антропогенні мікроосередки, а також процеси, що відбуваються в їхніх межах. Зазначена тенденція свідчить про виникнення нових взаємозв'язків у сфері ландшафтів, енергії, речовин та інформації. Мета статті – дослідити процес формування антропогенних мікроосередків та обґрунтувати їхню актуальність як індикаторів екологічного розвитку. Матеріали та методи включають конструктивно-ландшафтний підхід; принципи комплексності та природно-антропогенної співіснування; методи ретроспективи, природної аналогії, моделювання та геоінформаційних технологій. Ми визначаємо антропогенну територію як територію, на якій розвиваються антропогенні процеси, що призводять до змін у структурній організації відповідних географічних компонентів та ландшафтних комплексів. Різноманітність антропогенних мікроосередків та процесів, що відбуваються в їх межах, розглядається як результат господарської діяльності, так і структури ландшафтних комплексів. Об'єктом дослідження є Середнє Побужжя. На його основі досліджуються формування та структура рекреаційних зон басейну Південного Бугу. З огляду на показники процесів, що відбуваються в антропогенних мікроосередках, розглядаються варіанти залучення цих характерних ландшафтних структур до розробки проектів раціонального природокористування.

Ключові слова: антропогенний ландшафт, антропогенний мікроосередок, процеси, індикатори, структура, навколишнє середовище, управління навколишнім середовищем.

Relevance of the research. The present-day environment is seen as the destabilized one, in terms of landscapes and ecology. Characteristic of it are the abnormally rapid changes within the framework of its geocomponents and landscape complexes as well as the interrelationships between them. It gives rise to new phenomena and their respective responses to external, mainly anthropogenic, impacts, which leads to unpredictable trends in the environment and the ways it functions. Under given circumstances increasingly widespread are microspatial processes, such as the emergence of new environmental interrelationships in the realm of landscapes, ecological systems, energy, substances, and information. Investigations into the given problem are both urgent and having good prospects. On the one hand, microspatial processes reveal the causes and mechanisms of fluctuating transformation trends at a local level as well as the prospects of their regionalization. On the other hand, the significance of microspatial processes as indicators opens up opportunities for managing the state of the natural environment as well as for preventing undesirable, sometimes rather aggressive, processes and phenomena at the early stages of their development *(Канський, Ставська, & Кізюн, 2024; Война, 2025)*.

Anthropogenic microspatial processes aroused scientific interest of Ukrainian geographers and landscape scientists in the late 20th – early 21st centuries. In their scientific publications, L. I. Stefankov and N. V. Parashchuk (*Stefankov & Parashchuk, 2002; Stefankov, 2008*) address the issue of local disturbances in the form of focal processes of desiccation or excessive moistening caused by irrigation activities and reservoir construction. The authors point out the indicator significance of the above processes in the development of the Southern Buh River floodplain.

A more detailed study of microspatial processes within anthropogenic landscapes of Podilia is represented in the collective monograph by H. I. Denysyk, M. O. Shmahelska, and L. I. Stefankov (*Denysyk, Shmahelska & Stefankov. 2010*). O. Yu. Dmytruk and B. H. Denysyk (*Dmytruk & Denysyk, 2019*) researched recreational microsites of Middle Pobuzhzhia and the formation of respective recreational geoecotons. Works revealing methodological approaches to the research and appraisal of microspatial processes are of particular interest (*Hrodzynskyi & Shyshchenko, 1999; Shmahelska, 2008; Stefankov, 2008*). It is worth mentioning that findings of investigations into the problem of anthropogenic microsites are subject to scrutiny of the scientific community at various forums. Among the latter was the research and training conference "Anthropogenic Microsites" held at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University in 2018. Participants of the conference presented and discussed findings of investigations into anthropogenic microsites in the early 21st century.

Research aim is to substantiate the relevance of anthropogenic microsites and processes within their boundaries as indicators of the functioning of the modern destabilized (in terms of landscapes and ecology) environment.

Material and Methods. The constructive-landscape scientific approach as well as the principles of comprehensiveness and natural-anthropogenic coexistence provided the methodological basis of the given research. Other research tools included: a) general scientific (retrospective, systems, structural) methods; b) subject-specific methods, including those of analysis of literary sources, natural analogy, cartographic, and landscape field studies; c) interdisciplinary methods (modelling, geoinformation technology, and zoning).

Source materials for the research were documents of various institutions and organisations, such as State Environmental Inspectorate of Ukraine in Vinnytsia oblast, archive holdings of different regions of study, materials of the popular science journal "Dovkillia Ukrainy" ("Environment of Ukraine"), as well as research data of the authors' field studies carried out between 2014 and 2020.

Results. Under the conditions of the unstable environment that is increasingly affected by humans, diverse microsites are actively developing across the geographic spectrum. In some cases, they are of smaller size and inconspicuous, hence not always identified. Nevertheless, when they reach considerable numbers, such microsites and processes within their bound-

aries have a significant impact on the state of landscape complexes and can determine their further development. Until recently, landscape scientists did not pay due attention to the pattern structure of landscapes, confining themselves to considering only general characteristics of such a structure without singling out its components. Moreover, in most geographical dictionaries and encyclopaedias there is no entry for "mosaic of landscapes". By contrast, "mosaic of phytocenoses", i.e. a peculiarity of phytocenoses determined by the uneven distribution of plants within them, can generally be found in reference books. In the realm of landscape science and related disciplines there are a number of terms that are close in meaning to "mosaic of landscapes". The concept of "landscape patterns" is among the most common ones.

According to authors, a landscape pattern is a spatial unevenness of the landscape structure. Its other meaning suggests a style of a drawing (contour shapes, structural fragmentation, the nature of bounds etc.) (*Rikhlinh, Andreichuk, Rudenko & Chekhnii 2015*). There is a general agreement that a landscape pattern of a given area is a spatial mosaic that is made up of certain pieces of land surface. The latter are distinct in terms of natural spatial complexes or comprehensive micro formations developed in this area.

Thus, a landscape pattern is its mosaic. Therefore, the notions of "a landscape pattern" and "a landscape mosaic" can be used interchangeably in further research. Besides, "mosaicity of a pattern structure" can also denote the above concept.

Landscape mosaicity and microsite diversity. The spatial structure of a modern landscape is in most cases a complex combination of natural, natural-anthropogenic, and anthropogenic landscape complexes. Accordingly, three types of mosaicity can be distinguished.

Natural mosaicity of a landscape structure is its main feature that demonstrates the extent of its maturity as well as ensures its stability, crisis-free functioning etc. There are few natural landscape complexes left over. They include alder thickets that still can be found in floodplains and on first fluvial terraces, rocky areas of floodplains and dead stream branches, swampy or waterlogged terrace-adjoining lowlands etc. Being balanced in terms of mosaicity, natural landscape complexes mainly act as stabilizing factors in the functioning of modern anthropologically overladen landscapes of river valleys. They try not to use natural landscape components for economic needs. Despite it, the development of such components, for recreation use in particular, is increasing. It leads to the formation of recreational microsites and the development of respective processes within their boundaries. Such processes are not always favourable (*Dmytruk & Denysyk, 2019*). Both endogenous and exogenous processes form natural landscape mosaicity.

Natural-anthropogenic mosaicity is a second-order phenomenon. Within local areas it is quite often caused by an anthropogenic trigger. Nevertheless, further development of a landscape structure takes place according to natural patterns. Natural-anthropogenic mosaicity is widespread in the territory of Middle Pobuzhzhya. One example is the complication of riverine landscape complexes of rivers and their tributaries under the influence of numerous ponds and water-storage basins found here. The ecotone system "water-dry land" is formed in waterlogged areas. From three to five transition strips of riverine landscape complexes stand out clearly within the system. Natural-anthropogenic mosaicity of riverine landscape complexes increases significantly on temporary recreation microsites, especially fishing spots, one-off tourist camps, and weekend getaways. In the course of its development (complication) the natural-anthropogenic mosaicity turns into the anthropogenic one, since processes caused by an anthropogenic trigger gradually become dominant *(Амаман, 2024).*

Anthropogenic mosaicity is caused by the anthropogenic factor and develops under its impact too. As a rule, such mosaicity vastly differs from the initial natural one and even from the anthropogenic mosaicity that existed before a new transformation of a landscape.

One example of the anthropogenic mosaicity within boundaries of Middle Pobuzhzhya are pit and stockpile complexes that are formed due to mineral extraction activities, e.g. granites, gneisses, sands, clays, and peat. Thus, in the course of developing Hnivan-Vytava granite

and gneiss deposit in Vinnytsia Oblast, the coefficient of mosaicity of the local mining landscape has increased by 4.3 times in comparison with the natural mosaicity and is 2.4 times higher than that of the natural-anthropogenic mosaicity that existed here before mining activities (*Denysyk, 2014*).

An extent of danger of a microspatial process has so far been assessed conventionally, in the main from merely the anthropocentric perspective, i.e. from the point of view of its "utility". It is believed that respective deliberate changes such as hydrotechnical amelioration (irrigation or draining) bring about benefits. On the other hand, inevitable side effects of such deliberate changes are seen as "unfavourable" ones. The evaluation of the above unfavourable processes within microsites can be carried out based on their overall effect on the environment in the form of disturbances of water regime of hydrodynamically related areas, both adjacent and separated. The expansion of the area of microspatial processes can pose a problem. Hence, microspatial processes could be broke up into four categories: 1) *stable* (not leading to the expansion of microsites but merely maintaining them); *declining* (gradually degrading, resulting in the destruction of microsites); 3) *increasing* (processes that quickly "develop themselves" and lead to microsite expansion); 4) *pulsating* (processes that under the impact of diverse, mainly anthropogenic, factors may either develop or degrade, resulting in either microsite expansion or reduction) (Fig. 1).

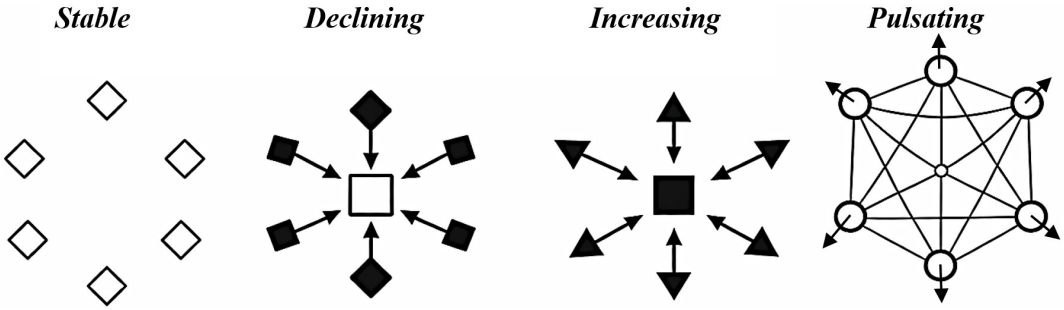


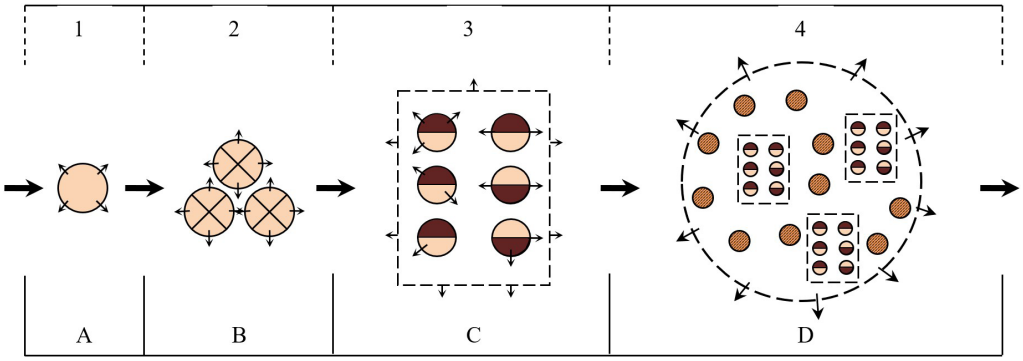
Fig. 1. Types of anthropogenic microsites, according to their dynamics (*Дмитрук, Денисик, 2019)*

Monitoring the development of the above anthropogenic microsites reveals that stable and increasing microsites come into being and function predominantly against the background of anthropogenic landscape mosaicity, whereas declining microsites – against the background of natural-anthropogenic mosaicity, and pulsating microsites – natural and anthropogenic ones.

Only increasing and pulsating recreational microsites are crucial for the emergence and further development of landscapes, particularly recreational ones. Figure 2 shows the pattern of the gradual transition of such microsites into recreational landscape complexes based on tracts, complex tracts, terrain type etc.

The use of microspatial processes as indicators of the anthropogenically disturbed environment can be made by means of historical and genetic series of landscape maps. Each "time sample" will indicate the presence of some microspatial processes that either added or did not add to the environmental disturbance. They will also show the extent to which respective processes added to the disturbance. What counts is the reliability of microspatial processes as indicators. While assessing the reliability, it is worth proceeding from the total area of microspatial processes (designator), determining its ratio to the area of a landscape complex – a tract, a terrain, or a region as a whole.

In anthropogenic landscape studies, the use of microspatial processes as indicators of the disturbed environment is closely linked to the correlation between areas of anthropogenic and natural landscape complexes. While areas indicate the extent of the anthropogenic impact on a region, microspatial processes as indicators show whether the above impact is favourable



Recreational structures: 1 – a recreational microsite; 2 – a group of recreational microsites; 3 – a recreational geoecotone; 4 – a recreational landscape complex.

Natural structures that form the basis for recreational structure development: A – facies or a simple tract; B – a tract or a complex tract; C – a complex tract or a terrain type; D – one type or two-three terrain types.

Fig. 2. Process of transition of recreational microsites into a recreational landscape complex (*Дмитрук, Денисик, 2019)*

or unfavourable.

Regional studies of recreational microsites. The case study is Middle Pobuzhzhya. Considered are processes and phenomena taking place within recreational microsites of the region. The analysis of natural conditions and resources of Middle Pobuzhzhya made it possible to conclude that virtually all types of landscapes (natural, natural-anthropogenic, and anthropogenic) can perform recreational functions here (*Denysyk, 2014*).

A number of recreational microsites along with respective processes and phenomena that are actively developing have been found within Middle Pobuzhzhya. Just as before, the number and development of recreational microsites that have to do with water and forest landscape complexes are increasing. A trend towards gradual recreational development of abandoned agricultural and industrial facilities is also observed: cattle farms located on terraces and flat interfluves are being turned into ranches for holidays and horseback riding at weekends; plants and factories are being converted into industrial cultural monuments.

Let us consider the recreational development of the riverside of the Southern Buh in the vicinity of the village of Kolo-Mykhailivka just outside Vinnytsia as a case study of a recreational microsite formation. Three recreational microsites each covering from 0,07 ha to 0,2 ha were formed as a result of the spontaneous development of the riverside on the stretch of 270 m. In its natural state, the riverbank is steep (60-70º), made up of sands of the boron terrace reaching the height of 1,5 m to 3,0 m, sodded and overgrown with willow-stand, alders, pine trees, and pedunculate oaks. The formation of recreational microsites started with holidaymakers overburdening some riverside areas with a convenient access to the Southern Buh.

First trampling and then woody vegetation removal led to the emergence of circular recesses on the sandy bank. It takes 2-3 years for such recreational microsites to be formed. A 1,0-1,5 m ledge shapes on their perimeter. Negative processes that lead to vegetation and ground cover destruction, sand slumping and its transfer towards the river via a microsite, and sanding up the Southern River channel, actively develop on the ledge. Old pine and oak trees on edges of recreational microsites sometimes develop into a “drunk” wood or grow with their roots exposed. Although such trees are fixed, they still pose a potential threat for holidaymakers.

Unfavourable processes within recreational microsites of Middle Pobuzhzhya are especially active in the swimming season (June-July). While children’s recreation camps, holiday homes and health resorts are located on pine wood terraces of the Southern Buh, recreational microsites become the destination for beach goers.

According to our estimates, from 20-30 to

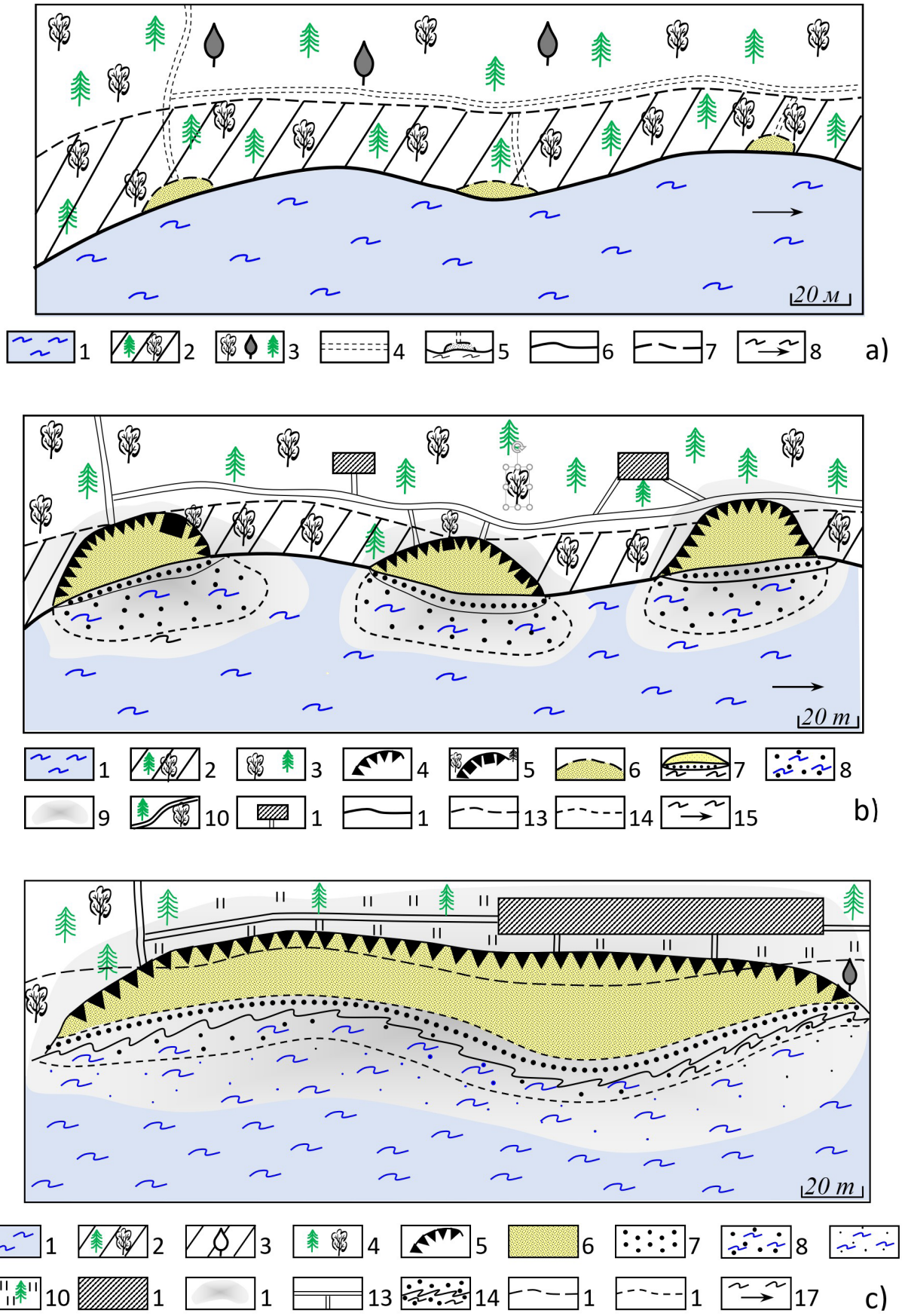


Fig. 3. Transition of recreational microsites into a recreational geoecotone *(Kanskyi V., Ataman L., Chyzh O.)*

a) stored (1972-1974) landscape structure

Natural-anthropogenic landscapes. *River channel type of terrain*. *Tracts:* 1 – shallow (up to 2.5 m), 10-12 m wide, with a silted, occasionally sandy bottom, without riparian vegetation, the Southern Buh River channel. *Above-floodplain terrace type of terrain. Tracts:* 2 – steep (25-35°) sandy-loam, 2.5-3.5 m high first terrace ledge with thin light-grey soils, covered with 30-40-year-old pine and oak trees; 3 – levelled-off terrace with occasional water-logged low grounds, thin light-grey soils, covered with pine and oak trees, occasionally linden trees.

Anthropogenic landscapes. *Road landscapes. Tracts:* 4 – twin-track 3-4 m wide sandy wood roads. *Recreational. Tracts:* small (5-15 m) temporary summer beaches without vegetation. *Boundaries of terrain types:* 6 – river channel type and terrace type; 7 – tracts. *Other designations:* 8 – the Southern Buh set of current.

b) Restored (1996-1998) landscape structure

Natural-anthropogenic landscapes. *River channel type of terrain*. *Tracts:* 1 – shallow (up to 2.5 m), 10-12 m wide, with a silted, occasionally sandy bottom, without riparian vegetation, the Southern Buh River channel. *Above-floodplain terrace type of terrain. Tracts:* 2 – steep (25-35°) sandy-loam, 2.5-3.5 m high first terrace ledge with thin light-grey soils, covered with 30-40-year-old pine and oak trees; 3 – levelled-off terrace with occasional water-logged low grounds, thin light-grey soils, covered with pine and oak trees, occasionally linden trees.

Anthropogenic landscapes. *Recreational microsites. Tracts:* 4 – steep (45-80°), 0.7-1.2 m high sandy ledge with exposed roots of oak and pine trees; 5 – steep (60-90°), 1.0-1.5 m high sandy ledge with slanted or half-dry oak and pine trees which roots are fixed by means of the metal grid and stones; 6 – sandy beach surface without vegetation, sloping (5-8°) towards the river channel; 7 – riverside beach shoal formed as a result of sand transfer into the river channel; 8 – shallow (0.3-0.5 m) river channel sanded up from the beach of the recreational microsite; 9 – zone of influence of recreational microsites. *Road landscapes. Tracts:* 10 – twin-track 2-5 m wide sandy wood roads. *Other designations:* 11 – temporary points of holidaymaker service. *Boundaries:* 12 – river channel and above-floodplain terrace types of terrain. *Tracts:* 13 – natural; 14 – anthropogenic; 15 – the Southern Buh set of current.

c) Modern (2017-2018) landscape structure

Natural-anthropogenic landscapes. *River channel type of terrain*. *Tracts:* 1 – shallow (up to 2.5 m), 10-12 m wide, with a slightly silted, occasionally sandy bottom, without riparian vegetation, the Southern Buh River channel. *Above-floodplain terrace type of terrain. Tracts:* 2 – steep (25-35°) sandy-loam, 2.5-3.5 m high first terrace eroded scarp with heavily eroded thin light-grey soils covered with "drunk" oak and pine trees; steep (35-50°) first terrace sandy ledge, 3.0-3.5 m high, with erosion furrows and heavily eroded thin light-grey soils covered with shrubs; 4 – levelled-off terrace with occasional water-logged low grounds, thin light-grey soils, covered with pine and oak trees, occasionally linden trees.

Anthropogenic landscapes. *Recreational geoecotones. Tracts:* 5 – steep (45-80°), 0.7-1.2 m high sandy ledge with exposed roots of oak and pine trees; 6 – 5-8 m wide sandy beach surface sloping (3-5°) towards the river channel; 7 – 1.0-1.5 wide periodically flooded riverside beach; 8 – narrow (up to 2 m), 0.5 m deep sandy beach shoal; 9 – shallow (up to 1.0-1.5 m) river channel exposed to sanding from the beach that is actively used for swimming by holidaymakers; 10 – levelled-off sandy terrace with thin light-grey soils, covered with pine trees, used for walks, mushrooming, and phytotherapy; 11 – riverside tree-covered terrace under a recreational and restaurant complex; 12 – recreational geoecotone affected area. *Road landscapes. Tracts:* 13 – 4-6 m wide partly paved but sandy in the main wood roads. *Boundaries between terrain types:* 14 – river channel and above-floodplain terrace types of terrain in the structure of a recreational geoecotone. *Tracts:* 15 – natural; 16 – anthropogenic. *Other designations:* 17 – the Southern Buh set of current.

50-60 persons have their rest on recreational microsites of the Southern Buh in the vicinity of the village of Kolo-Mykhailivka every day in summertime. It is in summer, when the largest volumes of sand are transferred to the Southern Buh channel damming the river up to 20-35%, creating shallow beaches, changing the riverbed profile and a flow velocity of the river.

Let us consider the *significance* of researching microsites by the example of setting suburban area boundaries. Each suburban area has its own unique fringe. Therefore, in each particular case of setting suburban area boundaries one should take into account both *general* and *specific* discriminatory criteria. In our opinion, the spatial layout of the most characteris-

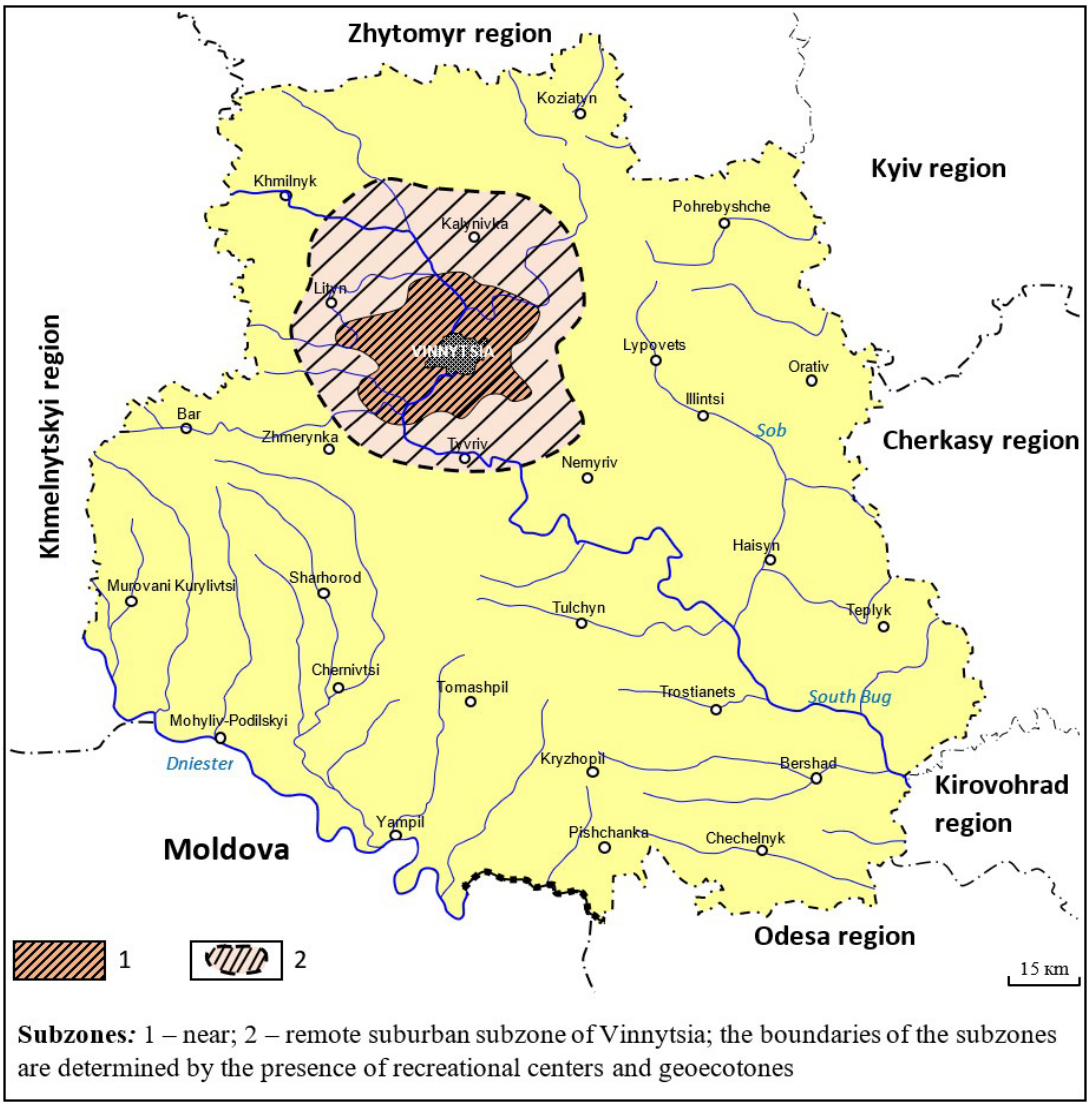


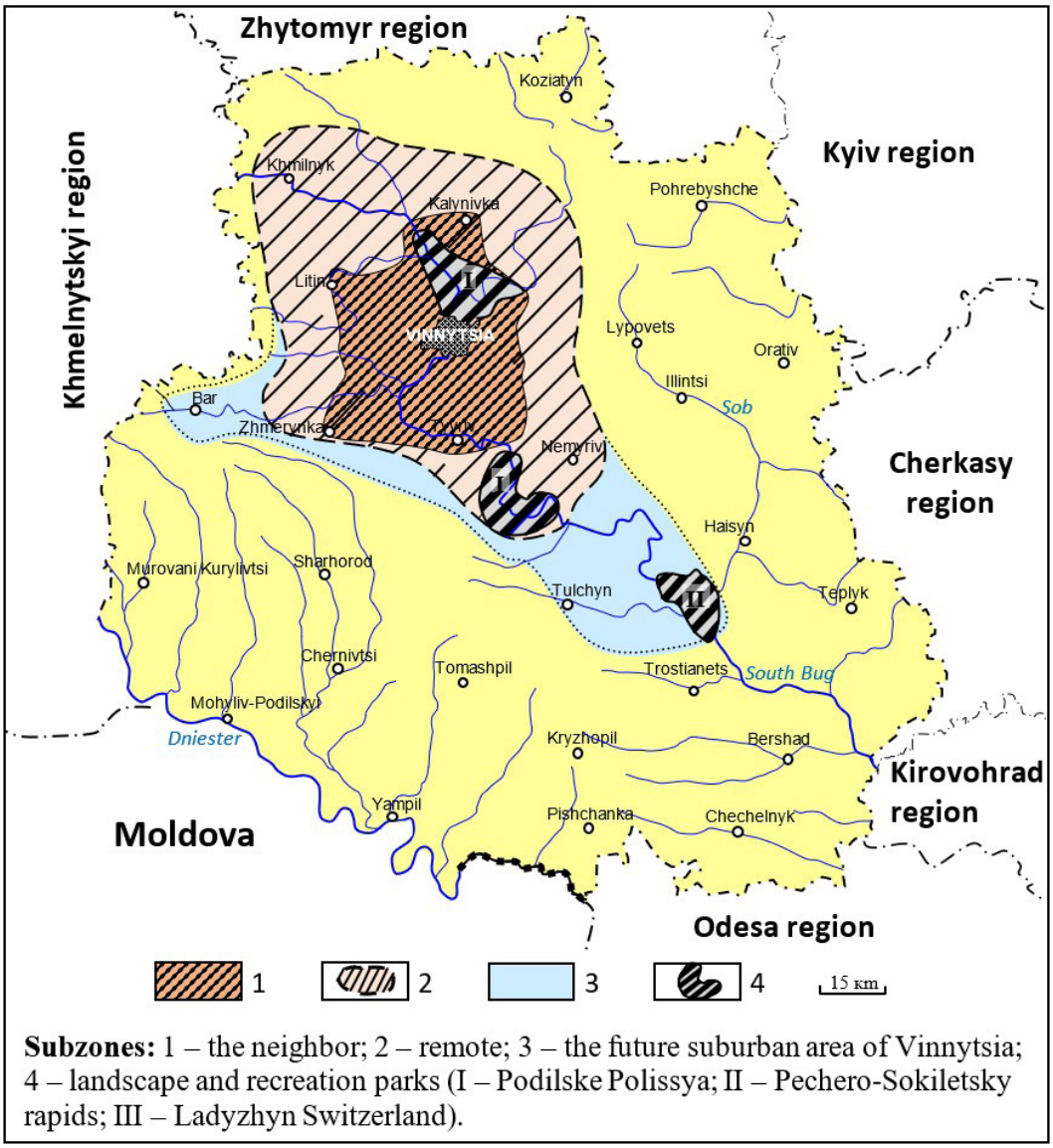
Fig. 4. Present-day suburban area of Vinnytsia
(Kanskyi V., Ataman L., Chyzh O.)

tic anthropogenic landscapes must be taken as the main general criterion for determining the outer boundary of a suburban area. Characteristic of suburban areas are the following types of landscapes: residential areas, forests, roads, partially industrial zones. Being dominant in suburbs, they are much less common outside urban centres. They do not even make up a respective landscape background.

Nowadays recreational needs of people rank third after their needs for dwelling and employment. No wonder, recreational business is among the most important and profitable lines of business now in places adjacent to residential areas, especially suburbs. Moreover, since the late 20th century the recreational landscapes that were formed as a result of recreational business activities have been considered one of the criteria for determining outer boundaries of sites adjacent to residential areas, predominantly suburbs (*Denysyk & Babchynska, 2006; Hrodzynskyi & Shyshchenko, 1999*).

Field studies of the suburbs of Vinnytsia conducted in 2014-2020 revealed the dominance of *recreational landscapes* that in some places are background ones. Hence, the suburban zone of Vinnytsia begins and ends where recreational landscapes start prevailing and become background. One criterion for determining boundaries of places adjacent to residential areas are recreational hotbeds and geoecotones that subsequently develop background recreational landscapes of such areas.

Such an approach makes it possible to



Subzones: 1 – the neighbor; 2 – remote; 3 – the future suburban area of Vinnytsia; 4 – landscape and recreation parks (I – Podilske Polissya; II – Pechero-Sokiletsky rapids; III – Ladyzhyn Switzerland).

Fig. 5. Boundaries of the suburban area of Vinnytsia in 2050
(Kanskyi V., Ataman L., Chyzh O.)

lay out specifics of both the structure of places adjacent to residential areas (subareas) and that of their inherent landscapes, particularly recreational ones. Researches into recreational hotbeds and geoecotones as well as the recreational landscapes developed on their basis provided for the distinct setting of boundaries of Vinnytsia suburbs. They also made it possible to devise the strategy of further investigations aimed at refining the master plan of developing suburbs of Vinnytsia by 2050 (Fig. 5).

Conclusions. Characteristic of the present-day environment that is largely imbalanced in terms of ecology and landscapes are abnormally rapid changes in the structural organization of geocomponents and landscape complexes, as well as their interrelationships. New phenomena, such as microsites and their inherent processes are emerging and actively developing across the geographic spectrum as a response to increasing anthropogenic impacts.

It is nothing more than the initial, incipient development of new landscape, ecosystem, energy, substance, and information interrelationships in the external environment. Thereby, researching anthropogenic microspatial processes is an important methodological means of estimating both processes that once took place and those that are currently taking place in the disturbed environment. It is specifically true

for regions where the anthropogenic load has reached or is reaching critical levels. In such regions, microsites and processes within them are diverse. One crucial research task is to establish whether these microprocesses are reliable indicators of environmental conditions.

The increasingly active development of anthropogenic microspatial processes within Middle Pobuzhzhya eventually leads to the complete transformation of certain geocomponents and landscape complexes bringing about changes in their structure. When merged, individual microsites within which undesirable processes are taking place can grow into local and then regional ones, creating prerequisites for ecological crises. Thus, microspatial processes, especially those taking place in ecologically unstable regions can serve as indicators of patterns of future regional environmental changes.

It is worth working out measures for the optimization of undesirable microspatial processes brought about by anthropogenic factors in two stages: a) developing individual projects of the stabilization of negative microspatial processes (all processes – in case of sufficient resources); b) developing regional projects (based on individual ones) of certain areas (e.g. Middle Pobuzhzhya, Middle Prydnisteria, and Podillia as a whole) that stand out due to specific features of their natural conditions or the relevant anthropogenic impact. In both cases one must take into account ecological networks found in areas under consideration.

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Статтю надіслано до редколегії 16.10.2025 р.
Статтю рекомендовано до друку 02.12.2025 р.