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# LANDSCAPE-ECOLOGICAL PLANNING – A TOOL OF FUNCTIONAL OPTIMIZATION OF THE TERRITORY (CASE STUDY OF TOWN BRATISLAVA)

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Abstract

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Landscape-ecological planning as a tool of ecological organization of the area and sustainable development is an unavoidable part of spatial planning processes. The aim of landscape-ecological plans is a proposal of ecologically optimum spatial organizaton and functional land use. Just urban ecosystems can be characterized by the fact, that on a small area a large number of people is concentrated and there appear many activities with different influences on the environment. They may cause unpredictable responses damaging and decreasing the quality of the environment. The presented paper gives the methodological procedure of creation and application of abiotic, ecological and selected hygienic limits in the proposal of the optimum spatial organization of selected agricultural use of arable land in Bratislava.

*Key words*: landscape-ecological planning, decision-making process, abiotic, ecological and hygienic limits

## Introduction

Landscape-ecological planning as a tool of ecological organization of the area and sustainable development is an unavoidable part of spatial planning processes. The methodology of landscape-ecological planning – the methodology LANDEP (LANDscape-Ecological Planning) was prepared in the Institute of Landscape Ecology of the Slovak Academy of Sciences at the turn of the seventies-eighties of the 20$^{th}$ century and it is a suggested basic methodology for integrated approach to the management of natural resources and landscape of Agenda 21 (Chapter 10). It is a systemically arranged special complex of applied landscape-ecological methodologies and methods the aim of which is a proposal of the ecologically optimum land use in order to define the suitability of landscape-ecological complexes from the viewpoint of proposed activities (Ružička, Miklós, 1982).

The aim of landscape-ecological plans is a proposal of an ecologically optimum spatial organization and functional land use. The landscape-ecological plan is a complex process of mutual harmonization of spatial demands of economic and other human activities with landscape-ecological conditions of the area following from the landscape structure. A new dimension of creation of the land use plan of the region and municipality provides Act No. 237/2000 of the Slovak National Council modifying and amending the Act No. 50/1976 on territorial planning and Building Code (the building act), where landscape-ecological planning aimed at an ecologically optimum land use gained larger scope.

In evaluation of the environmental problems of urban ecosystems the methodology LANDEP was used for the first time in the planning of the housing estate Bratislava-Lamač (Ružička et al., 1974). Other special questions following from the evaluation of the environment of Bratislava were aimed at e.g. influence of commercial development on the forest park (Ružička et al., 1982), influence of the high-speed rail on the environment (Miklós et al., 1981), ecological evaluation of the town (Hrnčiarová et al., 1982; Kozová et al., 1990; Hrnčiarová, Krnáčová, 2001; Izakovičová, Hrnčiarová et al., 2001; Krnáčová, Hrnčiarová, 2002) etc.

The urbanized environment is an intensively used area, where are many new artificial and modified natural elements. Its special part are urban ecosystems – there appear different collisions of human activities and interests. Antrop (2004) characterizes the urban landscape as a very dynamical, multifunctional complex. In landscape-ecological evaluation of the urban ecosystems it is necessary to focus the attention mainly on the determination of the problems of the present and future land use and only slightly can be decided about the optimum location of activities because the significant part of the territory is built-up or it is intensively utilized by another way.

For urban ecosystems is characteristic, that in small area many people are concentrated and there are many activities with different environmental impacts. So in urban ecosystems comes to unpredictable responses disturbing and decreasing the quality of the environment. These changes are more significant in larger urbanized areas.

During the historical development as well as nowadays a very dynamical development of Bratislava can be observed, as to its extent, but also design and intensity of use. From many aspects the town reached its maximum dimension and in certain parameters it exceeds the capacity of utilization, for example the traffic system, intensive building up of the area, deterioration of air quality, contaminated and anthropogenic soil etc. For example anthropogenic soils predominate over unchanged soils (anthropogenic soils are natural soils partially or basically changed and modified by man) (Bedrna, 2002). Many processes in an urban landscape are influenced by new ecosystem properties and relations. Another negative phenomenon is the increase of the built-up area. In 2002 its land area enlarged by 291 ha opposite to 1997 (6007 ha). On the contrary in 2002 the area of agricultural soil during the same period decreased by 139 ha. In 1997 its land area was 14 862 ha (Statistical yearbook of the capital of the Slovak Republic Bratislava, 2003). In the further development of Bratislava it is necessary to proceed not only according to environmental limits, but it is unavoidable to search for different economic and technical solutions (to change the outdated technologies etc.).

## Method of elaboration of the landscape-ecological plan of Bratislavy

The analysis of landscape-ecological bases – abiotic, biotic and socio-economic ones is an unavoidable part of evaluation of the urban ecosystems of the area. The further procedure depends on their properties and degree of knowledge. Landscape-ecological assessment of the area is one of the basic conditions of sustainable land use. Disharmony in land use is a basic cause of ignoration of the properties of landscape elements and their interrelations. In the analytical part in urban ecosystem assessment the following bases are decisive:

**Natural conditions (mainly abiotic complexes)** – they determinate the basic frame of land use. Especially abiotic complexes enter into the evaluation, while the created quasi homogeneous spatial areas are the representatives of same natural features, same landscape load by anthropic activity as well as same use. In town agglomerations these conditions are much affected, changed and frequently artificially created. They serve as a basis of abiotic limits.

**Ecologically significant elements** – they identify the ecological priorities in the landscape (protected areas, elements of territorial system of ecological stability, important natural resources etc.) which ought to be conserved in order to maintain ecological stability and biodiversity. They serve as a basis for ecological/ecosozological limits.

**Environmentally risk factors** – they characterize the main environmental problems in the landscape, especially endangerment of ecological stability and quality of natural resources (water, soil, air as well as vegetation and animals). They have natural and also anthropogenic character. In urban ecosystems they are frequently dominant and determinate many new natural-anthropic processes. They serve as a basis for hygienic limits.

### *Formation of abiotic complexes*

The abiotic complex (ABC) is a combined, spatially limited geosystem consisting of abiotic landscape elements integrated by interrelations (Tremboš, 1994). In landscape-ecological assessment of the area the content of abiotic synthesis is the formation, characteristics and classification of homogeneous spatial distribution areas with approximately equal abiotic features. The issue are the types of abiotic complexes distinguishing from the neighbouring homogeneous distribution areas by different combination of values. The basis for formation of abiotic synthesis are **relief – geological ground – soil – climate.** For each landscape element (component) is specified a complex of applied parameters, brief characteristics and the procedure of formation of the categories of partial synthesis units. Each analytical landscape component was elaborated into a digital form together with nongraphic database data which were interlinked with graphic data by identificators (Fig. 1). The formation of abiotic complexes (ABC) is one of the decisive steps in the methodology LANDEP. It is the base for determination of abiotic limits and the borders of selected types of ABC are also the borders for the proposal of changes of land use. The types of abiotic complexes in the area of Bratislava were characterized by the following analytical parameters:

$X_{1\text{-}6}XXX$ 1. code slope inclination
$XX_{A\text{-}N}XX$ 2. code soil
$XXX_{1\text{-}11}X$ 3. code climate type
$XXXX_{A\text{-}K}$ 4. code geological ground,

then the types of abiotic complexes arose according to the relation:

ABC ($X_{1\text{-}6}\,X_{A\text{-}N}\,X_{1\text{-}11}\,X_{A\text{-}K}$).

According to the combination of analytical parameters each type of ABC has different suitability (carrying capacity) for utilization – they are the basic operation units of a further decision making process. In the model area of Bratislava 483 types of ABC (Table 1) have been arisen.

The created units present partial physico-geographical complexes composed of selected features of abiotic landscape elements having specific regularities of structure, development and functioning on the basis of topic relations. In investigation of each area they are significant spatial database. According to analytical parameters each type of ABC has different suitability for use – they are the basic operation units of the further decision making process. The aim of abiotic syntheses is the formation of classificational homogeneous units of typological character expressed as spatial subsystems and simultaneously they give basic information about the state and utility of single elements.

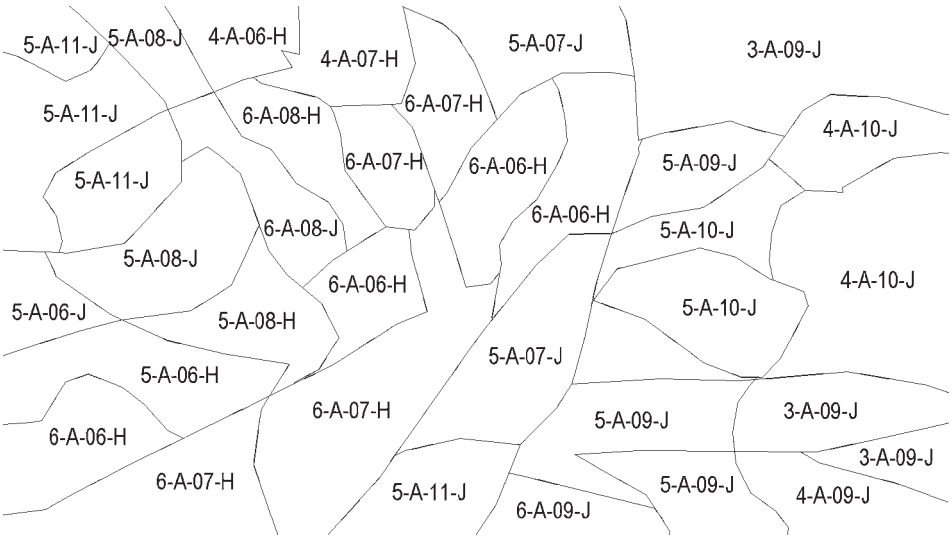


Fig. 1. Types of abiocomplexes (segment in the model area). Type of abiocomplex (ABC), e.g. 5-A-11-J: 1. code inclination, 2. code soil, 3. code climate types, 4. code geological ground.

## *Ecologically significant elements*

In Bratislava all legislatively permitted protected areas and natural resources as well as the areas significant from the viewpoint of genepool and biodiversity protection or falling within international conventions have been ranged among ecologically significant elements:

- elements of landscape and nature protection – protected landscape areas (PLH Malé Karpaty and PLH Dunajské luhy grassland), 32 sites of the 4$^{th}$ and 5$^{th}$ degree of nature protection (natural reserves, natural monuments, protected areas)
- elements of the territorial system of ecological stability
- elements of protection of forest resources (protective forests and special forests demanding special regime of management)
- localities selected according to international conventions (Ramsar sites – alluvium of the Morava river and Dunajské luhy grassland) as well as the sites of endangered plant and animal species
- protection of water resources is permitted for protection of their yield and quality (protective belt of water resources and protected water-management area).

## *Environmental risk factors (stress factors)*

In the area of Bratislava can be identified many stress factors influencing the quality of the environment as well as the quality of natural resources, decreasing biodiversity etc. These factors can have a display spreading from a point, line or it can be observed in larger area. For the landscape-ecological plan the most significant factors were those with areal character. Their cumulation is the strongest in the south-western part of the town. We evaluated:

- polluted air
- contaminated soils
- polluted underground waters.

T a b l e 1. Types of abiotic complexes (example of elaboration)

| Type of ABK | Area and occurrence of types of ABC | | Type of ABC | Area and occurrence of types of ABC | |
|---|---|---|---|---|---|
| | area [km²] | abundance | | area [km²] | abundance |
| 1-A-02-J | 0.033158731 | 1 | 1-F-03-F | 0.259547459 | 2 |
| 1-A-03-H | 0.016883389 | 1 | 1-G-03-B | 0.755464955 | 4 |
| 1-A-03-I | 0.016514105 | 1 | 1-G-03-F | 0.176050829 | 4 |
| 1-A-03-J | 0.017114215 | 1 | 1-G-05-B | 4.046280790 | 5 |
| 1-A-05-I | 0.028644667 | 1 | 1-G-05-E | 1.101124691 | 1 |
| 1-A-10-J | 0.089558148 | 1 | 1-H-02-B | 0.024528591 | 1 |
| 1-C-02-E | 0.453904686 | 2 | 1-H-02-F | 0.095319152 | 1 |
| 1-C-03-A | 0.056954596 | 1 | 1-H-03-B | 2.920581407 | 8 |
| 1-C-03-B | 0.669544829 | 5 | 1-H-03-F | 0.713533073 | 3 |
| 1-C-03-E | 0.441910200 | 1 | 1-H-05-B | 1.004884376 | 2 |
| 1-C-03-F | 0.397509485 | 1 | 1-H-05-F | 0.019389579 | 1 |
| 1-C-03-H | 0.113538907 | 3 | 1-I-03-B | 39.443264622 | 22 |
| 1-C-03-K | 0.047071410 | 1 | 1-I-03-C | 27.737268558 | 18 |
| 1-C-05-E | 0.365607674 | 1 | 1-I-03-D | 1.807877524 | 5 |
| 1-D-02-B | 0.049606182 | 1 | 1-I-03-F | 8.353881990 | 9 |
| 1-D-03-A | 1.764928708 | 2 | 1-K-03-B | 5.010527070 | 10 |
| 1-D-03-B | 30.998685300 | 19 | 1-K-03-C | 1.216927457 | 3 |
| 1-D-03-C | 11.506025795 | 7 | 1-K-03-D | 1.078227339 | 3 |
| 1-D-03-F | 9.468130092 | 12 | 1-K-03-F | 1.326059814 | 4 |

Notes: type of abiotic complex (ABC), e.g. 1-A-02-J: 1 – code of inclination, A – code of soil, 02 – code of climatic type, J – code of quaternary sediments

## Decision making process within the landscape-ecological plan

In ecologically rational use (development) of each area the limit – threshold value of the given area ought not to be violated. It is the highest acceptable value of load by human activity. It is necessary to conserve sustainable acceptable land use, in which the damage and degradation of natural resources and endangerment of ecological stability does not occur. Violation of the allowable border by any load causes different changes in the ecosystems which provoke environmental problems in the landscape, endangerment to damage of environmental quality. Limit (limit value) – is the upper (boundary) value – that can be characterized as a borderline between two states (levels) of ecosystem, when reversible phenomena change to irreversible ones.

Intensive attention is paid to identification of environmental limits because they take part in the decision making process of the proposal of functional land use (Miklós et al., 1986; Drdoš, Kozová, 1992 etc.). In the papers of foreign authors we meet with the creation of limits in environmental planning, solution of ecological carrying capacity, evaluation of

recreation areas etc. (Ortolano, 1984; Stankey et al., 1985; Lime, 1995 etc.). The mentioned methodological approaches we used also in the model area of Bratislava. In the decision making process we observed the following basic principles:

- to elaborate and conserve unique criteria of decision making for the whole area
- to select the most significant abiotic, biotic and socio-economic parametres entering into the decision making
- to prepare the list of activities and use for wich are searched the most suitable location in the model area
- to respect the area limitation according to landscape-ecological limits; biotic limits in comparison with abiotic and selected socio-economical ones become more significant within the frame of evaluation.

Landscape-ecological evaluation is the process of determination of suitability of land use for location of single social activities. There appears the confrontation of the demands of single activities on landscape-ecological conditions with existing landscape values. To the evaluation process enter:

- Landscape-ecological bases – a complex of unambigously defined analytical landscape-ecological bases represented by synthetical units – types. Types have their own real spatial expression in maps with different combination of natural and socio-economic landscape indices (e.g. abiotic complexes determining abiotic limits).
- Social demands – proposed activities and use – a complex of unambigously defined proposed social demands for the given area. For the model area of Bratislava we have proposed 7 main groups of activity and use: housing, home building, arable land, vineyards, orchards and gardens, summer recreation, winter recreation.
- Formation of landscape-ecological (abiotic, ecological and hygienic) limits.

In the evaluation process the degrees of suitability for proposed activities and use are attached to each established analytical and synthetical value of landscape element (numerical or oral) according to selected criteria. The same value of an element can get high suitability for one and simultaneously low suitability for another activity. For example great relief inclination is inaccesible for arable land, but for winter recreation (downhill run) it is accessible. This span of degrees of suitability for proposed activities and use are expressed as follows:

- **overlimited (limited, eliminated) value of landscape elements for proposed activities**
  0 – unsuitable
- **limit (threshold, boundary) value of landscape elements – "limit" for proposed activities**
  3 – conditionally suitable
- **underlimited (suitable) value of landscape elements for proposed activities**
  2 – medium suitable
  1 – suitable.

In the procedure of establishing the limit values is used the method of decision tables (schemes) to which are marked the degrees of suitability or limits. The values of single analytical landscape elements are compared with the presumptions of realization of proposed activities and use. In decision tables is obtained a survey which activities are and which one

are not limited in the given element or type. The last step is the transmission of the results of decision making process from tables into maps - it is the stage of proposal. The decision making sets out from certain criteria that can be summarized into the following points:

- not to endanger the quality of the environment, which is not on accessible level from many aspects
- to ensure the protection of natural resources, i.e. to exclude housing on natural resources of high quality
- to situate as much activities as it is possible to the area which ensure ecological functions
- to dislocate the activities in the areas where the conditions do not allowed it
- to maintain also social and cultural conventions in proposal
- to decide according to ecological criteria, i.e. to determine suitable areas beforehand e.g. for agricultural production and not to propose it as a building area
- to propose the areas enduring larger load for more intensive use etc.

*Abiotic limits*

Because the model area of Bratislava is very much built up, many proposals according to abiotic limitation remain only as proposals. This fact can show the harmony and disharmony of the present landscape structure with the proposed use. According to abiotic limits the following analytical parametres enter into the decision making process:

a) Determination of limit and non-limit values of use according to inclinations

Morphometric relief indices express the quantitative properties of the shape of land surface. They are a limiting factor of location of agricultural crops, terracing of plots, division of agricultural and forest soil, use of large mechanisms etc., but they are also the limiting factor for anthropic activities, e.g. for the proposal of multi-storied buildings, recreation activities etc. For certain use they are not limiting factors at all, e.g. for the proposal of forests, meadows etc. In the model area we have chosen inclination as the decisive factor. The example of determination of limits according to inclination is presented in Table 2.

For single activities and use we used the degrees of suitability in 4 categories: the first two categories present non-limit values, the third one is close to the limit value and the forth one strictly excluded the considered activity. Table 2 shows that lower inclinations are suitable for housing as well as for arable land. It means that in these areas different collisions – ecological problems will appear or are already now.

b) Determination of limit and non-limit values of use according to soils

Soils are exposed to intensive influence of natural as well as anthropic processes. Production and non-production soil functions predestine their priority use for foodstuff produc-

T a b l e 2. Limit and non-limit values of inclination for selected activities and use (partial abiotic limit)

| Inclination (1. code in type of abiotic complex) | Selected types and use | | | | | | |
|---|---|---|---|---|---|---|---|
| | housing | family houses | arable land | vineyards | orchards and gardens | summer recreation | winter recreation |
| < 1° | 1 | 2 | 1 | 3 | 1 | 1 | 0 |
| 1° – 3° | 1 | 1 | 1 | 2 | 1 | 1 | 0 |
| 3° – 7° | 2 | 1 | 2 | 1 | 2 | 1 | 0 |
| 7° – 12° | 0 | 3 | 0 | 2 | 0 | 1 | 2 |
| 12° – 17° | 0 | 0 | 0 | 3 | 0 | 1 | 1 |
| > 17° | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

tion. From this aspect we set out also in the determination of degrees of suitability for social demands. Soils with conserved production and non-production functions have been proposed for agricultural production. In Bratislava it is a specific problem, because a part of non-built up areas suitable also for different type of housing has the most suitable conditions for agricultural production.

c) Determination of limit and non-limit values of use according to climate types

In spite of that the model area of Bratislava is not large the influence of climate is great from the aspect of location of selected activities. This differentional factor is caused by the geomorphological configuration of the mountain range and lowland. This factor is very important for certain activities and use. For example wine growing needs much sunshine – it can be found mainly on the foothills of the Malé Karpaty Mts with southern exposition. This type of climate is suitable for summer recreation as well as for home building. In the final proposal e.g. of wine growing also other abiotic bases are decisive determining the most optimum area for a concrete use. From the aspect of suitability of climate for housing it can be stated that the climate of the area is favourable (but the aspect of wind and frog is absent).

d) Determination of limit and non-limit values of use according to geological ground

Geological ground is the last limiting factor within the types of the abiotic complex. This factor was evaluated from the viewpoint of engineering-geological suitability of foundation engineering, litological composition, genesis and basic chemisms, possible infiltration of pollutants etc.

e) Determination of limit and non-limit values of use according to types of abiotic complexes

Analytical abiotic indices according to which limits are created do not appeal to the landscape separately but synergetically. It means, that in the decision-taking about the ecologi-

cally optimum proposal we proceed according to single abiotic parameters, then according to complex abiotic limitation, i.e. according to all investigated abiotic parameters – according to abiotic complexes. Decision is carried out :

- in the decision table according to analytical indices – determination of limit values for proposed activities on the basis of analytical indices, this step is necessary for objective decision in the whole area (example in Table 2)
- in the decision table according to types ABC – determination of limit values for proposed activities on the basis of synthetical units – this is the main output of the decison making process – formation of complex abiotic limitation.

The created decision scheme is an important ground in which limit values are attached to the types of ABC, the degrees of suitability to existing landscape elements (their properties) in relation to the proposed activity are determined. In determination of the limit values certain principles are applied, and the degrees of suitability are recorded to the scheme according to:

- if all analytical indices from the types of ABC create suitable conditions for realization of the given activity ⇒ activity is proposed – nonlimited activities according to the types ABC (degree of suitability 1)
- if all analytical indices or at least one of the types ABC create the medium suitable conditions for realization of the given activity ⇒ activity is proposed – nonlimited activity according to the types ABC (degree of suitability 2)
- if all analytical indices at least one of the types ABC create conditionally suitable conditions for realization of the given activty ⇒ activity with limitation is proposed – limited activities according to the types ABK (degree of suitability 3)
- if all analytical indices or at least one of the types ABC create unsuitable conditions for realization of the given activity ⇒ activity is not proposed – excluded activities according to the types of ABC (degree of suitability 0).

In the decision table according to the types ABC we obtained a survey about the activities in the given types which are and are not limited. The features of the types ABC are relatively stable, therefore they ought to be respected but in the next phase this proposal has to be completed by ecological and hygienic limits.

*Ecological and hygienic limits*

Proposed activities according to the types ABC are only a basis for the proposal of ecologically optimum use. Ecological and hygienic limits enter into the decison making process in the next phase. The procedure of elaboration as well as the principles of decision-taking are the same as in the creation of abiotic limits.

From ecological limits the biotic complex composed by the elements of nature protection, territorial system of ecological stability – ecological network and natural resources (forests, water, soil) enters into the decision making process. In creation of ecological limits we set out from the following principles (Table 3, Fig. 2):

T a b l e 3. Suitability of land use for arable land according to abiotic and ecological limits

| Degrees of suitability of use according to abiotic limits | Ecological limits | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Without ecological limits | Protected water management area | PWMA, area with 2nd degree of nature protection and TSES | PWMA, area with 4th degree of nature protection and TSES | Protective belt of water resource | PBWR, area with 2nd degree of nature protection and TSES | PBWR, area with 4th degree of nature protection and TSES | TSES without nature protection | TSES, the rest of forests and forest land resource without nature protection | Area with 2nd degree of nature protection and TSES | Area with 4th and 5th degree of nature protection and TSES |
| Suitable | | | | | | | | | | | |
| Medium suitable | | | | | | | | | | | |
| Conditionally suitable | | | | | | | | | | | |
| Unsuitable | | | | | | | | | | | |

Notes: PWMA – Protected water management area, PBWR – Protective belt of water resource, TSES – Territorial system of ecological stability (ecological network). Colors mean concretely occurring combination in Fig. 2.

Degrees of suitability according to abiotic and ecological limits (presented in Fig. 3).

Suitable  Medium suitable  Conditionally suitable  Unsuitable

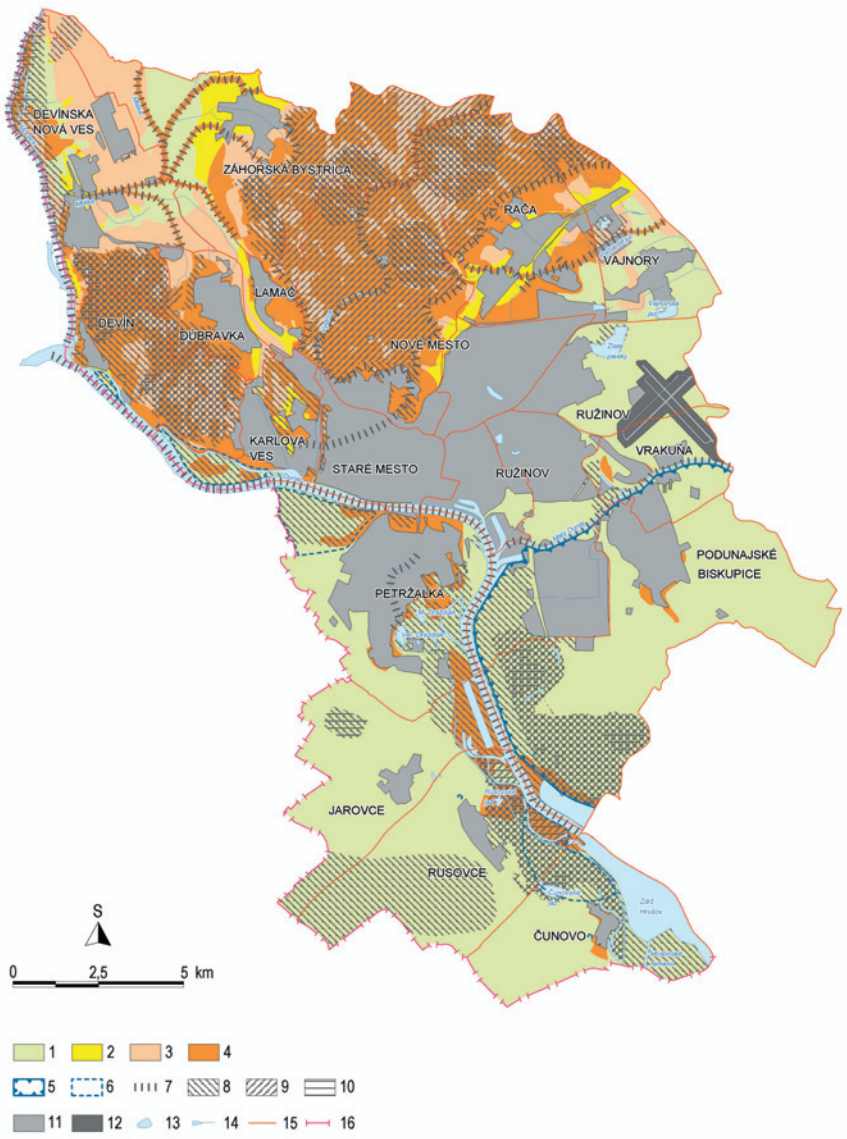


Fig. 2. Suitability of land use as arable land according to abiotic and ecological limits. Degrees of suitability according to abiotic limits: 1 – suitable area, 2 – medium suitable area, 3 – conditionally suitable area, 4 – unsuitable area; degrees of suitability according to ecological limits: 5 – conditionally suitable area (protected water management area), 6 – unsuitable area (protective belt of water resources), 7 – unsuitable area (elements of ecological network: biocorridor), 8 – unsuitable area (elements of ecological network: biocentre or other forest stand and forest land), 9 – unsuitable area (2nd degree of nature protection), 10 – unsuitable area (4th and 5th degree of nature protection). Unvaluated areas and other symbols: 11 – built up areas, 12 – airport, 13 – water planes, 14 – water courses, 15 – cadastral border, 16 – frontier (real combinations of abiotic and ecological limits are in Table 3).

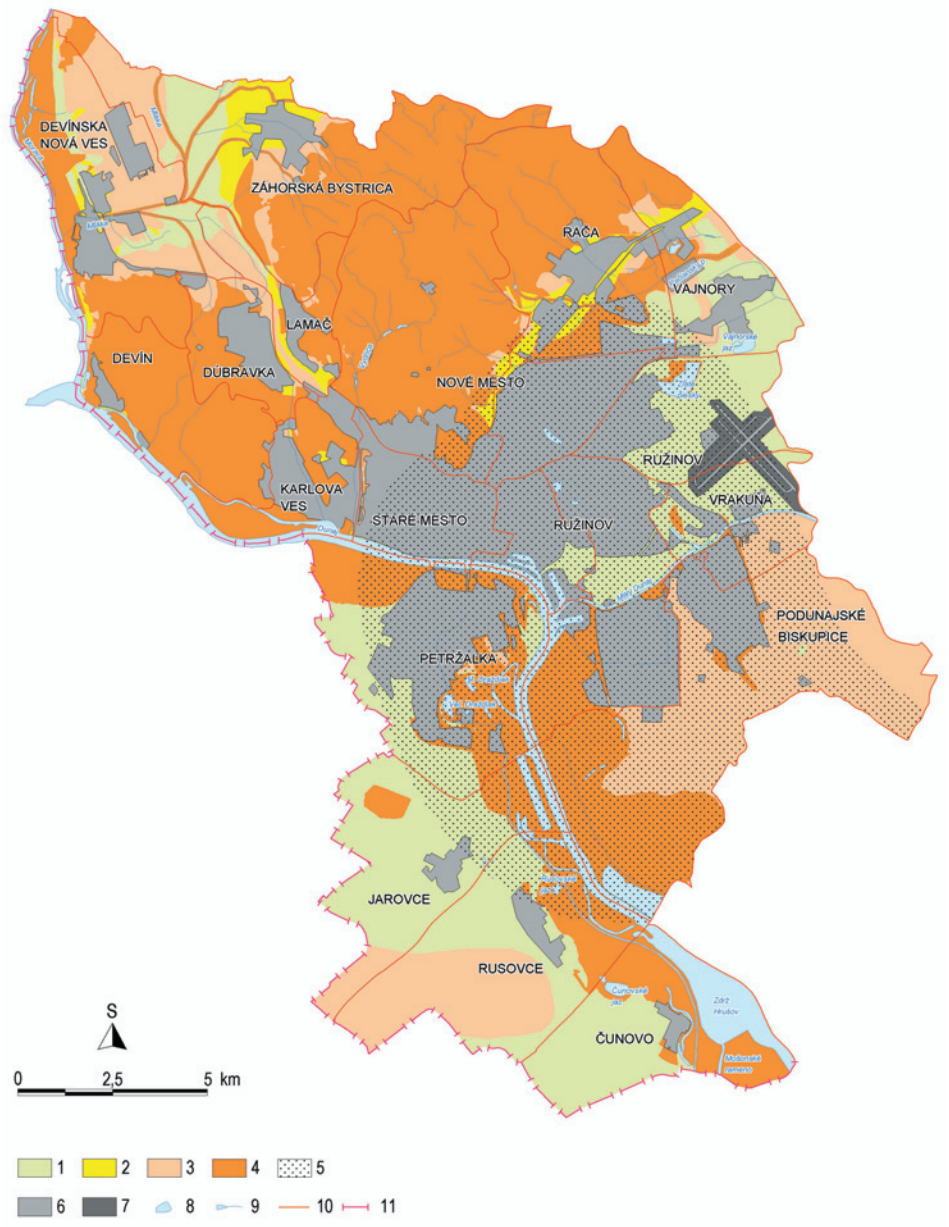


Fig. 3. Landscape-ecological suitability of land use for arable land. Degrees of suitability according to abiotic and ecological limits: 1 – suitable area, 2 – medium suitable area, 3 – conditionally suitable area, 4 – unsuitable area; degree of suitability according to hygienic limits: 5 – limited land use; unvaluated area and other symbols: 6 – built up areas, 7 – airport, 8 – water planes, 9 – courses, 10 – cadastral border, 11 – frontier.

- the degree of nature protection is higher the proposed land use is more limiting, at the highest degree of nature protection, i.e. for example agricultural use is discharged at 4th and 5th degree, but recreation is suitable on certain conditions
- almost all existing forest ecosystems had higher degree of area limitation
- the degree of limitation according to natural resources was obeyed by the degree of protection or utilization level of natural resource, a different rule was applied in water source protection and another at high quality of soil resources.

Ecological limits formed the decisive criteria in the proposals of ecologically optimum land use also in the areas where arable soil was proposed according to abiotic limits. The ecological limit is more important than abiotic suitability and so that appears a change of decision-taking, for example ecological limits excluded the area as arable land according to abiotic limits.

Ecological limits discharged or by certain way limit the proposal of such activities which could affect these protected areas. In the 5th and 4th degree of nature protection all economic activities (dwelling, urbanization, recreation, traffic, agriculture etc.) are excluded. In the 2nd degree of protection certain activities are only limited, i.e., they can be realized in acceptance of certain parameters. Special position has the Protected Landscape Area Dunajské luhy grassland, that is formed mainly by the areas of the 4th and 5th degree of nature protection and by the elements of TSES – this fact means an increased limitation. In water resource protection the limitation of use follows e.g. from the degree of protection zone. The 1st degree totally excluded the development of all socio-economical activities, because there is a toughened protection eliminating all economic activites and so the potential pollution of water resources is minimized.

Hygienic limits are another significant limits. In Bratislava especially polluted air and contaminated water and soil are the main decisive socio-economic limits. The fact that these grounds are changeable and sometimes heavily mapped and there are no reliable grounds caused, that they were considered only as significant limits. For example contaminated soil is a limiting factor for arable land where agricultural crops for direct consumation ought not be cultivated or heavily polluted air is a limiting to excluding limit for building of houses etc.

Ecological and hygienic limits significantly influenced the suitability of land use as arable land according to abiotic limits (procedure of limitation demonstrated in Table 3). This proposal was ascertained in certain sites and in some of them it was excluded mainly according to ecological limits, because hygienic limits do not exclude arable land, they only modify the possibilities of its further use (Fig. 3).

## Conclusion

The result of the landscape-ecological evaluation of the urbanized environment are alternative proposals for functional landscape division with the determination of degrees of suitability setting out from natural principles and relations among landscape components.

Soils with high production potential as well as suitable morphogenetic properties and favourable climate create the optimum presumptions for the development of arable land. The most extensive areas of the most productive soils are model carbonate chernozems in the vicinity of Rusovce and Čunovo as well as modal carbonate fluvisols between Jarovce and Petržalka, in the surroundings of Vrakuňa in the Podunajská nížina lowland. In the future it is necessary to preserve soils of highest production ability for agricultural production.

In the built up area the prevailing part of soils gradually lost almost every environmental functions and their restoration would be capital-intensive. Another example are forest soils where these soil functions have been conserved and so the area of forest soils is a natural potential also for agricultural use. From the abovementioned reason the built up area was excluded from the process of evaluation on contrary to the forest land resources.

For the proposed activities is selected a concrete area and in the next stage they can be compared and revaluated with the urban plan. Within urban ecosystems the proposal of optimum spatial location of selected agricultural use in the category of arable land was used as an example on the basis of abiotic, biotic and selected socio-economic limits.

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Krnáčová Z., Hrnčiarová T.: **Krajinnoekologické plánovanie – nástroj funkčnej optimalizácie územia (prípadová štúdia mesta Bratislava).**

Krajinnoekologické plánovanie ako nástroj ekologickej organizácie územia a trvalo udržateľného rozvoja je nevyhnutnou súčasťou priestorových plánovacích procesov. Účelom krajinnoekologických plánov je návrh ekologicky optimálneho priestorového usporiadania a funkčného využívania územia. Práve urbánne ekosystémy sú charakteristické tým, že sa na malej ploche koncentruje množstvo obyvateľov a vyskytuje sa veľa činností s rôznym vplyvom na životné prostredie a tak dochádza k nepredvídaným reakciám, ktoré narúšajú a znižujú kvalitu životného prostredia. V predkladanom príspevku uvádzame metodický postup tvorby a aplikácie abiotických, ekologických a vybraných hygienických limitov pri návrhu optimálneho priestorového umiestnenia vybraného poľnohospodárskeho využívania ornej pôdy v rámci mesta Bratislavy.