EKOLOGIJA. 2007. Vol. 53. No. 4. P. 19–24

Integral ecological approach to the concept of optimal landscape

Ričardas Skorupskas,

Paulius Kavaliauskas

*Vilnius University, M. K. Čiurlionio 21,
LT-03101 Vilnius, Lithuania
E-mail: ricardas.skorupskas@gf.vu.lt
paulius.kavaliauskas@gf.vu.lt*

A comprehensive, or integral, ecological approach combined with bio-psycho-socio-ecological and ergo-economical requirements to the environment now becomes the main necessity and way for of landscape optimization. Being very relative, the structure of society determines that the concept of optimization (optimal landscape) is instable in time. This is a result of many factors, especially geoecological determinativeness, perceptional comfortness, social conventionality and ergo-economic suitability.

A set of anthropo-ecological criteria determines different interpretations or of the optimal horizontal structure of landscape: ecological, perceptional, socioecological and ergo-economical. The most fundamental concept of optimal landscape ecology structure formulated in this paper is based on the universally accepted golden proportion principle which is functioning at various levels of spatial (natural and anthropogenic) structures.

Three geometrical indices of horizontal structure were defined for landscape optimality that served as a base to derive and substantiate the following indices of the qualitatively optimal level of landscape ecological structure: 1) naturalness, 2) natural ecotonness, 3) technogenic ecotonness. Regionalization by landscape ecological optimality of the Lithuanian spatial structure shows that the optimality levels in new territorial units through value combinations of its horizontal structure indices can serve as a base for applying the same land management procedures for similar territorial units.

Key words: integral ecological approach, optimal landscape, landscape ecological structure, land management

INTRODUCTION

The landscape is exposed to the growing anthropogenic pressure due to the increasing technical potential of society and the deepening crisis of human values, which affect the attitude to the natural environment as a source of material welfare and a storehouse but not as an equivalent component of the environment determining the quality of life.

Intensive human activity makes the landscape more structurally diverse and complex, adding a number of anthropogenic components to the natural ones that are already functioning. Local territorial units, on the contrary, show a significant reduction of biodiversity, resulting in the degradation of stability and resistance of landscape components.

Therefore, one of the principal tasks today is to determine an optimal proportion between natural and anthropogenic (unnatural) parts in a territory according to the conception of sustainable development, seeking to ensure a stable development of both landscape components, – progressive development in one of the parts and close to progressive development or at least stability in the other (Naveh, Liebermann, 1990; Butterfield et al., 2006).

Today's landscape is under growing influence of the intensive development of human activities. The problem of environmental optimization became relevant more than half a century ago with starting extensive environmental reclamation works. In fact, the approach to environmental optimization in that period was too technocratic. In the last decade when the conception of sustainable development has become more important and relevant, the process of landscape optimization has gained a new orientation. Realizing today's main objectives of landscape optimization related to the problem of territorial symbiosis between human and natural environment determines a harmonious functioning of all structural components of the landscape. To neglect this problem would mean a risk of digression both to society and man, as well as to in general natural environmental components, because the quality of life of man (society) depends significantly on the quality of the natural environment as a result of its stability and resistance (Steiner, 2002). Therefore, to ensure a territorial balance between society and the natural environment is an important issue of a harmonious existence and functioning of separate integrated anthropo-ecosystems.

Questions related to landscape optimality and analysed herein are important not only for a narrow circle of experts; they should be actualized as problems of national importance, because the social-economic development of each country is closely related not only to the scientific-technical but also to the ecologic progress. A comprehensive or integral anthropo-oriented ecological approach encompassing the bioecological, psychoecological, socioecological and ergo-economical requirements to the environment (Каваляускас, 1989) now becomes a pressing necessity and a constructive way for landscape optimization. It is purposeful to take a wider look at the management of cultural landscape, which seems to be a very topical, many-sided and negotiable issue.

PREREQUISITES FOR THE CONCEPT OF OPTIMAL LANDSCAPE

When landscape optimization is treated as a process which is constantly getting more complex, the following two qualitatively different optimization levels are distinguished: componential and integral.

The componential level is the first and basically not yet perfect stage of landscape optimization (Skorupskas, 2001), related to determination of the optimal structure of individual landscape components. Whereas the systemic approach to natural and anthropogenic landscape components is a basis for the integral optimization level, and these components are treated as inseparable constituents of landscape structure interrelated by complex structural links. It is the integration of anthropo-ecological criteria into the landscape optimization process that shows an equivalent treatment of its naturalization and humanization principles (Kavaliauskas, 1992).

The need for landscape optimization emerged in society with a very instable structure, and the concept determining society needs is certainly volatile in time. A system of various factors determining changes of the optimal landscape conception is provided in this paper (Fig. 1) to show the internal content of the factor set forming this conception indirectly (through an individual or society). The objectivity of a concept is basically determined by the fundamental macrofactor – landscape ecological determinativeness, while the subjectivity implies social conventionality, perceptional comfort and ergo-economic suitability.

Optimal landscape as the main result of the land management process is a possibility and also a purpose of economically strong countries. Striving for this purpose and the adequacy of the results of these efforts are increasing proportionally to the economic growth. In an ideal territorial social system, there is usually the following arrangement of society priorities influenced by the level of socio-economic development: physiologic, consumer, spiritual and environmental needs.

The development and perception of the concept of optimal (good, favourable) landscape depend on a complex of cultural trends, confessional orientation, political attitudes, values, priorities and other human factors (attitudes towards each separate landscape element) of society. Also, the concept of optimal landscape is developing at the current level of knowledge about the system to be optimized. Qualitatively new information concerning landscape components can allow changes in the optimization process and optimality conception itself, determined by a new highlighting and reevaluation of the functioning regularities or internal structural features of individual landscape elements. Society cannot exist in an environment without a developed technical potential; a higher level of technical development should be more advantageous to natural systems due to a more rational and effective use of natural resources and isolation of anthropogenic energy from natural structures.

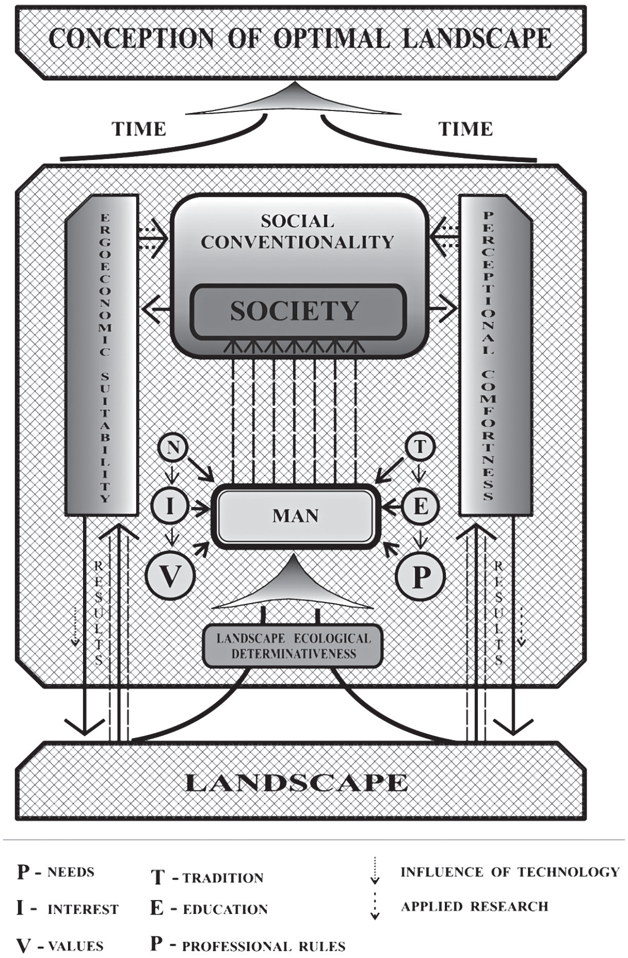

Fig. 1. Factors of integral ecological optimality of the landscape

The starting point in the landscape structure optimization system provided in this concept Human as the most unpredictable and labile component as well as the manager of landscape's anthropo-ecosystems, permanently influenced by a number of social factors like traditions, education, professional attitudes, needs, interests, values.

Search for optimal alternatives is a readily achievable task only under trivial conditions. However, it should be stated that exactly this way has been so far used to solve the problem of landscape optimality. Efforts to simplify the optimality problem and to solve it using only one (seemingly the main) or several landscape content features by underestimating the equivalent importance of all environmental structure components constitute a serious obstruction for constructive and objective land management. Therefore, simplification of landscape optimization solutions should be related only to a deep cognition of the system to be optimized.

The growing complexity and spatial transformation treated as the development of one part (anthropogenic) of landscape leads to digression of another (natural) part. The structure of each part of natural landscape was developed during a long-time evolution, checking every possible option and selecting the most advantageous ones. Its core is accumulation and connection of an element and material complex. Whereas the development of the second landscape factor, society, which makes a transforming impact on its environment, is more related to generation of entropy flows leading to more and more intensive changes in the environment. Unfortunately, society commonly evolves not by selecting most favourable development options but by cognition of wrong options. An option is acknowledged as unsuitable for development only when its negative impact on the social environment is encountered, mostly indirectly, through changes in the natural environment.

It should be stated that optimization of the two groups of contrariwise developing landscape components (natural and anthropogenic) is generally a very complicated and paradoxical question (Antrop, 2005). The essence of the optimization paradox is a rational compromise solution which establishes minimum conditions to satisfy the vital needs of the solution process participants, but it doesn't guarantee their progressive development.

On the other hand, this deadlock to which the optimization of landscape structure parts is coming can even be useful for them, because any restrictions of structural development, both natural and artificial, give a strong impulse for development. It is likely, under conditions of spatial restriction conflict, that it will lead to alternative solutions, structural diversity and new relations required for the development (Величко, 1993, Tiknius, 2002).

Optimal conditions can exist only for one part of the landscape system, while the dynamic balance level of both parts is expedient to be considered as suboptimal. Then, only the suboptimal level is possible between society and nature, and it should be treated as a basis of the sparing management of nature.

Landscape structure optimization stages must be identified and evaluated in respect of object (nature) and subject (society). This better reflects the real situation of relations between man and his environment. It would be rational to look at it philosophically, striving to find the truth, but not a truth oriented only towards man or nature, but a general comprehensive ecological truth that is inseparable from the coexistence of man and nature.

THE STRUCTURES OF OPTIMAL LANDSCAPE

Assumptions of an anthropo-ecologically optimal horizontal landscape structure could be formulated by a complex of bionomic, psychonomic, socionomic, ergonomic and economic criteria and indices (Kavaliauskas, 1992). The set of these criteria determines some different interpretations or kinds of the optimal horizontal landscape structure: 1) optimal landscape ecological structure, 2) optimal perceptional (psycho-ecological) structure, 3) optimal socioecological structure and 4) optimal ergo-economical structure.

Fundamental among them is the **optimal landscape ecological structure** based on the polarization principle (Tiknius, 2002; Родоман, 2002), in which the horizontal components are grouped into two categories – natural, especially bioproductional, and artificial, and the percentage they should cover in an area is determined.

Firstly, it should be noted that the main components of the landscape system (natural and anthropogenic) differ in their activity, changeability or adaptability, therefore, areas they cover in the landscape should be different in size, because the activity (potential) of one landscape component should be compensated by the size of another (passive) component, i. e. the proportion between the *active* and *passive* parts of landscape should be increased at the expense of the latter. Consequently, the principle of dynamic symmetry (asymmetric symmetry) serves very well in this case to express activity of the landscape. This principle defines motion, development, growing, and rhythm. It covers landscape features and the fluctuation of component areas or segments at the level of golden proportion values. According to the golden proportion, active and passive components of the landscape should cover about 38% and 62% of the whole area respectively. This ratio reflects the stabilization (optimality) level in territorial structures like geobiosystems.

The active part is distinguished by an intensive and active expression of physical, chemical and biological processes, lower stability and, most importantly, by a more extreme character of expression with a more diverse set of phenomena and processes. The active part of an area can be defined as a territorial system its that destabilizes the landscape structure through active processes.

The passive part, which performs compensatory functions, is relatively more stable and shows a considerably less variety of phenomena. Processes occurring in the passive part of an area are less intensive. They perform an important compensatory function by smoothing or fully neutralizing the results of processes in the active part.

Application of the *golden proportion principle* to form the conception of optimal geoecological landscape structure can be based on examples from natural global structures like the ratio between areas of continental (195–200 million km^2, or 38%) and oceanic (310–315 million km^2, or 62%) (Николаев, 2003). Another fundamental example is Earth's crust, or the percentage of folded (mountains – 75 million km^2) and platform areas (plains – 120 million km^2).

When identifying active and passive parts in a territory, one of the most important problems is determination of area naturalness level, which is solved in this work by providing weighted coefficients for areas with a preserved bioproduction function according to their external conformity to forest as an area with primary naturalness. Cultivated areas have a rather lower naturalness. In this case, absence of forest can be compensated by subnatural areas to perform the bioproduction function.

The other versions of the optimal landscape structure – **perceptional, socioecological and economical** – represent mostly a subject(society)-oriented approach and are distinguished by a changed sense of optimality, especially the sets and value of its indices. These kinds of optimality are not analysed in the paper.

OPTIMALITY OF LANDSCAPE ECOLOGICAL STRUCTURE OF LITHUANIAN TERRITORY

Realization of the idea of landscape ecological optimality of a territorial structure is related to defining the parameters to describe the optimality level. Landscape ecology operating with an abundance of structural metric study indices, such as patch richness, patch size, shape, number and density, area proportion, radius of gyration, contagion, edge contrast, nearest neighbour distance, proximity and others (Leitao et al., 2006). It can be stated that the landscape structure itself is the source of optimality parameters. Therefore, cognition of landscape components with their interrelations and processes should allow a significantly simplified determination of horizontal geometric structure parameters important to shape the parameters describing the optimality level of a landscape structure.

Each of the landscape mosaic components (forest, swamp, etc.) functioning in 3D space is closely interacting with the environment both in the vertical and horizontal directions. It should be noted that ecotones (in this paper *contact zones*) can exist not only in a horizontal line (between adjacent components of the horizontal landscape structure), but also spatially, i. e. within separate areas in the form of individual vertical surfaces (planes) or their groups.

Every component of a landscape structure includes two substance flows with different expression strength, origination and content, which are in this case considered as directions of interaction between energy and substances or as axes interconnecting landscape components (biosphere with atmosphere, forest with field, etc.).

Vertical connections are related to the ability of ecologically active natural or relatively natural territorial landscape structures (areas that perform the bio-production function) to assimilate solar energy and transform it into a biologically active substance (bio-production) which then participates in vital biogeochemical circulation processes of the landscape, whereas these processes assimilate pollution and neutralize anthropogenic loads.

For the expression of vertical substance flows, it is very important that bio-production areas are natural and integral, with conditions and processes typical of a particular geo-biological complex. In this case, we can even talk about a minimal area unit with typical conditions for a natural landscape component.

Horizontal substance flows occur between adjacent landscape components – geosystems or their groups. Horizontal flows mean an ability of an edge of natural territorial biocomplex to influence the behaviour of an adjacent bio-complex, mostly in a positive way, by transforming its typical properties, and speaking about technoecotones, this is an ability of a bio-contour to neutralize anthropogenic impacts. These flows should be purposefully linked to the effect of a bio-contour "edge" and this in turn to the landscape ecological conception of ecotone as contact zone.

There is evidence to suggest that the more active substance flows and more effective energy assimilation as a result of vertical connections, the more energy returns in the horizontal direction. It is useful to concentrate around two geometrical structure features of the landscape that define the optimality level of a landscape structure.

The main index of the horizontal landscape structure (Forman, 1990, 1995) area that defines its internal contour properties is *naturalness* – percentage ratio of natural and technogenic landscape contour area sums. The point of reference is conformity of the ratio to the golden proportion (62% and 38%, respectively). The naturalness is evaluated as an area surface roughness degree (thickness of vegetation cover according to local hydro-climatic conditions), i. e. as conformity to the primary roughness degree. The article presents the result of evaluating the optimality of Lithuanian territory according to the weighted index of naturalness (Fig. 2).

The linear horizontal landscape structure defines external properties of contour edge and can be described by two different indices: 1*) natural ecotonness* – the size of active impact zones of natural contour contacts (%) and 2) *technogenic ecotonness* – the

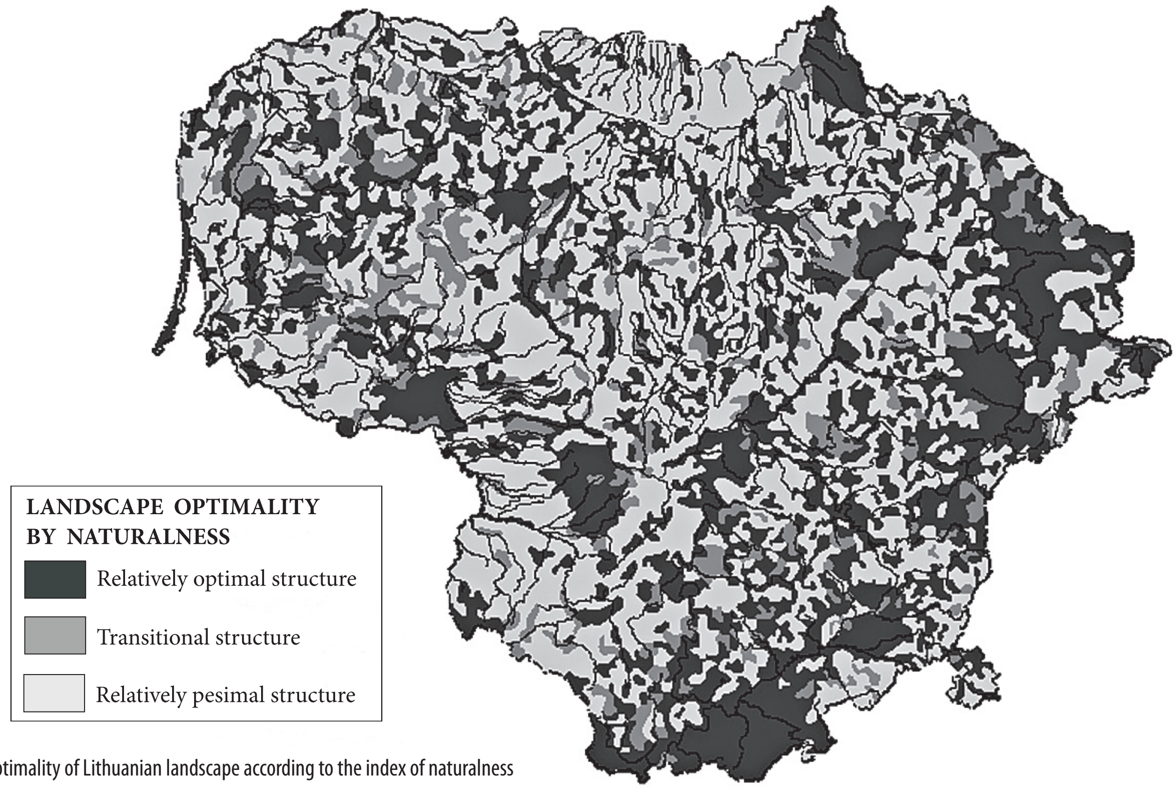

Fig. 2. The optimality of Lithuanian landscape according to the index of naturalness

size of active impact zones of technogenic and natural contour contacts (%).

Naturalness of a landscape component is in this case related to surface roughness. The more natural is the surface and close to its primary state, less anthropogenically impacted or transformed, the rougher it is under hydro-climatic conditions in Lithuania. The roughness level of a territorial unit is caused by thickness of the vegetation cover. A rough surface minimizes the impact of various processes.

When calculating the parameter of landscape naturalness, areas with non-primary naturalness (roughness degree) are equated to forest bio-systems with maximal roughness under Lithuanian conditions by adding an appropriate coefficient. The main components of a horizontal landscape structure are listed in this paper with appropriate value coefficients. It should be noted that this segmentation is relative and valid only if areas are viewed outwardly, i. e. without detailing their internal properties.

The parameter of ecotonness is calculated not using the length of ecotones, but as a percentage of ecotonised areas with an active impact (sectors with a particular width where the impact of the adjacent contour is appreciable) in a given territory. In this case, ecotonness is considered not traditionally, but as the size of a zone with an active impact of the adjacent bio-productive contours or a percentage from the entire area of a given territorial unit (in our case, this is the area percentage of a given statistical grid).

In order to ascribe active impact zones to particular areas, they were grouped by similarity of features and landscape ecological potential in the descending order of their ecological potential – forest, water bodies, swamps, grasslands and cultivated areas. The integration of less important contours allowed avoiding analysis of a great number of additional contact variants.

Finally, ten variants of bio-contour contacts were identified based on different inner potentials to define zones with an active impact which break in the adjacent area contour. Every area contour has its own active zone in an adjacent territorial unit, and this unit has in turn its own impact zone on the first contour. The width of the zone is mostly evaluated by changes of separate meteorological, sometimes biological parameters in the contact zone. Contact impact zones of adjacent areas are summed up to give an active impact zone with some width defining a contact variant of area contours. Summing up active impact zones of all bio-contour contact variants allows calculating the percentage of active impact zones in a given territory.

The techno-ecotonness index is based on evaluating the active impact zones of technogenic contours or, in other words, bio-contour resistance zones. The more active a technogenic contour, the wider its impact zone on an adjacent natural contour. Among bio-contour groups arranged in the descending order of resistance and technogenic contour groups (settlements, roads and other technogenic objects) arranged in the descending order of activity, there are 15 possible contact variants with active impact zones of some width that are identified only for technogenic contours. The width of an active impact zone is evaluated according to the ratio between activity of technogenic contour and resistance of natural contour in contact variants.

The indices describing the optimality of a landscape structure could be used for the regionalization of ecological optimality of the Lithuanian landscape structure in a logically correct taxonomy. The boundaries of the largest typological units – regions of landscape optimality – must be determined by the distribution of qualimetric complexes (joined types by descending optimality level) of natural ecotonness and the naturalness of the horizontal landscape structure. The complementary dividing of these regions gives an opportunity to recognize districts of landscape ecological optimality.

Preliminary eighteen structural landscape regions and more than hundred districts with different levels of integrated landscape ecological optimality and different requirements to land management procedures were determined in Lithuania. Areas with mostly optimal ecological landscape structure are situated in East highlands, South Lithuania and the Curonian spit, and those moderately optimal lie in the central part of West Lithuania. Hereupon North (Žiemgala) and South-West (Suvalkija) plains were recognized as regions with a landscape of ecologically most blasted territorial structure. This scheme of regionalization will be improved and detailed in the nearest future, so it is not presented in here in more detail.

Unfortunately, the optimality of Lithuanian landscape structure by other anthropo-ecological research aspects – psycho-ecological, socio-ecological, ergo-economical – is practically only on the discussion level and has no adequate methodology, a clear set of criteria or particular implications. These problems still remain to be very important tasks for further investigations and optimization of the whole system of land management.

CONCLUSIONS

1. The problem of landscape structure optimality is a very important interest and research area of many sciences and therefore is extensively analysed both in Lithuania and in other countries, using a great variety of research aspects and approaches. A comprehensive ecological approach integrating the bio-psycho-socio-ecological and ergo-economical requirements to the environment now becomes the pressing necessity and a way for landscape optimization.

2. Being very relative, the structure of society determines that the concept of optimization results (optimal landscape) is instable in time. This is a result of many factors, especially geoecological determinativeness, perceptional comfort, social conventionality and ergo-economic suitability.

3. Having cardinally different development principles and tasks, the main componential parts of the landscape, man and nature, are not able to form an anthropo-ecologically optimal landscape in their coexistence. Only the balanced (suboptimum) level is possible in these mutual relationships, and although it is not able to ensure a progressive development of any qualitative landscape part, in case of inner conflict under stagnation conditions it can lead to alternative solutions that can be beneficial for the co-evolutionary development and formation of optimal landscape.

4. The set of integral ecological criteria determines some different interpretations or kinds of the optimal horizontal landscape structure: 1) optimal landscape ecological structure, 2) optimal perceptional structure, 2) optimal socio-ecological structure and 3) optimal ergo-economical structure. Most fundamental among them is optimal landscape ecological structure based on the natural-artificial polarization principle.

5. The concept of optimal landscape ecological structure, formulated in this paper, is based on the universally accepted golden proportion principle which is functioning at various levels of active (anthropogenic) and passive (natural) structures. Following this principle, active and passive components of the landscape structure should cover about 38% and 62%, respectively.

6. Based on the principles of substance flow dynamics, three geometrical features of the horizontal structure (areal and linear) were defined for landscape optimality, which served as a basis for deriving and substantiating the following qualitative indices of the optimal level of landscape structure: 1) naturalness, 2) natural ecotonness, 3) technogenic ecotonness.

7. A tentative regionalization of Lithuanian territory by landscape ecological optimality shows optimality levels in new territorial units through value combinations of their horizontal structure indices and can serve as a basis for applying the same land management procedures to similar territorial units.

Received 24 April 2007
Accepted 26 September 2007

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OPTIMALAUS KRAŠTOVAIZDŽIO KONCEPCIJA KOMPLEKSINIU EKOLOGINIU POŽIŪRIU

Santrauka

Kraštovaizdžio struktūros optimalumo problema, būdama itin aktualı daugelio mokslo krypčių interesų ir tyrimų sritimi, yra nagrinėtina įvairiais aspektais bei požiūriais, tarp kurių ypač svarbus yra kompleksinis ekologinis požiūris, integruojantis bioekologinius, psichoekologinius, socioekologinius bei ergoekonominius reikalavimus aplinkai. Šiuo pagrindu formuojama į žmogų orientuota kraštovaizdžio optimalumo koncepcija turi įvertinti visuomenės raidą ir optimalaus kraštovaizdžio sampratos nepastovumą, kuriam įtakos turi kraštovaizdinis ekologinis apibrėžtumas, percepcinis komfortiškumas, socialinis sąlygotumas bei ergoekonominis tinkamumas.

Pagrindiniai kraštovaizdžio elementai – gamta ir žmogus – turėdami kardinaliai skirtingus raidos principus ir tikslus, bendrame sambūvyje negali formuoti antropoekologiniu požiūriu visiškai optimalaus kraštovaizdžio, galima tik dinaminė pusiausvyra (suboptimumas). Antropoekologiniai kriterijai lemia keleto skirtingų horizontaliosios kraštovaizdžio struktūros optimalumo interpretacijų arba rūšių: kraštovaizdinę ekologinę, percepcinę, socialinę bei ergoekonominę, kurių fundamentaliausias ir santykinai stabiliausias yra kraštovaizdinis ekologinis teritorijos optimalumas. Jis rekomenduojamas remti visuotinai pripažįstamu ir įvairaus rango erdvinėse gamtinėse bei antropogeninėse struktūrose funkcionuojančiu aukso pjūvio santykiu, pagal kurį kraštovaizdį formuojantys aktyvusis ir pasyvusis komponentai teritorijoje turėtų sudaryti atitinkamai apie 38 ir 62%. Šis natūralios ir antropogeninės teritorijos dalies santykis turėtų užtikrinti žmogaus ir gamtos teritorinės simbiozės būseną.

Remiantis substancinių srautų dinamikos principais išskirti trys kraštovaizdžio optimalumą nusakantys, horizontaliosios jo struktūros geometriniai rodikliai (plotiniai ir linijiniai): 1) natūralumas, 2) gamtinis ekotoniškumas, 3) technogeninis ekotoniškumas. Pagal juos atliekamas kompleksinis Lietuvos kraštovaizdžio struktūros optimalumo rajonavimas išskiria skirtingo kraštovaizdinio ekologinio optimalumo arealus, kuriems turėtų būti taikomos ir skirtingos kraštotvarkinių priemonių sistemos.

Raktažodžiai: optimalus kraštovaizdis, kompleksinis ekologinis požiūris, kraštovaizdinė ekologinė struktūra, kraštotvarka