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EXPERIENCE ANALYSIS AND SAMPLE DISTRIBUTION PROBLEMS IN LOCAL LEVEL LANDSCAPE MONITORING

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Abstract. *After summarizing experience of various countries in the field of landscape monitoring, it appears that the real changes of landscape have to be observed in a large scale (not smaller than 1:10,000) in order to avoid generalization of small landscape elements. Usually there are several levels of distributing the places of monitoring: 1) the level of sample area, when monitor territories are stratified by landscape types; 2) the level of investigation site that is distinguished inside the sample area for the more detailed research; 3) the level of transect or field investigation site, sometimes created in order to multiply the statistical data for some special aspect of monitoring. The paper offers an original method of distributing the landscape sample areas in Lithuanian territory, differing from most methods based on random choose of sample areas though thorough analysis of the analogous methods abroad was performed.*

Keywords: *landscape monitoring, sample areas, best representation principle, land cover structure, natural landscape types.*

Introduction

Landscape is a result of interaction between many natural processes and functional interests influencing use and protection of territory, it's a creation of natural forces and society's land management efforts. Current Lithuanian landscape contains reflections of various past social-economical reforms recorded in landscape mosaics and land use structure. Especially sudden as seen from our modern perspective, appears landscape structure changes that have taken place in Lithuania after regaining the Independence and after approving certain programmes of land restitution. The latter stimulated fragmentation of owned land, bringing our country somewhat back to the interwar period, only with the traces of soviet land management and signs of some new elements in our landscape. Such a situation requires objective and scientifically grounded monitoring of landscape state and spatial structural change especially seeking to ensure sustainable formation of landscape.

In order to ensure correctness of data collection for landscape state and spatial structure change, it is important to have a methodology that could represent landscape changes in the main landscape types and could generate a reliable basis for comparison of Lithuanian landscape change with the other countries' respective data.

In Lithuania, landscape structure analysis was being performed mostly in national and local levels, as well as in several areas of special interest like coastal, karst region, and protected areas. For national and regional level landscape change fixation a land cover data, such as CORINE (scale 1: 100.000) was used.

However, at the local level Lithuanian experience quite less, where the aerial photographs (giving images in scale of 1:10.000 or larger) should be used as a basis, complemented by specific local field investigations in linear transects. These change fixations could be highly valuable for assessment of landscape stability and for basing ecological optimisation means, as well as legal regulations of territory use.

Methods

A study of experience of landscape monitoring in other European countries was conducted in order to offer and adapt a methodology of landscape spatial structure changes in local level for Lithuania. Attention was focused on the selection of sample areas, monitoring indicators and data collection methodology.

It is notable, that some European countries like UK, Sweden, Denmark, Austria, Estonia, Finland have much deeper and longer experience in landscape monitoring, having started their legally approved activities as early as in 80s or even earlier as in case of Denmark where the programme of the monitoring of the smaller biotopes was initiated even in late 70s [1].

Problem of sample area selection. Most of mentioned countries in their landscape monitoring systems do not distinguish national, regional and local levels. On other hand, every country has its own point of view how to implement their respective landscape monitoring programme, following the attitude towards landscape admitted in that country, the depth and character of landscape knowledge, research traditions and technological equipment. Western countries possess more ecosystemic attitude towards landscape, therefore, they are strongly investigating biodiversity of landscapes, or particular species, that serve as indicators [2,3]. Quite often for such a kind of monitoring the elements that indirectly reflect the biodiversity spread are used, namely land cover. It is the landscape element that reveals the main aspects of human influence to landscape, therefore this indicator fits well in Lithuanian case as well, especially because here the prevalent concept of landscape is more morphological than bioecological.

Important characteristic of landscape monitoring is the necessity of sufficient technological facilities and mathematical process of data, as well as maximum objectivity of monitoring. Usually there are several hierarchical levels in the monitoring system, because selected sample areas that are wider, like buffer areas, contain one or several sites of investigation where data is collected in much detailed level. Sample area is usually related to the representation of some landscape or habitat type, whereas site that is inside it is a main feeder of data in local level. In this sampling process there can be several variations in different countries, sometimes appearing even lower level of monitoring in case it is needed to collect more data, namely field data collection site or transect.

In national monitoring programme of Sweden (in 2003) 500 randomly selected sample areas were defined in three main landscape types: 1) agrarian territories, 2) wetlands, and 3) northern mountainous region. Size of each sample area is 5x5 km, but inside it there was a smaller site of intensive monitoring distinguished [4].

Similarly, but proportionally less (100) samples were selected according to the Austrian landscape monitoring programme's sub-programme SINUS (1996-2000), the size being 5x5 km of each. 80 sample areas were selected in eight agrarian landscape classes, differentiated according to cultural type, relief, geology. Each landscape type was represented by 10 sample areas distributed in the territory in random way. The other 20 sample areas of the same size were selected subjectively in areas of the greatest interest. In every sample area, were distinguished two sites of detailed monitoring (1x1 km each) [5, 6].

There are 58 landscape types in four regions monitored in Finland using sample areas selected one in each type. Each sample area, being of 1x1 km in size was divided into four parts in order to enlarge statistical volume, and besides that, contained 20 transects of 50 m in length [7]. Norway created its own methodology dividing the whole country by 18x18 km quadrangles, 1000 sample areas selected systemically within them. This monitoring system was matched with already functioning agrarian landscape monitoring programme 3Q [7].

Estonian experience differs from the mentioned countries by methodology of selecting areas for landscape monitoring. According to the landscape monitoring sub-programme of Environment monitoring programme, approved in 1996, 6 protected areas were selected with

3 km wide buffer zones. Thus landscape monitoring was conducted both inside and outside of protected areas, additionally with field observations in 84 sites. Landscape monitoring covers about 10% of Estonian territory.

In 1995 German Federal Nature protection agency created and tested the system of ecological area sampling, according to which 1x1 km size samples were selected in the whole country stratified by land classes and land cover types. In later stages, inside of these sample areas, smaller sites of observation are selected with the purpose of recording plants and animals in the biotope.

Denmark can boast with the quite early (started in late 70s) programme of smaller biotopes, having 32 sample areas of 2x2 km size, where detailed investigations are performed [10].

British landscape monitoring system being technically strong represents landscapes of the country in detail, their specialists indicate some important points for successful monitoring: 1) clearly defined observation territories, 2) objectivity in sample area selection, 3) representation of landscape, 4) equal and unchangeable size of sample areas. Besides that, it is important that field observations in landscape monitoring must not take much time so that the fixation of all the sites was taken with the least difference in time. Successful monitoring includes optimal staff and equipment transfer, or generally, logistics, as well as ensured quality control and data reliability [7].

Problem of indicators and data collection methodology. In most of mentioned countries, landscape monitoring is related to the collection of information about biological constituents, but alternatively there can be other indicators more related to the culture influence on landscape structure, like indicators in already mentioned Sweden programme such as land cover, lengths of linear elements, density of point objects, frequency of indicative or key species, indexes of captured insects' abundance, proportions of various landscape elements (species, vegetation types, tree crowns) [4].

Austrian SINUS landscape monitoring in 1x1 km sites includes indicators like land use, patch origin, defined matrix-patch model, hemerobiotic state and species richness. Austrian project BINKL (1998-2001) was devoted to distinguish indicative species of organisms that could be applied in describing changes in different agrarian landscape classes [7].

In Finland's 58 landscape sample areas, monitoring indicators are related to landscape structure changes and evaluation of captured insects species diversity. Norwegian 3Q programme's monitoring indicators are numerous and belong to several groups like landscape spatial structure (including patch type area and occupied part, fragmentation, diversity and heterogeneity indexes, terrestrial and water bodies boundaries indexes, urbanization density, etc.), spatial structure of agricultural lands (land use types, fragmentation indexes, field shape, field boundaries indexes, point objects indexes), biodiversity, evaluated by Shanon diversity index, cultural heritage (historical buildings, cultural monuments and sites, historical boundaries, roads and paths, and their indexes), connectivity indexes, as well as data on noise near roads, etc [7]. Estonian landscape monitoring programme comprise two main groups of landscape diversity indicators, namely measured (area statistics) and estimated like boundary neighbourhood indexes, diversity metrics [8, 9].

Results and discussion on new methodology

In the process of creation of Lithuanian landscape monitoring system, there are the same tasks raised like sample area number and location selection, indicator system creation, data collection periodicity.

A distinctive feature of Lithuanian landscape monitoring system that was offered for Environment protection agency under Ministry of Environment of Lithuanian Republic is the principle of representativity instead of random selection method. The optimal number of sample areas for the country like Lithuania (somewhat smaller than Austria) was chosen 100,

the size being of 2.5 km^2 (~1.5x1.5 km). The representation principle implied that the sample areas were distributed among main natural landscape types proportionally to the area occupied by these types. Proportionality was corrected in a way that unique and small area occupying landscape types (spit, delta) received greater weight coefficient determining number of sample areas, than the most popular landscape types, like clayey plains or morainic hills (Table 1).

Table 1.

Landscape monitoring sample area distribution in the main natural landscape types of Lithuania

No	Natural landscape types	Represented area (total area of Lithuania is ~65300 km^2), km^2	Part of Lithuanian territory, %.	Number of attributed sample areas (direct proportion)	Number of attributed sample areas (corrected proportion)
A	**B**	**E**	**F**	**G**	**H**
1.	Clayey plains	23862.4	36.10	42	22
2.	Clayey downy plains	11002.5	16.64	19	17
3.	Morainic hills	9974.4	15.09	17	16
4.	Sandy plains	5527.3	8.36	10	13
5.	Valleys	3966.6	6.00	7	11
6.	Lake terrains	2535.1	3.83	4	9
7.	Spit	101.4	0.15	0	5
8.	Delta valley and delta	238.4	0.36	0	4
9.	Sandy coastal plain	189.1	0.29	0	3
	Total	**57397.2**	**86.83**	**100**	**100**

Particular locations of sample areas in the destined for them landscape types were selected once again by application of representation principle, not a random generation of coordinates, that is a popular way in other countries'monitoring systems to achieve objectivity of location selection. In our case, representation principle was an expression of objectivity obligation. A special computer programme was created (by A. Kryžanauskas) in order to find locations in a chosen landscape type that in their land cover structure were most similar to the summarized land cover structure of the respective landscape type. The principle of the programme work was the „striding" of the sample area shape (quadrangle of 1.5x1.5 km) across the landscape type and automatically calculating its inner structure and presenting the result in a data base table. Depending on size of the landscape type, positions of the sample shape tested inside the landscape type area were several hundreds to several tens of thousands, the total possible sample area positions tested being 67,758 (Table 2).

Later analysis enabled to calculate and sort tested positions of the striding sample shape and to select the best representing ones. Data of each sample shape's land cover (in our case CORINE land cover data of 2006 was used) structure was compared to the land cover structure of the respective natural landscape type by calculating a relative distance between these structure using the following formula (1):

$$D = \sum_j \left| z_j - Z_j \right| \qquad (1)$$

where D – relative distance of the land cover structure in a sample shape from the respective landscape type measured in %, j – running number of the land cover type (the total number of

land cover types according to CORINE is 30); z_j – percentage of *j* land cover type in a sample shape, Z_j – percentage of *j* land cover type in a respective landscape type.

Table 2.

Number of tested positions of sample shape striding across the different landscape types

No	Natural landscape types	Number of sample areas	Number of tested positions of sample areas
1.	Clayey plains	22	27518
2.	Clayey downy plateaus	17	11265
3.	Morainic hills	16	10605
4.	Sandy plains	13	5550
5.	Valleys	11	8884
6.	Lake terrains	9	2555
7.	Spit	5	407
8.	Delta	4	237
9.	Coastal Plain	3	737
	Total	**100**	**67758**

As the land cover structure of the sample shapes is much less diverse as that of the whole landscape type, an additional index, namely number of land cover types, was introduced into the sample selection process, preference giving to those with the largest meaning of this index. In fact, sample shapes with the largest number of land cover types contain only 50 to 70 percent of the total number of land cover types found in hosting them natural landscape type.

Regional representation (principle of equal spread of sample areas) was also taken into account, meaning that we avoided selection of sample areas in one region or in several close regions trying to find sample areas with the best representation characteristics in the most distant landscape regions.

To generalize, the final choice for the locations of the sample areas was determined by the position the sample shapes being the most similar in land cover structure (the least distant from the natural landscape land cover structure), having richest diversity of land cover types, and representing different regions of the same natural type landscapes (Fig. 1).

Landscape condition and structure change investigation in local level are important for substantiating directions of landscape protection, formation and management, as well as for preparation of territorial planning document of different rank. Especially important is the knowledge of landscape spatial structure and state in ecologically sensitive natural complexes, as e.g. in nature frame territories, areas of specific problems, and protected areas, that require introduction of specialized and adequate use conditions, regulations for economical activities and their limitations.

Additional analysis has revealed that most of the selected hundred sample areas fall into the areas of mentioned sensitive character. Thus, ignoring the overlapping, we might state, that 62 sample areas will be able to represent parts of Lithuanian nature frame (legally approved network of geoecologically important territories of Lithuania), 23 of them will describe landscape changes in regional and national parks (protected areas), 14 will describe nature reserves, and 2 will represent biosphere polygons.

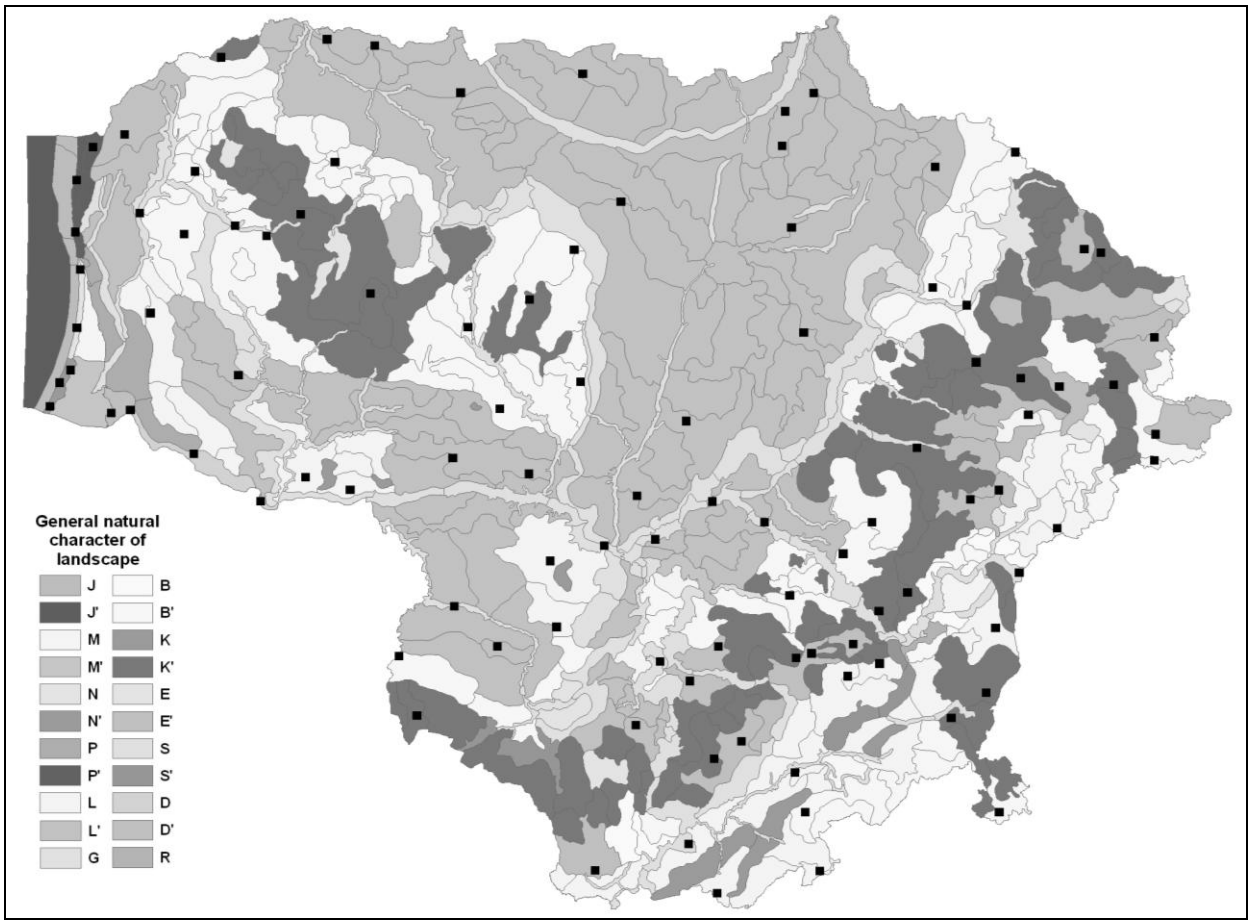

Fig. 1. **Landscape monitoring sample areas (black squares) in different natural landscape types of Lithuania (map according to [11])**

Natural character types of landscape: J – marine landscape in the coastal zone (at a depth of < 20 m); J‘ – underwater plateaus and troughs; M – shallow lagoon (at a depth of < 2 m); M‘ – deep lagoon; N – smoothened spit; N‘ – rugged spit; P – lagoon coastal plain; P‘ – sandy coastal plain; L – continental sandy plains; L‘ – clayey plains; B – sandy downy plateaus; B‘ – clayey downy plateaus; G – morainic hills; K – sandy hills; K‘ – morainic hills; E – troughs with lakes; E‘ – lake terrains; S – valleys; S‘ – old valleys; D – delta valley; D‘ – delta; R – erosion washes.

Conclusions

Experience from countries having longer experience in landscape monitoring, including the local level one, show the main methodological tasks that has to be resolved, namely territorial distribution of sample areas, system of indicators to be monitored, ways of collecting the data, ways of processing and generalization of collected data. There are also some principles that each country must develop for distinguishing monitoring sites, namely strict definition of monitoring area, objectivity, representation, size of sample areas, periodicity of data collection.

Adapted to Lithuanian case, the principles of landscape monitoring using local level monitoring sites could comprise the following points: 1) number of monitoring sites is 100; 2) territorial distribution represents main landscape character types; 3) size of monitoring sites – 2,5 km^2; 4) indicator system is tied with landscape cover structure with additional evaluation of vegetation state.

In the process of sample area selection, a principle of representation instead of random selection method was offered. Thus the choice for the locations of the sample areas was determined by the most similar to the natural landscape type land cover structure, richest

diversity of land cover types (as the way of approximation to the landscape type richness), and considering the even territorial distribution of most representative sample areas.

The offered landscape local level monitoring sample areas will reliably represent landscape state condition and spatial structure change not only in the context of the whole Lithuanian territory, but also the situation in ecologically sensitive landscape complexes like Nature frame (62 sample areas), protected areas (39 sample areas) and several areas of specific problems like karst region, coastal region, etc.

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