METHODS OF MONITORING AND ASSESSMENT OF CHANGES IN LAND USE AND LANDSCAPE STRUCTURE

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Abstract

Landscape ecology in its dynamic concept is focused on three large topics concerning landscape: 1. structure; 2. functions and processes; 3. changes and developments. Horizontal structure of the landscape and its changes have a key importance for all processes of landscape functioning, i.e. flows of matter and energy, species movement and exchange of information. Fast changes in landscape structure actually expressed by changes in land use and land cover are a characteristic feature of the present cultural landscape. Both geography and landscape ecology are traditionally focused on monitoring of landscape changes. Both disciplines have elaborated their own methodological approaches to investigate changes in horizontal landscape structure. The methods differ depending on used data, the scale, size and character of the area under investigation. Changes and developments in landscape macrostructure are investigated using summary statistical data on land use, usually available for administrative units from which cadastral areas are the smallest. Research methods aimed at monitoring of changes in landscape microstrucutre are based on data derived from maps, aerial and satellite images. Both approaches often complement and permeate each other at the present. Methods of monitoring and assessment of of changes in landscape macrosructure as well as landscape microstructure are reviewed in the paper. The terms „*landscape macrostructure*" and „*landscape microstructure*" are explained in the text, too.

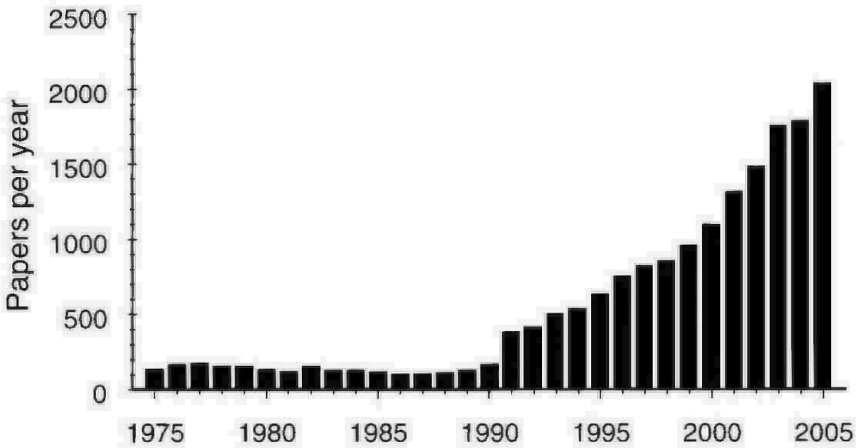
Changes in landscape structure may eventuate in changes in landscape character alternatively in destruction of characteristic landscape types. But at the same time landscape changes are in keeping with the concept of cultural landscape as a dynamic result of interactions between natural and social processes. Some changes are universally wellcomed, others may cause conflicts among landscape users. Changes that are positive in some respects may be negative for other landscape values. Permanent landscape changes are described in the concept of ephemeral landscape and in the concept of transitional landscape as a continuous process. Accordingly the assessment of the changes in the landscape does not mean a precarious refuse of man alterations. It should result from the knowledge about the influence of the changes on biodiversity and ecological stability of the landscape, generally on the course of landscape processes and characteristics.

Key words: land use, landscape macrostructure, landscape microstructure, landscape metrics, landscape change

Introduction

The topic of land use and landscape structure changes represent an extremely wide as well as very important and topical issue in all scientific disciplines dealing with landscape. The number of papers in scientific journals that focus on the topic of landscape changes has been increasing significantly during last 10-15 years. ASPINALL (2006) presents the rapidly growing volume of papers with „land use" as either a key word or in the abstract that are cited on ISI Web of Science (Fig. 1). Also in the Czech Republic the number of papers and research works aimed at changes in landscape use has significantly increased after the year 1990 which means a certain milestone in the development of the Czech landscape. Some trends in the development of the Czech cultural landscape have intensified and some others modified according to political and societal changes after the Velvet Revolution. Research works were concentrated on both the analysis and assessment of dramatic changes in landscape structure in the second half of the 20th century connected with the development of the socialist large-scale agriculture and new development tendencies after 1990 like decrease in the area of agricultural lands, abandonment as well as strengthening of non-producing functions and polyfunctionality of rural landscapes. Farther research trends are focused among other things on changes in outskirts of big cities, uncontrolled urban sprawl into open rural landscape and development tendencies of postagrar and postindustrial landscape.

Fig. 1: Number of papers with „land use“ as either a keyword or in the abstract that are cited on ISI Web of Science (after ASPINALL 2006)



Czech Society for Landscape Ecology (IALE-CZ) organised its annual conference titled "Present changes in landscape use in the Czech Republic" in January 2001 in České Budějovice. During the last Congress of the Czech Geographical Society (České Budějovice, August 30 - September 2, 2006) and the last International Symposium on Problems of Landscape Ecology in Slovakia (Stará Lesná, October 4-7, 2006), the sections dealing with landscape changes and transformations were the most visited by professional community as to the number of papers and posters. Problems of landscape changes resulted in changes in landscape character represent much frequented issue in recent research works oriented to practice of landscape protection and planning. It concerns both the Czech Republic, where four conferences on the topic of landscape character assessment were organised during last decade, and Europe (project ELCAI - European Landscape Character Assessment Initiative, WASCHER, ed., 2005). Among many international conferences, workshops and seminars dealing with the topic of landscape changes, the seminar *Landscape change and its ecological consequences in Europe* held in Tilburg in 1995, from which the important publication was published (JONGMAN, ed., 1996), should be mentioned. Last time the international seminar with the characteristic title *Landscape*

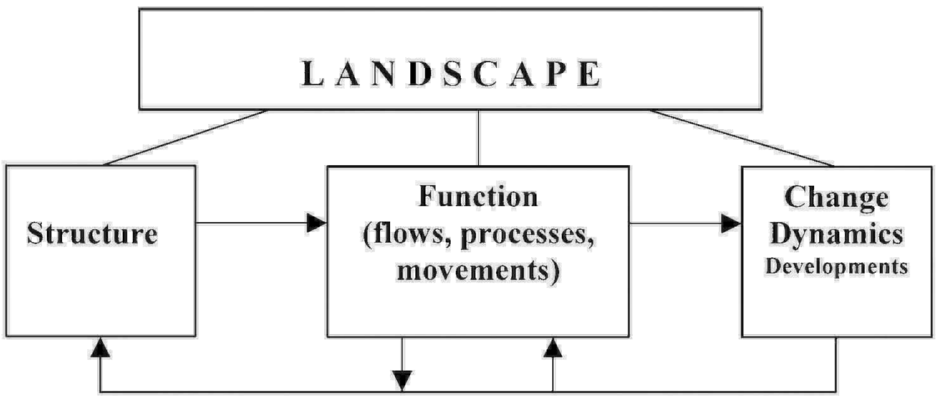
Change: Learning from the Past - Visions for the Future was organised in Norwegian Tromso in June 2006. Land use as well as general landscape changes are studied in the field both of geography and landscape ecology, apart from other scientific and applied disciplines dealing with landscape issues. In the framework of the International Geographical Union, the LUCC (Lans Use/Cover Change) Working Group is actively working to follow up land use changes around the world (HIMYIAMA et al. 2005), with the important intellectual contribution of the Czech geographical school (BIČÍK 1998; BIČÍK et JELEČEK 2003; BIČÍK et KUPKOVÁ 2005 and others).

Importance of land use and landscape structure changes from the point of view of landscape ecology

Landscape ecology in its wide thematic orientation is dealing with three main subjects in the landscape: 1.structure; 2. functions and processes; 3. changes and developments. These main general attributes of every landscape are mutually connected by a complex system of feedbacks (Fig. 2).

One of the most important notions is that the landscape structure strongly influences ecological processes and characteristics. Functions and all processes running in the landscape depend directly on and arise from landscape structure, it means from the spatial composition of landscape segments. The pattern is an important feature if one studies the relationship between the various horizontally arranged complexes of landscape elements (ZONNEVELD 1995). FORMAN et GODRON (1986) formulate 7 main principles of landscape ecology. The principles are aimed at landscape structure, landscape functions and landscape change and all the principles stress the primary and absolutely determinant role of landscape structure. Any changes in landscape structure change the functioning of the landscape (i.e. flows of energy, matter and information as well as species movements among structural landscape components). And changes or alterations in landscape functions drive landscape dynamics, are driving factors of landscape developments and by a feedback path are once again reflected in landscape structure. That is why landscape structure and its changes represent a crucial issue in landscape ecology.

Fig. 2: Three main subjects of the interest of the landscape science in the landscape

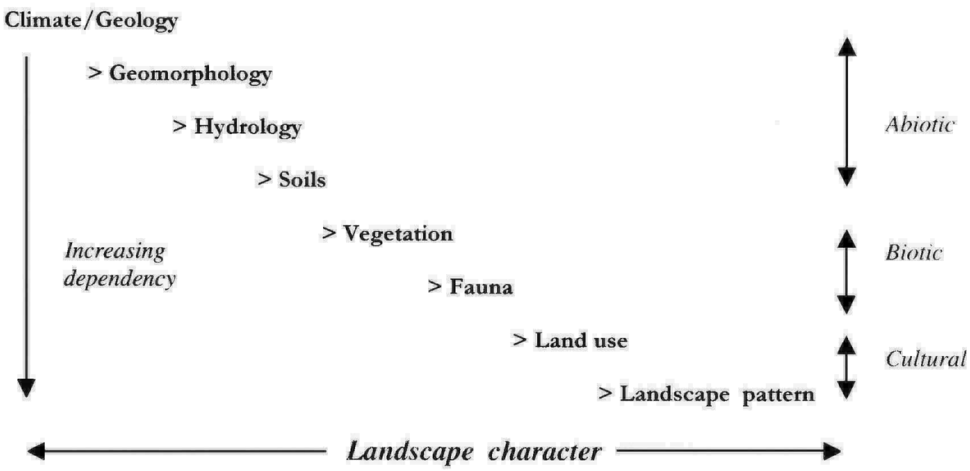


Two main concepts of landscape structure cover: 1. the „geocomplex“ model formulated by geographers (SOČAVA 1978, MORAČEVSKIJ 1994) and 2. the “patch-corridor-matrix“ model (FORMAN et GODRON 1986). The main spatial processes involved in the process of land transfromation conceived as changes in the arrangement and spatial composition of the so-called land mosaic (PIETRZAK 2001). The most common ones include: perforation, dissection, fragmentation, shrinkage and attrition of particular portions or elements of the landscape (FORMAN 1995). According to OT´AHEL (1999), the analysis of landscape changes is important for the assessment of landscape processes, dynamics of the changes, their causes as well as prognoses of further developments.

Landscape structure can be distinguished on three levels: vertical (mostly on the topological level), horizontal (chorostructure - on the chorological level) and chronological (chronostructure). Namely the horizontal landscape structure and its changes are in the focus of the research in landscape ecology. The landscape structure is studied and mapped on different space hierarchical levels from local to regional and global ones depending on the scale and purpose of the investigation. We can investigate both landscape macrostructure based on summary statistical data on land use and land cover and landscape microstructure based on methods of field mapping or interpretation of airphotos and satellite images (LIPSKÝ 2000). Terms „*landscape macrostructure*“ and “*landscape microstructure*“ are used here in the sense defined by KYJOVSKÝ (1989). Statistical data have got only limited spatial links related to the entire territorial units and do not evidence on the scale of the existing landscape mosaic. The concept of landscape microstructure is concisely aimed at the space composition of landscape segments, their mutual relations and connections as well as individual parameters of single landscape components (LIPSKÝ, 2000).

Another terminological and conceptual approach used in landscape typology and landscape character assessment consists in a differentiation between primary, secondary and tertiary landscape structure. The primary structure is determined by natural conditions, i. e. by geology and soils, geomorphological forms, climatic conditions, natural waters and natural vegetation. The secondary landscape structure is a result of man activities in the landscape. It can be identified with land use or land cover of the present landscape. Both primary (natural) and secondary (anthropogenic) landscape structures have got a direct reflection in the face of the landscape. Especially methods of physiognomic landscape typology and landscape character assessment result from land use and land cover classifications. Land use as a secondary landscape structure combined with landscape microstructure is something like a mirror of the state of the society. It is a result of the dominant role of the man in cultural landscapes. A comparison of the secondary landscape structure with the primary one is very useful to determine the degree of naturalness or anthropogenic conversion of the landscape. As the tertiary landscape structure we understand spiritual, immaterial characteristics of the landscape like landscape history and memory, traditions, cultural and historical events which contribute to the specific landscape character but have got no direct physiognomic expression in the landscape. The chart on the Fig. 3 shows the increasing dependancy of landscape components and structures from abiotic to biotic and cultural ones. Biotic structures are depending on abiotic ones, the secondary structure is depending on primary one and such as loaded up it. This methodological approach and mutual dependancy of landscape components has been in a simplified form recently applied to compile the new Pan-European landscape typology map (MÜCHER et al. 2003) as well as in the typology of the present cultural landscape of the Czech Republic (KOLEJKA et LIPSKÝ 1999; LIPSKÝ et ROMPORTL 2007).

Fig. 3: Dependency of landscape components (after MÜCHER et al. 2003)



Changes in cultural landscapes

Landscapes and landscape structures are changing all the time; change is an intrinsic characteristic of every landscape. It concerns both natural and cultural landscapes. BJÖRKLUND (1996) discusses how to interpret landscape as a continuous process of flows and interactions between natural and human-induced processes. The flows are forming and permanently changing landscape structure(s). Landscape changes are running on very different time scales which range from seconds and minutes to long-term changes lasting hundreds, thousands and even more years (see Fig. 4).

Tab. 1: Time dimensions of landscape processes (after ZONNEVELD 1995; LIPSKÝ 2000)

10 6 years	geological platform tectonics; biological species evolution
10 5 years	macroclimatic processes (glacials, pluvials); development of relief macroforms
10 4 years	macroclimatic processes, macrogeomorphology (secular erosion)
10 3 years	soil formation and development (podsolisation, lateritization); geo-hydrological processes, long-term successions
10 2 to 10 1 years	processes of sedimentation (coastal, fluvial); biological feedback - succession after catastrophes and disturbances; biological invasions; forestry
10 -1 to 1 years	agriculture, horticulture, urbanization
months	biological epidemics (diseases), seasonal climatic and vegetation changes, species migrations, gardening, construction
days to hours	catastrophs caused by meteorological extrems (floods, typhoon, gale,......), volcanic activity (eruptions); landslides; accelerated soil erosion and sedimentation
minutes to seconds	earthquake; avalanches; rock caving, nuclear explosion

BRASSLEY (1997) proposed the concept of the ephemeral landscape. Within the permanent structure of the landscape, the ephemeral landscape is more or less constantly changing. It is undisputable that changes in agricultural technologies produce changes in agricultural landscapes. Human-induced ephemera are usually associated with agriculture, principally because agriculture is the major land use in Europe. The way of cultivation, structure of field crops, harvesting methods, whether of grass or corn, methods of livestock farming as well as other agricultural processes have been radically altered during last 50 years with concomitant effects on the ephemeral landscape structure. The appearance of the country side during the corn or hay harvest has been fundamentally changed. Instead of the lines of stooks which typically covered the cornfields often for several weeks in the summer season and were many times admired by landscape painters and photographers, bales of straw of different size and shape (depending on used technologies) are a characteristic feature of the present agricultural landscape in the late summer. Thus we can find numerous landscape features which are ephemeral, some natural, some produced by human activities. BRASSLEY (1997) argues that ephemeral components and ephemeral changes have a major impact on the appearance of the landscape and on the way in which it is perceived and valued.

Present cultural landscapes under dominant influence of the man passes through very dynamic, fast changes in land use and landscape structure. Anthropogenic processes are (in average) much faster in comparison with the course and speed of the majority of natural processes. Any change in the society, whichever economic, in ownership, technological or demographic, call up changes in the way of landscape use, in landscape structure and as a result changes in landscape character, biodiversity, ecological stability and in the course of all processes running in the landscape. As societal changes are all the time faster, also landscape changes are faster and deeper with more significant ecological consequences.

The secondary landscape structure formed by the use of land has changed repeatedly throughout history, depending on political, economic, technological and demographic changes following development of the society. Various types of cultural landscapes have got their history of landscape as well as memory lasting hundreds and thousands years. The socialist collectivization of agriculture running since 1950ies in the Central and Eastern European countries was many times presented as a typical example of the fast and dramatic landscape structure changes caused by deep political, social and economic changes in the life of the society. The changes resulted in far-reaching negative consequences for the functioning of the whole landscape system. During the transition to a socialist large-scale production, landscape structure changed rapidly towards its significant simplification. Parcels of arable land were unified so as not to be interrupted by meadows, pastures, scattered greenary and other elements hampering the smooth cultivation of land. The size of agricultural holdings was increased 50 times, plenty of meadows in floodplains were ploughed and most of the permanent vegetation structures in the open agricultural landscape were removed. During the unification of parcels in just one common cadastral district some 350-400 adult trees were felled and 2500-3500 m2 of shrubs were cleared (LIPSKÝ 1995). The size of agricultural plots and chemicalization in agriculture reached its maximum in the 1980ies. Now we are wondering that still 25 years ago mountain plains in the Šumava Mountains were ploughing, grasslands in alluvial floodplains were turning into arable lands and agricultural research institutes solved serious projects how to „clean up“ agricultural landscape and remove all barriers like scatterred greenary, small wetlands and water withdrawel areas hampering the smooth cultivation of agricultural plots using heavy machines.

We can also find opposite changes with a prevailing positive environmental effect like afforestation and spontaneous successive distribution of shrubland vegetation on slopes, a dispersal of tree stands and wetlands along unmainted water streams and on other places not suitable for heavy mechanization and large-scale agriculture. These dispersed sites with a decreased anthropic pressure as localities friendly to natural processes have become a refuge for endangered plants and animals which were forced away from intensively used agricultural lands. Although it seems to be illogical, the area of permanent greenary had increased during the era of socialist agriculture in the landscape (KUBEŠ 1994), while its structure and quality were shifted from the ideal state (LIPSKÝ 2005).

However, negative ecological consequences highly predominate. They have roots in the dramatic simplification of landscape microstructure followed by a severe reduction of biodiversity as well as ecological stability of the landscape. Besides biotic subsystem of the landscape, the abiotic subsystem was negatively influenced as well. The intensity of soil erosion by water has increased 10 times and an increased risk of floods and unbalanced water régime does not effect agriculture only. The traditional character of the Czech rural landscape with its small-scale mosaic of patches has changed into large-scale landscape of collective openfields (LIPSKÝ 1995). Quite different development in the South East Poland has been caused by keeping of private ownership in agriculture during the whole socialist era till the present. The landscape of Poland strip fields corresponding to traditional small-scale private agriculture is such specific in landscape character that it has been distiguished as one of 30 significant Pan-European landscape types in the first Pan-European landscape typology (MEEUS 1995).

At the present time we register very fast landscape changes not only in agricultural landscapes, but locally even in large-scale protected areas . These changes in contrast to the changes in agricultural landscapes mentioned above are connected with non-productive functions of the landscape (a strengthening of sport and recreation functions, new ski-routes and lifts even in national parks etc.). Urban sprawl and rapid increase in built-up areas is one of global problems.

Methods of monitoring and assessment of landscape macrostructure

Generally there are many papers dealing with and analysing landscape structure issues (e. g. BOTEQUILHA et AHERN 2002; FORMAN 1995; MIKLÓS 1986; O´NEILL et al. 1988; SKLENIČKA et LHOTA 2002; TURNER et GARDNER 1991 etc.). Traditionally these studies have been split up into studies of the structure and dynamics of the main types of human land use, such as agriculture, forestry, water bodies, urban built up areas, and the study of the structure and dynamics of different types of land cover with natural and semi-natural vegetation. Economic geographers in general, and more specifically agronomists, foresters, urban planners and engineers have dealt with the first part, whereas biologists and landscape ecologists are concerned with the other part (BRANDT 1999). Recently both methods converge and complement each other. There is a very common routine method to follow up changes in landscape macrostructure using statistical data on land use which are usually available per cadastral areas, per districts and other administrative units. This approach is widely practised by human geography (BIČÍK et al. 1996) and is suitable for large areas. But administrative boundaries are not the best from the ecological point of view because they do not correspond with natural boundaries of catchments or other landscape units (morphological, biogeographical). Moreover the cadastral unit is like a black-box: we do not know what happened inside. Recently statistical data on land cover from the uniform CORINE Land Cover database derived from satellite images are commonly used to follow up landscape changes on large areas, optionally on the scale of the whole countries and regions in Europe (FERANEC et al. 2004).

The research team of human geographers from the Charles University in Prague have built the original digital database of historical land use in Czechia. The database contains data on land use for approximately 13 000 cadastral units (average area 609 ha), which were transformed into almost 10 000 basic territorial units (average area 7 km2). To obtain a comparability among historical land use data from different sources, originally more than 50 categories of land use were unified and simplified into seven main categories: 1. arable land, 2. permanent grasslands (pastures and meadows), 3. permanent cultures (orchards, gardens, wineyeards, hopfields), 4. forests, 5. waters, 6. built-up areas, 7. others. Comparable data are now at disposal for four time horizons: 1845, 1948, 1990, 2000 (BIČÍK et JELEČEK 2003). Original statistical and cartographic methods have been elaborated to use this database and demonstrate historical changes in the area of arable and total agricultural lands, grasslands, forests, built-up areas and other land use categories. Land use changes in the Czech Republic as a whole as well as in administrative regions and landscape units like districts , landscape protected areas and biosphere reserves have been routinely evaluated by this way (BIČÍK et al. 1996). In smaller model areas selected to cover different developments according to different landscape types of the country from lowlands to mountains and from core areas to periphery statistical data on land use per cadatsral units are combined with methods of a detailed field mapping and interpretation of old maps and aerial photographs. The aim of the research is to demonstrate regional differences in historical land use development depending on natural conditions, geographical position, historical and socioeconomic development. Results of the research achieved by the research team of Czech geographers managed by Ivan Bičík were many times presented and highly appreciated on the international forum (HIMYIAMA et al. 2005). Close co-operation has been developed in the Central Europe among Czech, Slovak, Austrian and Slovenian historical, social and environmentally oriented geographers because all these countries have identical structure of historical data on land use (statistical data per cadastral units, old cadastral and detailed military maps) as a heritage of the common history under the Austrian Monarchy. Two international conferences focused on the topic of historical land use changes were organised in Prague: *Land Use/Land Cover Changes in the Period of Globalization. IGU-LUCC Conference (2001)* and *Dealing with Diversity. 2nd International Conference of the European Society for Environmental History (2003).* Mr. Ivan Bičík has become the Head of the IGU LUCC (Land Use/Cover Change) Working Group in 2006.

All attempts to calculate a complicated phenomenon of ecological stability of the cultural landscape are based on the proportion of different land use categories /classes/ in the area under investigation. Generally, coefficient of ecological stability of the landscape is formulated as the proportion of ecologically relatively stable (positive) areas like forests, waters, grasslands and ecologically relatively unstable areas (like arable lands, built-up and disturbed areas, industrial sites etc.). The simplest coefficient of ecological stability after MÍCHAL (1992) is counted as:

$$Kes = S/L$$

where S is the total area of all ecologically relatively stable land use categories with permanent cultures (principle of permanent vegetation) and L is the total area of all ecologically relatively unstable land use categories. Because it is very simple, the coefficient is routinely used in the Czech Republic to characterize the area under investigation for planning purposes. All catchments, biogeographical regions and administrative units are characterized by this way. The authors realize shortages of the method: it is too schematic and can be far from the reality which is much more complicated. The simplicity of the coefficient is reasoned by the structure of statistical data on land use which are at disposal in a unified form for the whole state territory and for all cadastral units. Using this statistical data, it is not possible to differentiate the quality within categories because for example in case of forests only one official statistical category of land use exists. The same is true for waters, meadows, orchards and other basic land use categories.

A similar basic approach, that is the proportion of the area of different land use/land cover categories in the landscape under investigation, has been used by more authors to quantify ecological stability of the landscape. The authors seek to reduce the shortages mentioned above using partial coefficients, for example the coeficient of ecological importance for different types of land cover (MIKLÓS 1986), or divide ecologically stable and ecologically relatively unstable areas into more categories (LÖW 1987). Logically similar but opposite approach has been used by BIČÍK et KUPKOVÁ (2005) to count the coefficient of anthropogenic transformation (Kac) of the landscape or the index of general land use changes.

Both types of coefficients - Kes as well as Kac had been also used to document temporal historical changes in ecological stability of the landscape and in the grade of its anthropogenic transformation. But it is a weak point of such coefficients that they are not able to quantitate different ecological quality of arable lands, grasslands, orchards and other land use categories in different historical periods. It is simply clear that ecological quality of intensively used arable lands in modern large-scale agriculture with high level of chemicalization and heavy machinery on large plots is much worse in comparison with traditional small-scale agriculture using farmyard manure and horse power, but a mechanical applications of the above mentioned coefficients often demonstrate a paradox of an increase in ecological stability of the landscape because of an increase in the area of forests and a decrease in the area of arable lands especially during last 50-100 years. Original statistical data on land use (landscape macrostructure) are not able to respect landscape microstructure which is extremely important for landscape processes, its biodiversity and ecological stability. That is why the coefficients are not suitable to use them in historical comparison (LIPSKÝ 2000) however many authors do it.

Methods of monitoring and assessment of landscape microstructure

Landscape ecological research oriented at landscape microstructure has been influenced by Forman´s concept of landscape structure and his definition of a landscape as a heterogeneous land area composed of a cluster of ineracting ecosystems, embedded in a matrix of a dominating land use (FORMAN 1995). Landscape is perceived as a mosaic; landscape ecology is dealing with its structure in the sense of spatial arrangement of various types of land cover, ecosystems and patches with different use. Terms like matrix, patches and corridors are used as a conceptual apparatus to describe landscape structure elements and characterize a degree of landscape heterogeneity, fragmentation or connectivity. On this conceptual basis it is then possible to formulate a set of characteristics and indicators of landscape microstructure like landscape diversity (number of types of ecosystems or land cover types), length and density of lines, boundaries and corridors, porosity and mosaic character, connectivity and fragmentation of the landscape. A relation between biodiversity and the structure and heterogeneity of land cover and land use is a central issue of these studies (BRANDT 1999). That is why landscape ecological approach consists especially in the investigation of landscape microstructure, using detailed topographical and cadastral maps, airphotos, field mapping etc. There has been an explosion of literature during recent years concerning biologically oriented studies of spatial ecology linked to island theory, metapopulation theory and the study of connectivity in fragmented landscapes (see FORMAN 1995; FARINA 1998). Results of the research can be retrospectively used in ecologically oriented assessment of historical development of landscape microstructure as well as in practical planning of revitalization projects in landscape.

There are many statistical and analytical methods how to investigate changes in landscape microstructure based on measuring and calculation of landscape metrics and indices. In the last two decades, the rapid development of electronic equipment has enabled the use of modern quantitative methods (FARINA 1998; TURNER et GARDNER 1991). Some metrics and indices are used only to describe individual characteristics of landscape elements, some try to describe the whole pattern of a landscape structure. Assessment of landscape microstructure applies different statistical and analytical methods of landscape pattern analysis (like index of heterogeneity, Shannon´s diversity index, edge and boundary characteristics, patch characteristics and measures etc.). As it is difficult to describe a landscape pattern with a single index or metrics, so a set of metrics should be used. Many of the metrics can be correlated because all spatial metrics are calculated from a limited number of primary measurements and parameters (e.g. patch size, shape, edge length, perimeter-area ratio, interpatch distance). A selection of frequently used metrics is given in the table 2. A serious question remains how to evaluate the metrics objectively and whether their importance is not overestimated.

Practical application of landscape pattern quantification with landscape metrics includes describing temporal land use changes, future predictions regarding landscape change and evaluating differences in landscape pattern between landscapes (PIXOVÁ 2005). Landscape structure changes are increasingly used to monitor changes in landscape character of different landscape types and to identify pressures and responses. In recent years, more countries have developed refined methodologies in terms of spatial resolution and policy orientation, resulting in monitoring landscape changes. The main goal of the English project *„Countryside Quality Counts"* was to obtain better information about changes in character of English rural landscape. Key elements forming a typical landscape character of English country side were chosen as indicators of landscape changes in the project: forest area, shape of boundaries, agricultural land cover, semi-natural stands, historical artefacts, rivers and further water elements (HAINES-YOUNG et POTSCHIN 2005). Landscape structure is the indicator that is most commonly in use and where an increasing number of techniques (e.g. GIS) are being developed. Satellite images and methods of statistical analysis are used to select and calculate the indicators of landscape structure changes (WASCHER et PÉREZ-SOBA 2004).

Remote sensing methods have got an irreplaceable potential to record temporal landscape changes. The multispectral and multiple spatial domain data provided by remote sensors are ideally suited for integration into a geographic information system. The remotely sensed landscape is multidimensional, multitemporal and multiscaled. Remote sensing attributes like measurement of spatial properties are successfully applied to analyse landscape ecological spatial characteristics like shape, size, pattern, arrangement and texture (QUATTROCHI et PELLETIER 1992).

Table 2: An overview of often used landscape structure metrics (after PIXOVÁ 2005):

Metric	Description
Basic patch characteristics	Patch size, patch perimeter, distance to the nearest neighbour, path shape, accessibility, isolation of patches
Fractal geometry	Complexity of element shapes, quantification of total complexity of the matrix
Proportion	Proportion of particular land use and land cover categories as a fundamental metric used to calculate many other matrics
Relative richness	Relative richness of land cover types, depends on the number of observed land use types and possible cover types
Dominance	Determination of dominant land use types
Shannon evenness	Evenness of attribute classes.
Contagion	The aggregation or dispersion of elements in a landscape
Mean nearest neighbour distance	Average edge-to-edge distance between a patch and its nearest neighbour in a landscape
Proximity index	Helpful for setting the isolated patches within a complex of patches or for measuring the isolation of a patch in a given specified search radius; mean proximity index: average of the proximity index of all patches

CORINE Land Cover database represents land cover identified from satellite images at the original scale 1: 100 000 for years 1990 and 2000. These data layers allow to identify, analyse and assess landscape structure changes by a unified method on the European level. Six types of the most important landscape changes were interpreted as urbanization (industrialization), intensification of agriculture, extensification of agriculture, deforestation, forestation and other changes (FERANEC et al. 2004). Next important characteristics of landscape microstructure significant for landscape character assessment like fragmentation, openness or enclosure of landscape scenery is possible to derive from satellite images, too.

Table 3: Categories of landscape structure indicators (after WASCHER et PÉREZ-SOBA 2004)

Category	**Indicator**
1. Patch Density, Patch Size and Variability Metrics	Number of Patches (NUMP) Mean Patch Size (MPS) Median Patch Size (MedPS) Patch Size Standard Deviation (PSSD) Patch Size Coefficient of Variance (PSCOV)
2. Edge Metrics	Total Edge (TE) Edge Density (ED) Mean Patch Edge (MPE)
3. Shape Metrics	Mean Perimeter/Area Ratio (MPAR) Mean Shape Index (MSI) Area Weighted Mean Shape Index (AWMSI) Mean Patch Fractal Dimension (MPFD) Area Weighted Mean Patch Fractal Dimension (AWMPFD)
4. Diversity and Interspersion Metrics	Mean nearest Neighbour (MNN) Interpsersion Juxtaposition Index (IJI) Shannon´s Diversity Index SDI) Shannon´s Evenness Index (SEI)

Potential of satellite images has been well illustrated on the example of the analysis of landscape structure and its pattern in the landscape of the North-West Greece. 10 categories of landscape use were identified from the LANDSAT 7 scene. Using statistical analysis in the Arc View 3.2a. Programme, in total 29 different landscape structure indicators were calculated, from which 17 indicators given in the table 3 were finally used (WASCHER et PÉREZ-SOBA 2004).

Conclusion

Landscapes are very dynamic in structure, functions and spatial pattern. Landscape changes are running on different time scales, they are of different magnitude and extent of changes. Disturbances and changes in landscapes are an intrinsic factor of their existence and development. In cultural landscapes the disturbance regime is dominated by changing land use practices. The assessment of changes in the landscape and of man interventions into the landscape does not mean a precarious refuse but evaluation whether and how the changes comply with or counteract natural processes, whether they affect the landscape ecological stability and biodiversity negatively etc. (LIPSKÝ 2000). Both landscape ecology and geography have elaborated methodological approaches to landscape changes monitoring and assessment. Focus of the research in landscape ecology needs to be on how landscape dynamics interacts with species tolerances in time and space (DUNN et al. 1991). According to FORMAN and GODRON´s (1986) main principles of landscape ecology, land use and landscape structure changes have got a decisive influence on:

- flows of matter and energy in the landscape
- flows (movement) of species and infomation
- biodiversity of the landscape
- landscape character, aesthetics and perception of the landscape
- passability of the landscape (for the man)

Landscape changes represent a big issue in the contemporary Europe. Present trends in developments of the Czech as well as European cultural landscapes are characterized by two antagonistic tendencies of land use: intensification and extensification. More regional cultural landscape types vanished during the last century, some new ones like semi-urban or hybrid urban, recreation, postindustrial and postagrar types of landscapes originate at the present. There are very different opinions of specialists as well as stakeholders concerning current landscape changes, especially abandoning of agricultural lands. The attitudes are also changing in time according to the development of knowledge and new ideas. What is undisputed, the changes in the land use and landscape structure have many relevant environmental consequences. As every cultural landscape is a mirror of the state and development of the society, there is a great responsibility of the man for the state of the landscape and its function as well as a possibility to improve them.

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