Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2013, 10, 36–52

USING GEOINFORMATION AND GIS TECHNOLOGY FOR SPATIAL ANALYSIS, DESIGNING AND PROTECTION OF ECOLOGICAL NETWORKS AT THE REGIONAL SCALE OF LANDSCAPE

Jarosław Czochański

Department of Physical Geography, Institute of Geography, University of Gdańsk
Bażyńskiego str. 4, 80-952 Gdańsk, geojc@univ.gda.pl

Summary. One of the key factors, which influence preservation of the biodiversity at an ecosystemic, species and genetic levels, is the structure and spatial connectivity of the landscape elements. The relation between the protection of ecological network, based on ecological patches and corridors, and the stability and diversity of habitats and species has already been proven. Identification and protection of landscape structures, which build connections of an ecological network, is an important task for spatial management and planning. The article aims at presenting methods of using geoinformation and GIS tools for identification and designing ecological connections at the regional scale against the interrelations as well as conditions and problems associated with the decreasing biodiversity. Delimiting the structures of ecological network is crucial for considering them in strategic documents of development and spatial planning as pre-requisites for management and protection.

Key words: ecological network, ecological patch, ecological corridor, biodiversity, GIS, geoinformation

INTRODUCTION

Biodiversity of habitats, species and their abundance in many European regions and states is decreasing. The trend is correlated with the growing human pressure on the natural resources; eroding natural spatial cohesion and continuity; and shrinking animal and plant populations. Moreover, the EU's plans for halting the decrease in biodiversity by 2010 have not been introduced, while the legal protection of networks of ecological connections is missing. All these factors pose fundamental challenges for the present policies of spatial development, planning and environmental protection at the level of the Polish regions, the whole country as well as for the whole European Union. Recognising spatial

structures of environment, delimiting the networks of ecological interrelations and protecting their stability stand as essential pre-requisites for reducing depletion of organisms and species, keeping their genetic and habitat diversity as well as for survival of protected species.

GIS tools and contemporary resources of geoinformatics, such as Topographical Database, remote sensing materials, CORINE database and regional databases of Land Information System, were used by the author to analyse location, functioning and conditions for the protection of ecological network. The study was based on the ecological structure at the regional level of the Pomeranian Voivodeship.

According to the author, the analysis of spatial distribution and of prerequisites for maintaining interrelations between environmental structures at the regional level provides a key contribution to the preservation of environmental biodiversity. Such a solution has been introduced into the documents associated with the regional development policy, including the voivodeship's spatial development plans. That practical case demonstrates a practical means to achieve a better sustainable development of a region, as well as stability of the biosphere elements, natural functional connections and spatial structures of a landscape.

PRE-REQUISITES FOR PROTECTION OF LANDSCAPE STRUCTURES

Landscape and its structure

Diverse typologies of spatial units and structural elements of the nature are used in environmental studies. They depend on the discipline, scale, topic and range of the research. Richling [2004] points at the two basic models of the spatial division – a „mosaic" and a one composed of „matrices, patches and corridors". In the mosaic model the environment is interpreted as a set of systems, which make „a relatively homogenous unity functioning in a defined way" [Richling 2004]. Such a set contains a huge variety of divisions and concepts, such as geotopes, ecotopes, biotopes, units, cells, habitats and sites or landscape components. They are all hierarchically connected. The model of „matrices, patches and corridors" uses the functional landscape concepts, which grounds the structure of geographical space on the assumptions of „the biogeographical theory of islands". This leads to delimitation of relatively homogenous and vast spatial units, i.e. „islands", their spatial and functional interrelations, i.e. „corridors", and the remaining surroundings of spatially diverse and broken up units, i.e. „matrix" or „background" [Urban *et al.* 1987, Forman 1995, Turner *et al.* 2001]. In the functional context, ecological nodal areas form an overarching element of this structure [Chmielewski 1988, 1992, Liro 1995]. They comprise extensive, country's representative and well preserved geographical macro' and mesoregions, such as e.g. the Kashubian Lake District, the Charzykowy Plain or the Tuchola Forest. Presently, this is the basic model, which describes the character of space, its structure and functioning relations. This concept is developing in two directions: „population" in reference to the theory of metapopulation, and

„landscape", also known as „structural", in reference to the structure of landscape not determined by life features of the species inhabiting the space [Cieszewska 2004]. Both these concepts delimit basic spatial units, crucial for functioning of the natural environment, which ensure the existence and stability of species. In the practical dimension, it means delimiting and designing ecological networks [Chmielewski 1988, 2012, Szulczewska 2001] based on the functional and structural criteria of the landscape. One of its fundamental elements are ecological patches, which are basic areas of existence and reproduction of organisms. The other one are ecological corridors, which enable organisms to translocate and thus penetrate and inhabit new territories, find mates, food and places for reproduction. This leads to maintaining genetic and species diversity. Beside purely scientific indication, such an operational concept has a substantial practical value. In a comprehensive approach, where delimiting and designing ecological network aims to provide conditions for environmental functioning, durability and protection [Chmielewski 1992, Ahern 2002, 2005], it implies a space management and use as well as protection of natural resources and values. In this way the research concept becomes a useful tool for spatial planning and development policy. This refers to all levels, from the regional, to the national and European. The author avoids the discussion, though, whether an ecological network is an object found in nature or just a scientific vision.

Biodiversity and its relations with the landscape structure

Ecological studies on life quality conditions of species in the biosphere indicate that the species variety, abundance and durability of individual populations depend on the size, stability, richness and accessibility of ecosystems [Bond 1994]. At the same time, spatial distribution of species within ecosystems is not even. It has to do with a number of factors, such as abiotic conditions of the habitat for plants, and the range of food resources for animals. An important issue is that the locally limited accessibility to required resources is compensated by translocation of specimens to the areas, which provide proper habitat conditions. Dispersion takes place along the areas, which offer specific living conditions for individual species. Loss of spatial connections in the ecological networks and, as a result, reduced penetration and colonisation of new territories is crucial for survival of groups of specimens and species. Other key factors include: anthropological degradation and contamination of space; damaging, limiting and fragmenting of habitats; loss of animals, existence of spatial barriers as well as introduction and influence of foreign species. If the overlapping negative factors limit the abundance of a large number of species at the same time, then the overall decrease rate in the number of species is growing due to interspecies relations [Sol'e and Montoya 2001]. In most cases, depletion of the number of species and their abundance is a final outcome of synergy between a number of processes. Every new threat overlapping the already existing ones influences the environment stronger than each of the threats separately.

In the mosaic-like landscape of Western and Central Europe most of forest, meadow, bog or synanthropic species are scattered, inhabiting the dispersed patches of favourable habitats. In case of plants, the durability of these habitats is often a sufficient guarantee that a given species in a local plant community (which may also have the form of endemic or relic species) may survive. In case of animals, however, respective of their behavioural features, survival is determined by their activity within a specific area, adequate size of their territory as well as the possibility of translocation. Plant and animal species of wide ecological amplitudes may be found in diverse types of habitats. For them landscape diversity and spatial accessibility to specific habitats is less important. Once the ecological structure of surface coverage is broken up and the habitat areas are limited, translocation between smaller ecological patches makes up for the accessibility to larger homogenous patches. Translocation of species, especially undertaken in search of food and shelter, increases while the area of habitats decreases and anthropopressure intensifies. For survival of such species the existence of ecological corridors is crucial as they complement spatial connectivity between patches or nodes and play the role of translocation pathways. Broken-up, mosaic-like spatial structure of the land use also determines the way of obtaining food. For instance, in such a structure wolf packs attack a much larger number of domesticated animals than in vast forest areas where they predominantly feed on forest ungulates, mainly deer, roe deer and wild boars.

For the last century the landscape of Poland and Europe has undergone rapid changes and anthropopressure has intensified significantly. This refers to both natural and cultural landscapes. These changes are seen as a dynamic interaction between the forces of nature and man. As a result, diversity, cohesiveness and identity are being lost. This process is often perceived as unavoidable. As Androp [2005] indicates, „Landscapes are dynamic and change is one of their properties. Humans have always adapted their environment to better fit the changing societal needs and thus reshaped the landscape". However, for part of the biosphere such changes may be catastrophic, as they increase isolation and fragmentation of natural areas, and spatial connectivity between them is being lost, while the number and size of anthropogenic barriers increases. Landscape is becoming more and more broken up. This situation is well illustrated by an example of forest complexes. In Poland as much as 96% of woodland areas is smaller than 5 ha, while only 1.9% is larger than 1000 ha. At the same time, about 65% of species living in the territory of Poland is bound to forests. Some of them, such as lynx (*Lynx Lynx*), do depend solely on an access to vast forest areas of specific species and age structure.

The very landscape changeability is concordant with its nature. However, fast rate of anthropogenic changes does not enable many species of the biosphere to adjust. The basic indicator of such reaction is the loss of habitats, specimens and species. Thus, landscape, especially in terms of its material and spatial structure, must be managed and protected in the same way as other resources and fields of human activity, namely economic, social and cultural. However, „trends of future

development of the European landscapes are rather well known, planning and managing future landscape remains difficult and extremely uncertain" [Androp 2005].

Contemporarily, landscape studies and their practical value for spatial economy are a must. They require the development of research tools and methods, as well as exerting of a pressure on political decision-makers so that the results of such research are considered at all the levels of managing the development – local, regional, national and European.

Ecological connections and their significance

The majority of studies on biosphere threats concentrate on endangered habitats and species. They also indicate relations between species and the network of ecological interdependencies [Chmielewski 1992, Lundberg *et al.* 2000, Dunne *et al.* 2002]. Less attention is paid to the spatial structure of ecosystems, their interrelations and accessibility. As mentioned above, it is the basic condition for maintaining durability and diversity of organisms as it shapes migration attributed to seeking food, new territories, mates, habitats for reproduction and shelter. Understanding the changeability and distribution of the structure elements of ecological interrelations need not only refer to natural areas. It must also concern the areas managed and used by man. Although being cultivated, some of them – forests, river valleys, bogs or meadows – remain crucial habitats of numerous organisms. Protecting spatial ecological structures and their connectivity needs to become an element of spatial planning and management. Recognising landscape structure properly as well as considering it and guarantying its existence should become the basic requirement for the activities aimed at protecting biodiversity as a part of political processes and development planning as well as spatial management routines.

As for the ecological network, landscape studies underline its structural dimension, which stems from land coverage and size and character of ecosystems. Secondly, functional interrelations are considered. They are often based on field studies. In Europe, especially in its central part along the east-west line, these interdependencies determine access of the species to space and possibilities of meeting their life demands (such as the type and character of a habitat, food base, shelter and reproduction, territory of living and range of feeding ground). Ecological connections tend to gain in importance in case of smaller patches. This is due to the fact that the damaging and limiting of the habitats' areas eliminates specimens and species from the biosphere. Beside the habitat fragmentation and break-up of landscape structure, another key issue is the existence of barriers, which isolate ecological patches and limit space permeability for specimens' translocation. According to the research, ecological corridors, which connect landscape structures of habitats, play the most important role for the survival of numerous animal species, predominantly predators [Gilbert *et al.* 1998]. However, protection of the very habitats, especially those more vulnerable to anthropopressure, should not be neglected.

Geoinformatics and GIS tools in space research

Access to information on natural space should become the basic organisational condition for planning and protection of spatial structures and biotic resources. Their delimitation is non-uniform and the analyses and delimitations are often based on diverse indicators. These indicators would differ depending on spatial scale, aims and topic of the research. They include morphological, landscape (complex), phytosociological, zoological, hydrographic indicators, or others. Proper definition of methodological approaches and research needs is a key to identification of geological structures and valuation of natural space.

For over 20 years GIS tools have been used for diverse and advanced environmental analyses and research, such as biodiversity, ecosystems, structures and processes in landscapes, land use, disturbances and threats to landscape as well as its monitoring etc. [Turner 1990, Scally 2006]. Most of all, GIS enables researchers to efficiently obtain and process data from various sources as well as integrate and present it cartographically. It is crucial for conscious shaping, understanding and modelling of the space where mankind lives [Environmental Management, GIS 2010]. The importance of geoinformation and tools for processing spatial data grows proportionally to the size of the studied area. Opposite relation refers to scrutiny of the studies. Access to up-to-date data, e.g. based on remote sensing, as well as the repetitiveness of obtaining it creates new possibilities for monitoring spatial processes or their theoretical modelling, such as those referring to damaging habitats [as suggested by Tilman 1994, Neuhauser 1998].

Importance of spatial information has recently led to developing of new projects in Europe, aiming at creating, collecting and building database systems as well as unified system of their accessibility. These undertakings are based on the INSPIRE Directive, the aim of which is to combine European, national and regional spatial information infrastructure into one coherent accessible system (ESDI – European Spatial Data Infrastructure). A significant amount of available spatial data refers to environmental and land use issues based on satellite images. Development of the EU's programme of environmental monitoring and security (GMES – Global Monitoring for Environment and Security), already accessible databases (such as system CORINE – Coordination of Information on the Environment) and launched work on GEOSS (Global Earth Observation System of Systems) are a good prognostics of integration activities aimed at public and environmental security, environmental protection, including natural resources, and the development of research methods in all EU member states.

CONDITIONS FOR DELIMITATION OF LANDSCAPE STRUCTURES AND THEIR ECOLOGICAL CONNECTIONS

Regions and their rank in environmental management and protection

Bearing in mind an opportunity to manage the development of regions as well as the detail, rank and range of planning documentation, regional analysis is the only tool to simultaneously grasp spatial, intraregional and interregional relations in land use and management. Determining location of larger ecological structures (nodal areas, patches and corridors), their survival and connections as well as the level of their naturalness and possibilities for protection is crucial for European biodiversity. Regional structures build continuity in the state's space, which in turn merges into continental structures. In reality, management of space resources takes place at a local and regional level. Strategic local decisions may be influenced at the regional level where development processes and spatial structures have larger territorial range and are better visible. At the national level, regional information is synthesized. At the regional level, in turn, it is possible to observe and determine the most important processes, such as the:

in terms of land use and management:

– topological changes of areas with diverse forms of land use,

– sprawl and distribution of built-up areas and those taken by infrastructure,

– growing number and location of technical barriers, which limit continuity of natural space (predominantly transportation objects and transmission lines),

– increasing size and location of degraded areas,

– location of areas and points of potential conflicts between functions, such as between transportation and protection, or economy and ecology;

in terms of natural space:

– disappearance of natural ecosystems and habitat patches, such as forest, meadow, bog or aquatic ones,

– intensification in fragmentation and isolation of habitats,

– disappearance and limiting of spatial connections in nature, including a system of natural ecological corridors, e.g. river valleys or forest sequences,

– migration of species, their numerical force and its changes, such as loss of specimens,

– spatial distribution of contamination and environmental pollution,

– indicating the areas whose aesthetic values are deteriorating;

in terms of organisational sphere:

– determining areas, which are threatened by anthropopressure, and not properly included into environmental protection schemes,

– determining areas, which are legally protected but threatened by loss of their values and anthropopressure,

– coordinating actions aiming at regulating environmental strategies, development policies and spatial management planning,

– determining environmentally valuable areas, which need protection.

The range of the above mentioned problems and issues, which can be

grasped at the regional level, indicates its rank and importance for analysing, delimiting and designing spatial ecological structures. They are crucial for both the land management and the maintenance of its material and functional features. Recognising and then maintaining ecological structures and interrelations is one of the main pre-requisites for biodiversity protection, which may constitute a component in regional development policy.

Identification and protection of ecological structures

Neither protection of species and habitats nor of precious natural objects, such as national parks, nature reserves or areas of Natura 2000, is sufficient for maintaining the biodiversity. The EU-based targets of limiting the biodiversity decrease in Europe by 2010 were not fulfilled as the actions turned out insufficient. In order to achieve that it is necessary to identify and protect the network of spatial ecological connections. Thus, the landscape and systemic (multispecies) approach seems a key to success. It results in delimiting and maintaining spatial structures, which would provide access to larger and more numerous areas better meeting the needs of species [Constanza *et al.* 1997, Ehrenfeld 2000]. It is crucial to consider the fact that spatial ecological structures, readable in terms of forms of land use, are not the only factor, which influences translocation of specimens. Ecological patches or corridors regarded as relatively continuous spatial structures are not necessarily directly functionally connected with the translocation of organisms, which have diverse needs and survival strategies. At the regional scale the picture gets generalised.

In a smaller scale landscape structures are seen as relatively homogenous (such as European ecological nodal areas). In detailed studies, however, they would rather be mosaic-like. For instance in local documentation, specific factors also need to be taken into account, such as a real distribution of habitats with feeding or shelter role. Moreover, lines of migration need to be determined [Solon 2004]. The layout of ecological network and possibilities for translocation of species are also determined by ecological barriers, like built-up areas and linear infrastructure. Spatial interrelations between ecological barriers and corridors are also significant for translocation of species and their distribution in habitats over larger areas. Delimitation of spatial structures at the regional, interregional or national level is impossible if based solely on field studies. It necessitates the use of geoinformation resources, such as cartographical and remote sensing materials and their transformations as well as environmental databases and ICT tools, predominantly GIS. Thus, with all the limitations known, an example of such a regional analysis was presented as a relatively easy and fast method of obtaining basic knowledge on the spatial structures for managing its development. Nowadays, this procedure is relatively simple and effective. However, assessing it as being important and useful, we should not treat the issue of delimitation of spatial forms as a solely technical problem, which can be based only on the analysis of the landscape structure. It needs to be considered that the routes,

along which species migrate, are not always the most optimal ones in terms of spatial structure. Some of them show non-structured character. In other words, there are no clearly visible organisational structures, which determine the course of the migration routes [Ostrowski 2004]. The final level of information minuteness is the assumed range and scale of the research. While analysing regional conditions, research methodology needs to consider both factors of local migration associated with life of species in their territories, and those which refer to taking over new territories and undertaking migration outside the already taken landscape units [Ricketts and Morris 2001].

Justification of studies on identification of landscape structures stems from both possibilities and needs for analytical scientific research, including research on development of landscapes, dispersal of species and maintaining biodiversity. Moreover, landscape structure in administrative documents dealing with development management is presented in a quantitative and spatial manner. Apart from a strong scientific justification, such a presentation of landscape structure [Jaeger 2000], if aimed at presentation of environmental changes and interrelations used in procedures of spatial planning, is also relatively easy understood. Nowadays, planning is the basic tool, if not the only one, for creating conditions to maintain the existing ecological connections and structures or to design their reconstruction based on analysis of geographical location and spatial changes [Dramstad *et al.* 1996.]. Moreover, if biosphere's habitats and species are to be protected, it is crucial to maintain the proper quality of environment as well as composite spatial monitoring [Czochański 2006, Leitão *et al.* 2006]. Only such a group of complex and integrated undertakings may bring positive quantitative, qualitative and spatial effects in protection of the biodiversity.

Delimitation proposal for regional ecological structure – analysis and synthesis

In spatial analyses and investigations on the natural structure of a region a number of geoinformation data as well as efficient ICT tools, predominantly GIS software come in hand.

In order to determine the regional ecological structure and its spatial connections of the Pomeranian Voivodeship, located in northern Poland, the following tools were used:

– digital topographic and hydrographical maps at the scale of 1:50 000, obtained from the regional Land Information System,
– vector layers of Topographic Database,
– remote sensing materials, including an orthophotomap of the voivodeship,
– database CORINE Land Cover 2000,
– selected results of the field studies and local nature inventories of gminas.

These materials were synthesised in order to delimit hydrogenic components (water reservoirs, rivers and swamp areas), natural meadows and pastureland as well as forest complexes (Fig. 1 a–c and Fig. 2). While delimiting the range and location

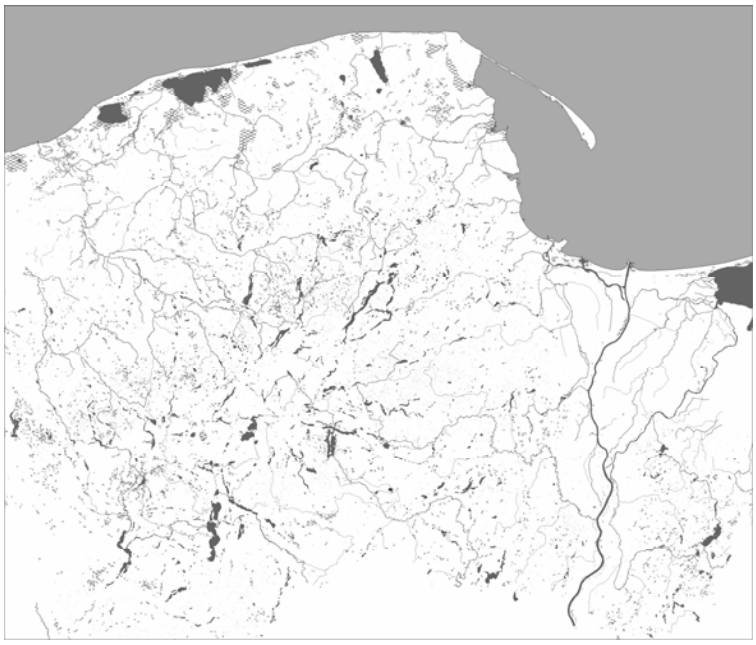

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1a–c. Analysis of ecosystems, which form the landscape structure and ecological connections: a – hydrogenic ecosystems (surface water, bogs and swamps); b – ecosystems of meadows and pastureland; c – forest ecosystems

Fig. 2. Landscape structure and the network of ecological connections based on CORINE Land Cover 2000 Database (includes hydrographical objects as well as forests and pastureland)

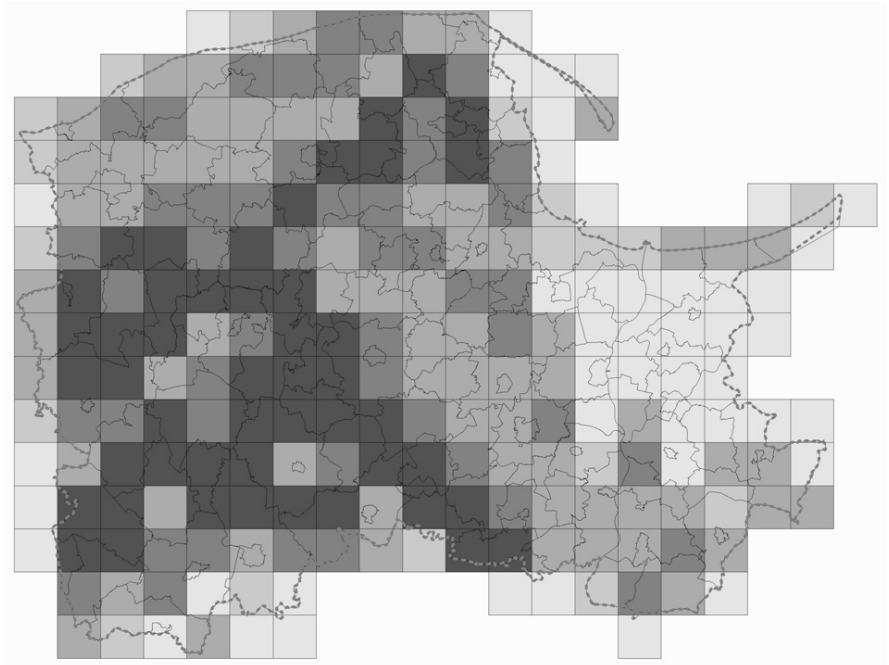

Fig. 3. A synthetic outcome of GIS analyses (based on estimation of the density/elongation of boundaries and the area covered by natural ecosystems in the GRID network) to determine spatial relations between forest, wetland and water ecosystems

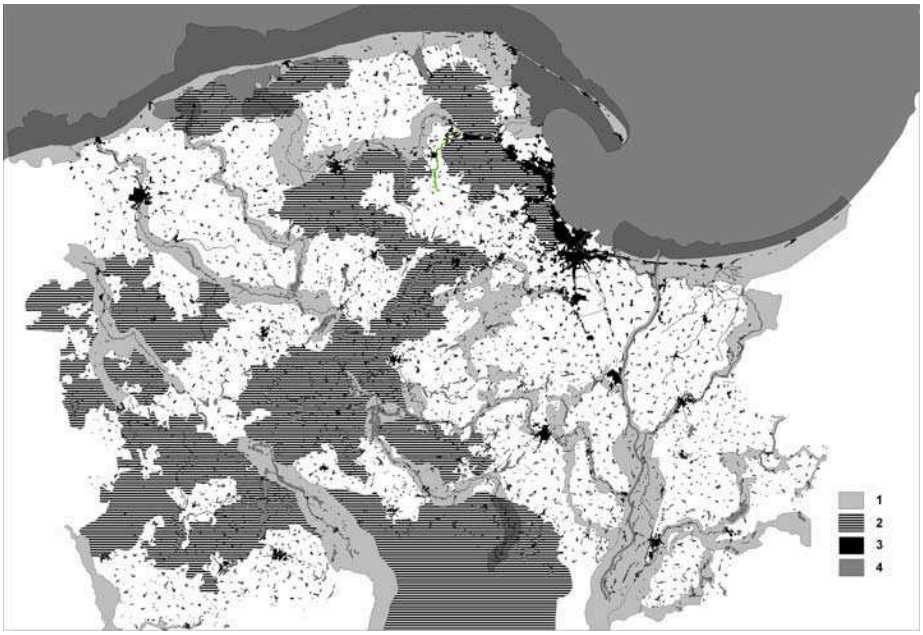

Fig. 4. Spatial structure of the regional ecological network – patches and corridors: 1 – ecological corridors, 2 – ecological patches, 3 – built-up areas, 4 – surface waters

of ecological corridors and patches, the main barriers of transport infrastructure and built-up areas were taken into consideration. The analysis of spatial structures also considered vast, relatively physiognomically and functionally homogenous areas, which were qualified as ecological patches. Moreover, it included continuous linear structures, such as river valleys and forest belts, and intermittent structures, i.e. the so-called stepping stones, which are sets of small ecological islands located at a relatively small distance and thus playing the role of corridors. The delineation and spatial relations of the ecological corridors were determined with the support of GIS tools, including information derived through the computed proximity analysis (through estimating the density of boundaries and the area covered by natural ecosystems in the GRID network).

While creating the picture of a landscape structure at the regional level a number of details, suggested for delimitation of composition and elements of landscape, were left out. This is because they often evoke discussions related to the way and purpose of their delimitation as well as on their nomenclature. At the regional scale they impede showing the most important spatial structures.

Theoretical analyses of spatial relations dealt with two issues – a real, physical distribution and size of the delimited units (as a synthesis of two overlapping components) as well as their density in the selected network of basic squares. Due to practical reasons and needs of the regional spatial planning, the final synthesis of natural components and delimited physiognomic-structural units were presented within their natural range. They include solely ecological patches and corridors as well as the remaining matrix area (Fig. 4). This structure of connections in the regional ecological network was taken into consideration in the planning documentation [Plan zagospodarowania przestrzennego województwa pomorskiego, 2009]. Moreover, the spatial management plans for the voivodeship suggest its protection as it determines maintenance of migration corridors and biodiversity. Additionally, spatial distribution of the elements making up the network of ecological connections and legally protected areas was compared. Location of ecological patches and corridors, including valuable natural areas, indicates that there is a need for further development of the system of protected areas, with due consideration given to European and national nodal areas.

RESULTS

The structure of the delimited ecological patches and corridors includes nodal areas of cross-regional, i.e. national and continental, regional and intraregional rank. This three-section approach stems from their size, location and spatial range, including, most of all, coherence with the neighbouring geographical regions. Due to the number and minuteness of delimitations the elements of senior local rank were eliminated from the results of the analyses. The delimited ecological network comprises:

8 elements – 3 ecological patches and 5 corridors – of cross-regional rank, which show high biodiversity, high level of maintenance of natural landscape features, and are of great importance for the environment and the spatial coherence of the country's ecological system as they connect it with the continental systems;

25 elements – 10 patches and 15 corridors – of the regional rank, which link the larger areas of the ecological network of a cross-regional character or which strengthen the regional spatial cohesion.

Each of the above network elements potentially stores plants and animals, maintains their biodiversity and is a source of genetic reinforcement for the neighbouring biotopes. Another important role of the elements in the system is their protective role for water and soil resources. A significant number of patches are especially crucial for water retention (forest and bog patches and water reservoirs). Apart from their ecological function, the regional network creates favourable living conditions for the region's inhabitants and shows large scientific and educational values.

CONCLUSIONS

The understanding of interactions between human beings and the surrounding environment, including its features and values, determines conscious and right decisions on spatial management. The ICT, and in particular the GIS software and applications, come in this context as a basic tool for the processing of detailed information [Environmental Management, GIS 2010]. Despite over 20 years' long record in using such software for spatial analyses and landscape studies this direction of research is still promising, notably due to a growing amount of spatial data (geoinformation), its increasing minuteness and timeliness, easier accessibility (including on-line) as well as greater possibilities and speed of remote sensing and ICT equipment. All these aspects result in a growing volume of studies in an extensive array of thematic areas. As a result, an opportunity emerges for more and more advanced regional studies and for more and more accurate assessments for the benefit of spatial management and protection of space resources. Such a direction has to be propagated and continued, including interregional and international cooperation. This would give a chance for creating an integrated, synthetic and homogenous picture of space at various levels – from regional to continental.

It must be stressed, however, that in Polish conditions, beside purely ecological aspects, a number of organisational and legal-administrative constraints appear. Indirectly, they significantly influence deterioration of ecological connections, including biodiversity. These constraints include:

– lack of legitimacy for delimitation and protection of ecological networks, especially ecological corridors,

– lack of hierarchic links between regional planning documentation and the contents of local and national plans,

– inadequate education and lack of understanding for the need to maintain ecological connections on the part of investors and local self-governments, predominantly interested in economic effects of the development,

– lack of a link between the system of environmental protection and financial solutions, which would maintain the level of income of local self-governments introducing spatial forms of environmental protection and limiting spatial investments,

– insufficient knowledge on functioning of the environment and its values among those engaged into planning processes (planners, town-planners, architects),

– low level of spatial planning, essential for environment; local development plans, the only documents of legal nature, are independent from the regional ones, which makes it impossible to comprehensively assess environmental conditions and to maintain the structure of landscape and ecological connections towards sustainable environment.

Finally, despite practical importance of ICT development, geoinformation resources, remote sensing and IT solutions, they cannot be the sole alternative for local research and field studies. Discovering landscape properties and features, determining the real distribution and diversity of species and habitats, assessing the level of their maintenance, threats and functional connection have to verify and complement the knowledge obtained from Earth observation techniques and cartographical transformation. Both administrative authorities and design offices need to practically apply natural sciences and landscape ecology by inserting the research results into their spatial management and planning processes. They cannot concentrate solely on minimisation of spatial conflicts related to meeting the socio-economic needs. They also should create conditions for real sustainable development and durability of the biosphere and its biodiversity.

REFERENCES

Ahern J., 2002. Greenways as Strategic Landscape Planning: theory and application. Wageningen University, Wageningen, Netherlands, 183 pp.

Ahern J., 2005. Integration of landscape ecology and landscape architecture an evolutionary and reciprocal process, in: Wiens J., Moss. M. (eds) Issues and perspectives in landscape ecology. Cambridge Studies in Landscape Ecology, Cambridge Univ. Press, p. 307–315.

Androp M., 2005. Why landscapes of the past are important for the future, in: Landscape and urban planning vol. 70, Elsevier B.V., p. 21–34.

Bond W.J., 1994. Do mutualisms matter? Assessing the impact of pollinator and disperser disruption on plant extinction, philosophical transactions of the Royal Society of London, Ser. B-Biol. Sci., 344, 1307, p. 83–90.

Chmielewski T.J., 1988. O strefowo-pamowo-węzłowej strukturze układów ponadekosystemowych, Wiad. Ekol. 34, 2, 165–185.

Chmielewski T.J., 1992. Próba modelowania funkcjonowania fizjocenozy jako dynamicznego układu poliekosystemowego, w: T.J. Chmielewski, A. Richling, K. Wojciechowski (red.) Funkcjonowanie i waloryzacja krajobrazu. Pol. Tow. Geogr., Lub. Tow. Nauk., Tow. Wolnej Wszechn. Pol., Lublin, s. 25–38.

Chmielewski T.J., 2012. Systemy krajobrazowe: struktura, funkcjonowanie, planowanie, Wyd. Nauk. PWN, Warszawa, 408 ss.

Cieszewska A., 2004. Model płatów i korytarzy – dyskusja pojęć, w: A. Cieszewska (red.), Płaty i korytarze jako elementy struktury krajobrazu – możliwości i ograniczenia koncepcji, Ser. Problemy Ekologii Krajobrazu t. XIV, Wyd. SGGW, Warszawa, s. 13–18.

Constanza R., d'Arge R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R., Paruelo J., Baskin R.G., Sutton P., van den Belst M., 1997. The Value of the World's Ecosystem Services and Natural Capital. Nature 387, 253–260.

Czochański J.T., 2006. Development Processes and Spatial Changes Monitoring as an Instrument of Regional Management, in: Myron Lesechko, Tomasz Michalski (ed.) Theoretical Aspects of Regional Development in Ukraine and Poland, Lviv Regional Institute of Public Administration National Academy of Public Administration Office of the President of Ukraine, Lviv, p. 87–101.

Dramstad W.E., Olson J.D., Forman R.T.T., 1996. Landscape Ecology Principles in Landscape Architecture and Land-Use Planning. Harvard University, Graduate School of Design, Island Press, Washington, 80 pp.

Dunne J.A., Williams R.J., Martinez N.D., 2002. Food-web structure and network theory: The role of connectance and size. PNAS 99, 12917–12922.

Ehrenfeld J.G., 2000. Defining the limits of restoration: The need for realistic golas. Restor. Ecol. 8, 2–9.

Environmental Management, GIS Best practices, ESRI USA, 2010, 32 pp.

Forman R.T.T., 1995. Land mosaics. The ecology of landscape and regions. Cambridge Univ. Press, Cambridge UK, 632 pp.

Gilbert F., Gonzalez A., Evans-Freke I., 1998. Corridors maintain species richness in the fragmented landscapes of a microecosystem. Philosophical Transactions of the Royal Society of London, Ser. B-Biol. Sci. 265, p. 577–582.

Jaeger J.A., 2000. Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecol., 15, 115–130.

Leitão A.B., Miller J., Ahern J., McGarigal K., 2006. Measuring Landscapes: A Planner's Handbook. Island Press, Washington, 245 pp.

Liro A. (red.), 1995. Koncepcja krajowej sieci ekologicznej ECONET-Polska. Fundacja IUCN – Poland, Warszawa, 202 ss.

Lundberg P., Ranta E., Kaitala V., 2000. Species Loss Leads to Community Closure. Ecol. Lett. 3, 465–468.

Neuhauser C., 1998. Habitat destruction and competitive coexistence in spatially explicit models with local interactions. J. Theor. Biol. 193, 445–463.

Ostrowski M., 2004. Struktura i funkcja jako kryteria wyróżniania korytarzy w środowisku, w: A. Cieszewska (red.) Płaty i korytarze jako elementy struktury krajobrazu – możliwości i ograniczenia koncepcji, Ser. Problemy Ekologii Krajobrazu, XIV, Wyd. SGGW, Warszawa, s. 178–186.

Plan zagospodarowania przestrzennego województwa pomorskiego, Pomorskie Studia Regionalne i Materiały, UMWP, Gdańsk, 2009, 330 ss.

Richling A., 2004. Systemy przyrodniczego podziału przestrzeni, w: A. Cieszewska (red.), Płaty i korytarze jako elementy struktury krajobrazu – możliwości i ograniczenia koncepcji, Ser. Problemy Ekologii Krajobrazu, XIV, Wyd. SGGW, Warszawa, s. 17–22.

Ricketts T.H., Morris W.F., 2001. The matrix matters: effective isolation in fragmented landscapes. American Naturalist 158, 1, 87–100.

Scally R., 2006. GIS for Environmental Management, ESRI Press, Redlands, California, 187 pp.

Sol'e R.V., Montoya J.M., 2001. Complexity and fragility in ecological networks, philosophical transactions of the Royal Society of London. Ser. B-Biol. Sci., 268, p. 2039–2045.

Solon J., 2004. The concept of landscape potentials and its application for the landscape connectivity evaluation, in: Patches and Corridors as Landscape Structure Elements – advantages and Limitations of the Concept, A. Cieszewska (ed.), Problemy Ekologii Krajobrazu, XIV, SGGW, PAEK, p. 29–41.

Szulczewska B., 2001. Sieci ekologiczne a planowanie przestrzenne. Człowiek i Środowisko 25, 2, 185–203.

Tilman D., 1994. Competition and biodiversity in spatially structured habitats. Ecology 75, 1, 2–16.

Turner M.G., 1990. Spatial and temporal analysis of landscape patterns. Landscape Ecol. 4, I, 21–30.

Turner M.G., Gardner R.H., O'Neill R.V., 2001. Landscape ecology in theory and practice, Pattern and process. Springer-Verlag, New York, Berlin, Heidelberg, 401 pp.

Urban D.L., O'Neill R.V., Shugart H.H., 19987. Landscape ecology. Bioscience 37, 119–127.

WYKORZYSTANIE GEOINFORMACJI I NARZĘDZI GIS DO ANALIZY PRZESTRZENNEJ, PROJEKTOWANIA I OCHRONY SIECI POWIĄZAŃ EKOLOGICZNYCH W REGIONALNEJ SKALI KRAJOBRAZU

Streszczenie. Jednym z kluczowych czynników wpływających na zachowanie różnorodności biologicznej, na poziomie ekosystemowym, gatunkowym i genetycznym, jest struktura i łączność przestrzenna elementów krajobrazu. Związek między zachowaniem sieci ekologicznej (opartej na płatach i korytarzach ekologicznych) a trwałością i zróżnicowaniem siedlisk i gatunków został wielokrotnie dowiedziony. Rozpoznanie struktur krajobrazowych, budujących powiązania sieci ekologicznej oraz ich ochrona pozostaje ważnym zadaniem dla zarządzania przestrzenią i planowania jej zagospodarowania. Celem artykułu jest przedstawienie propozycji metod wykorzystania zasobów geoinformacyjnych oraz narzędzi GIS do identyfikacji i projektowania powiązań ekologicznych w skali regionalnej, na tle zależności oraz uwarunkowań i problemów ograniczania różnorodności biologicznej. Wyznaczenie struktur sieci ekologicznej jest podstawą do ich uwzględnienia w dokumentach strategicznych rozwoju i planowania przestrzennego, jako warunku kształtowania i ochrony.

Słowa kluczowe: sieć ekologiczna, płat ekologiczny, korytarz ekologiczny, różnorodność biologiczna, GIS, geoinformacja